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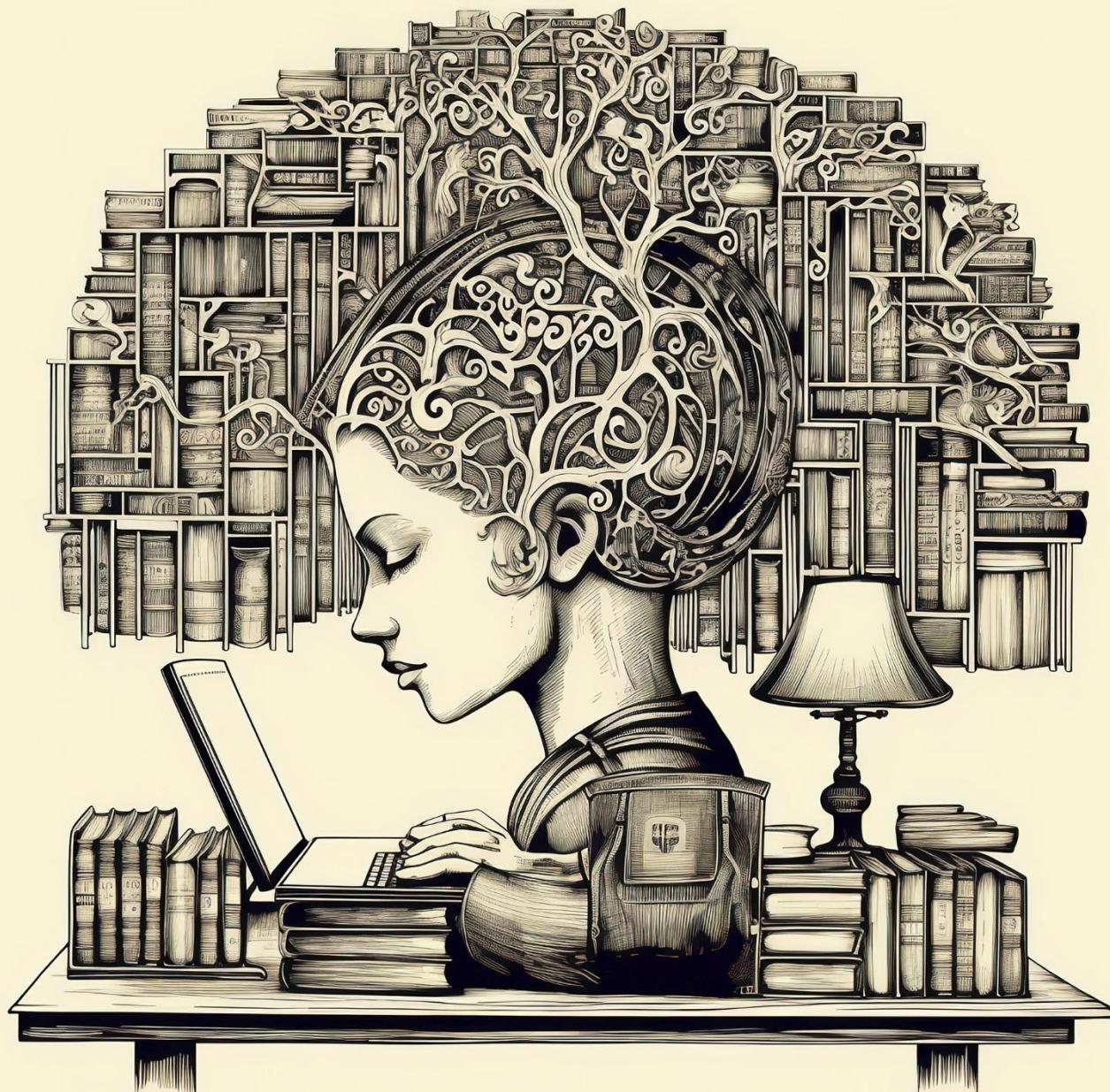
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THE ART OF THESIS WRITING

A Comprehensive Guide to Authoring Academic Theses
with Foundations of Research



Markus C. Hemmer · Thorsten Fröhlich

THE ART OF THESIS WRITING

A Comprehensive Guide
to Academic Theses
with Foundations of Research

Markus C. Hemmer

Thorsten Fröhlich



2023

THE ART OF THESIS WRITING

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PREFACE

The Art of Thesis Writing guides you through the fascinating maze of academic research and writing. The process of writing a thesis can be a roller coaster ride. One moment, you're scaling the heights of an interesting research question, and the next, you're plummeting down into the valleys of formatting and citation problems. What if you had a road map for this exhilarating ride? A guide that not only tells you what to do but provides good reasons and shows you exactly how to do it? Sounds like a dream. Consider this book your dream come true!

The Art of Thesis Writing encompasses a multifaceted journey that traverses not only the scientific methodologies and research processes but also delves into the realms of the philosophy of science, self-organization, and the craft of effective communication. This book seeks to serve as an indispensable guide for scholars, students, and researchers embarking on the transformative voyage of composing a thesis within diverse scientific disciplines.

WHAT SETS THIS BOOK APART

In case you're wondering how this book differs from all the others, this book doesn't just talk at you. It walks with you. It deals critically with prevailing but outdated paradigms, it justifies its recommendations rather than taking them for granted, it is full of practical examples, checklists and well-researched recommendations supported by scientific references, and it has several funny elements that will make your journey more enjoyable.

From conceptualizing complex forms of reasoning in the first part to fun episodes on what not to do (titled "The Worst Practice" at the end of many chapters), this text is designed to make the experience as interactive and enjoyable as possible. The checklists and practical examples are your trusty sidekicks in each section. Plus, it's organized into neat sections to help you select the content relevant to you.

WHAT IS COVERED

The book consists of five parts.

Part I: The Science Primer: We start by bringing you on a "Field Trip into Sciences" to explore everything from philosophical perspectives to forms of reasoning. We guide you through the epistemological underpinnings and the nature of scientific inquiry to understand what makes a research project meaningful. We don't just philosophise; we provide real-life examples and critical discourse on prevailing ideas.

Part II: The Composer's Guide: This section is all about getting your act together – literally. From organizing your work environment to using your word processor, we offer action plans and checklists to keep you on track.

Moreover, this book recognizes the significance of writing style in scientific discourse. It offers comprehensive advice on crafting a compelling narrative, structuring arguments, and employing clear and precise language to communicate complex scientific concepts effectively.

We also introduce ChatGPT and AI Tools. How could we not discuss this? Learn the good, the bad, and the nuanced about using AI tools like ChatGPT in thesis writing.

This part also delves into the strategies for effective visualization, empowering researchers to present their findings in a visually compelling manner.

Part III: The Creator's Guide: Here's where we delve into the nitty-gritty of selecting and refining your thesis topic. The guidance provided here navigates through the labyrinth of topic selection, assisting in refining ideas, framing research questions, and establishing a clear trajectory for investigation.

Part IV: The Writer's Guide: This section could be your best friend! The anatomy of a thesis is dissected, exploring the individual chapters, their purpose, and the interplay between them. From the introduction to the conclusion, each segment serves a unique role in building a coherent and persuasive argument. We serve it all on a plate with detailed guidelines and checklists for literature reviews to research designs, catering to the specific needs and nuances of different science disciplines, from engineering to the arts.

Part V: The Presenter's Guide: After all that writing, you must defend your thesis. This part addresses the crucial moments of thesis presentation and defence. It prepares you for the culmination of your efforts and equips you with the tools and confidence to present and defend your work with clarity, confidence, and authority.

WHO WILL BENEFIT?

While this book is primarily written for university students, it could also prove to be useful for college students. Or for teachers and university lecturers. Or for social scientists, natural scientists, managers, politicians, marketing experts, salesmen, bakery sales assistants, warehouse operatives, critics, creative artists, filmmakers, and science fiction authors. And other humans.

In fact, this book does not focus on a particular science discipline. It covers the essentials of generating knowledge, gaining insights from observations, understanding nature, and presenting concepts that are relevant to any kind of research endeavour, whether it is in natural sciences, social sciences, business, engineering, or the arts.

Your thesis is more than just an academic requirement; it's your opportunity to contribute something meaningful to your field. And guess what? With this book by your side, you'll master the art of doing just that.

ACKNOWLEDGEMENTS

This book has been thoroughly reviewed by experts from diverse disciplines, including the natural sciences, social sciences, business, management, design, and the arts.

We would like to express our sincere appreciation to Ioana Voica for her meticulous attention to detail and astute observations that greatly enhanced the understandability and coherence of this book.

We are equally indebted to our colleagues Muhammad Ashfaq, David Harding, and Claus Schröter for their thoughtful and constructive feedback to ensure the accuracy and consistency of the content.

Additionally, our deep appreciation goes to Susanne Lang, whose thoughtful suggestions and depth of knowledge in the arts greatly improved this book, and Stine Marie Quabs for her contributions to quality and usefulness from a student's perspective.

The dedication and commitment of these reviewers have been pivotal in creating a book that serves as a trusted companion, empowering individuals to not only produce impactful theses but also to contribute meaningfully to the evolution of scientific knowledge.

A final note: the use of the pronouns "he" or "she" in this book is, of course, gender-neutral and serves to simplify the language.

HOW TO READ THIS BOOK

Books are somehow peculiar. When they reside on the shelf, they turn their backs on us. When we take them out, they still remain closed. But when we turn the first page, they reveal a universe.

When you approach this book, it behaves like any other. It's pretty sturdy. It doesn't bite, you can touch it, open it (as you obviously did), or put it back on the shelf or under the table leg like any other book. However, if you purchased the electronic version, you should refrain from doing so unless you want to ruin your laptop.

If you want to engage with the book's universe, you need to begin at some point. To ease your decision on what to focus on, we divided this book into five parts (see Figure 1).

If you are new to the field of research, we recommend you begin with *The Science Primer*, which explains research principles and foundations of reasoning. It also provides the basics of statistics and mathematical logic.

In case you are familiar with research but want to know more about your text processor, AI support, the expected writing style, or the visualisation, you can begin with *The Composer's Guide*.

If you search for a topic, want to write a proposal, or develop a storyline, follow *The Creator's Guide*.

When you are ready to begin, use *The Writer's Guide*, which leads you through the thesis chapters with detailed advice for different disciplines.

Finally, you can delve into *The Presenter's Guide* to prepare for thesis presentation and defence.



Figure 1 Topics covered in the main parts of this book

Unless you decide otherwise, we will first invite you on a field trip into the universe of science and explain the terminology you encounter in the following chapters. If you feel you are not yet up to such a challenge, consider this:

- Don't be afraid if you do not understand everything at first sight.
No one did.
- Don't be afraid of terminology because you will get used to it.
Everybody did.
- Don't worry if the scholarly literature is inconsistent here and there.
Nobody ever got used to that, but it is a good reason to read *this* book.

When you are ready to take off, please return to your seat, put it in an upright position, and fasten your seatbelts.

PART I

THE SCIENCE PRIMER



1 A FIELD TRIP INTO THE SCIENCES

While positivists can be quite negative, interpretivists are often misinterpreted.

We could easily extend the list above with terms like constructivism (no, not about architecture), realism, idealism, existentialism, and more exotic species of the philosophical terminology jungle. In fact, if you try to look up the meaning of those words, you may feel like waking up in the middle of the rainforest with just your pyjama on. Fortunately, we will find that we can traverse those parts of the philosophical rainforest that we need for our thesis project quite well with a little choice of gear.

In this chapter, we address the philosophical framework of science to clarify how it shapes our research. We will learn about the consequences of assumptions, how they affect methodologies, elaborate on the principles of logic and how they apply to reasoning. The other main chapters of this book will return to operational details as they become necessary.

1.1 WHY PHILOSOPHY IS IMPORTANT

The first question we encounter is why philosophy should be a part of research. The answer is simpler than the context: the generation of knowledge has its origins in philosophy. We usually assume that research was developed by (natural) scientists. However, it has been philosophers who dealt in the earliest written artefacts with the questions around the creation of knowledge.

In ancient times, philosophers were much more scientists than they are today. In fact, before the different fields of science evolved, philosophers did a universal job.¹ Concepts like logical reasoning, induction, deduction, and others were discussed more than 2400 years ago by people that we today ascribe to philosophers.

Over time, many different fields of sciences emerged, and we tend to demarcate them further: physics was separated from chemistry, psychology from psychiatry, and eventually, philosophy was separated from all these sciences and nowadays deals with fundamentals like metaphysics, logic, and ethics, among others.

If we look at the original meaning of the word philosophy (Ancient Greek: *philia*, affection; *sophia*, wisdom), it literally translates to the ‘affection for wisdom’, and we can readily assume that every scientist, regardless of his or her discipline, will exhibit this attitude. Although wisdom might rarely be the primary outcome of research, it is at least the insights and knowledge that play a role in gaining wisdom.

Unfortunately, philosophy has disappeared from many educational programs. One reason might be the tremendous variety of thoughts, schools, and concepts that evolved in a history of more than two millennia. This poses a challenge for education, given the limited time at school. Another reason, however, can be attributed to the inability of some authors of philosophical and related writings to convey complicated thoughts in an adequate style, a fact that contributes significantly to banishing philosophy and other disciplines to an ivory tower.

How can we approach such a field if we have just little or no background? Let us lean back and think about what we want to achieve.

1.2 THE JOURNEY BEGINS

We start with a simple assertion that was already stated in the seventh century by the Buddhist philosopher Dharmakīrti:

Successful human action is preceded by right knowledge.²

It seems plausible that reasonable decisions can only be made based on the right knowledge. But what is needed to obtain the *right* knowledge? And

¹ An overview on ancient philosophy is given in (Graham, 2020)

² The original statement is found in Dharmakīrti’s Nyāyabindu (lit. ‘point of judgement’).

Coseru translates it as: “Right knowledge precedes the attainment of all successful human action, [and] this [is the reason for] giving an exposition of it” (Coseru, 2009, p. 431).

what does *right* mean? To approach this, we flip the coin and begin with the outcome of research to make our way down to the most fundamental question behind this endeavour:

5. We want to *obtain knowledge*.
4. To obtain knowledge, we must *understand* what happens.
3. To understand what happens, we need to *interpret* things.
2. To interpret things, we need principles of *reasoning*.
1. To establish such principles, we need to find an initial *true state*.
0. To find a true state, we need to define what *true* means.

The latter question is in the domain of metaphysics (Ancient Greek: *metá physiká*, beyond the physical) – the abstraction beyond the physical realm. Metaphysics covers the philosophical discourse about the origins, purpose, and meaning of things. We pay particular attention to the meaning of words to engage successfully in such discourse. However, while such metaphysical debate sheds light on different perspectives of truth, it rarely generates verifiable knowledge. That is, we would probably never reach the top of our list if we discussed the meaning of the word *truth*.

As a resort, we begin with a postulate – a demand to accept a proposition – that most scientists could agree with:

A postulate

We are not searching for truth in a metaphysical sense; instead, we try to explain our sensory perceptions and mental experiences to reach a state of the undeniable under given assumptions.

That is, we define something as *true* only in a system of assumptions, being aware that such assumptions delimit our knowledge-creation process. On this fundament, we can approach our first part: creating a theoretical framework that serves as the basis for our research project.

1.2.1 Starting with Assumptions

Every research project begins with assumptions for fundamental metaphysical questions. For instance, we accept that $2 + 2 = 4$ is true in mathematics. The reason is simple: we defined it in this way in mathematics. Nobody knows if it is true outside mathematics. Taking it out of its context would raise some challenging questions.

Would numbers exist if there were no mathematics? We can only answer this by looking at how we defined the terms *number* and *mathematics*. A number is a symbol that describes a quantity. In the system of mathematics, numbers are artificial instances; we invented them. It is a purely anthropogenic

concept. Nevertheless, our observations show us that animals (that did not invent numbers) have a feeling for quantities. We can observe that a sheep recognises where more sheep are when it follows the horde. In the same way, we find that a lioness identifies a single prey in a horde to concentrate the hunt on it. That is, quantity as a universal concept exists in some sense, and numbers are just individual representations that allow humans to express quantities. Accepting a truth in a mathematical statement is easy since it is an artificial anthropogenic system. The situation changes if we investigate nature.

Would colours exist if we were completely colour-blind? Although complete colour blindness is a rare dysfunction among humans, some animals, such as the racoon, don't see colours but grey scales.³ If we never knew anything about colour from our sensory experience, would we ever have investigated further? Probably when we find evidence that there must be a property like a wavelength. We have also found radar waves, even though we don't experience them ourselves. The reason is that we have found common features in all types of radiation, and we eventually created the concept of the electromagnetic spectrum based on radiation theory. But would we be researching radar waves if we had never experienced any phenomena related to radiation?

We have no other choice than to first live with what our human senses provide. The human eye has limited spectral sensitivity; we just see a small portion, the visible part, of the electromagnetic spectrum. The eye of a dragonfly extends to the infrared and ultraviolet part of the spectrum.⁴ That is, the dragonfly sees more of reality than a human.

That raises the simple question of how we can be sure that what we see is reality. Given what we know about the limitations of our senses, it is overwhelmingly unlikely that our brain creates a comprehensive picture of reality just with our senses. Even if we extend our abilities with instruments, such as eyeglasses, an infrared camera, or an ultraviolet spectrometer, we will not see the complete picture. In fact, we see a delimited one if we use instruments.

The reason is that we design an instrument assuming underlying natural regularities, such as electromagnetic waves. Without this assumption, we wouldn't even know how to construct an optical instrument. However, if

³ A phenomenon called cone monochromacy. About animals and their visual abilities, see (Ekesten & Ofri, 2021)

⁴ see, for instance, (Yang & Osorio, 1991); a recent overview on the spectral sensitivity of arthropods and its ecological meaning is given by (Yilmaz, Hempel de Ibarra, & Kelber, 2022)

our assumptions do not fully describe the nature of the system under investigation, the instruments will just show us what we want to see. The resolution of an electron microscope does not show an electron since it uses a beam of accelerated electrons to generate the picture.

Whenever we ask nature a question, it will give us the answer to exactly that question. If we ask the wrong question, we will receive a wrong answer. But even if we ask the right question, we will not gain any insights beyond our assumptions.

That is the difference between humans and intelligent systems. Let's say you are searching for a street and ask a pedestrian: 'Do you know Cumberland Street?' The answer would probably be: 'Yes, it's the second street on the left'. No polite human would say 'Yes' and walk away.

If you ask a conventional computer software, the answer would be: 'Yes'. Although it usually does not walk away, it will just answer your question, nothing more. This is different from artificial intelligence (AI). AI systems can mimic human behaviour, and an AI tool like ChatGPT will recognise the context and provide you with a more comprehensive answer. But even AI-based systems rely on existing knowledge; if it is limited, they will not be able to go beyond.⁵

From a human perspective, reality is not just a reflection of what we perceive with our senses but a product of our experience and our knowledge. We cannot assume that each human perceives the same reality. Humans are more complex. They cannot only associate a question with an intention, but they may exhibit behaviour which is unpredictable. If the pedestrian is afraid of you because you appear dirty or disgusting, he may even ignore you.

That is, we cannot assume the same reality applies to all humans. We need to interpret mental experiences using different principles. And we cannot build an instrument due to the lack of understanding of underlying laws. The same applies to AI systems that just mimic intelligent behaviour.

1.2.2 A Missing Link

The matter of reality raises a fundamental question: does reality exist, or is it just an imagination? When our senses perceive a phenomenon⁶ (such as seeing black and yellow stripes) of a physical object (such as a bee), our brain creates a mental phenomenon (a state in the brain). By comparing the

⁵ This is something that may change very soon, considering the fast development of AI systems.

⁶ Phenomenon (Greek: *phainomenon*, appearance): appearance of physical or mental states.

perception with a body of experiences (stored in our memory), we create cognitive associations that either contribute to the body of experiences (identifying it as a bee) or lead to an action (like backing off). Figure 1.1 exemplifies such a relationship.

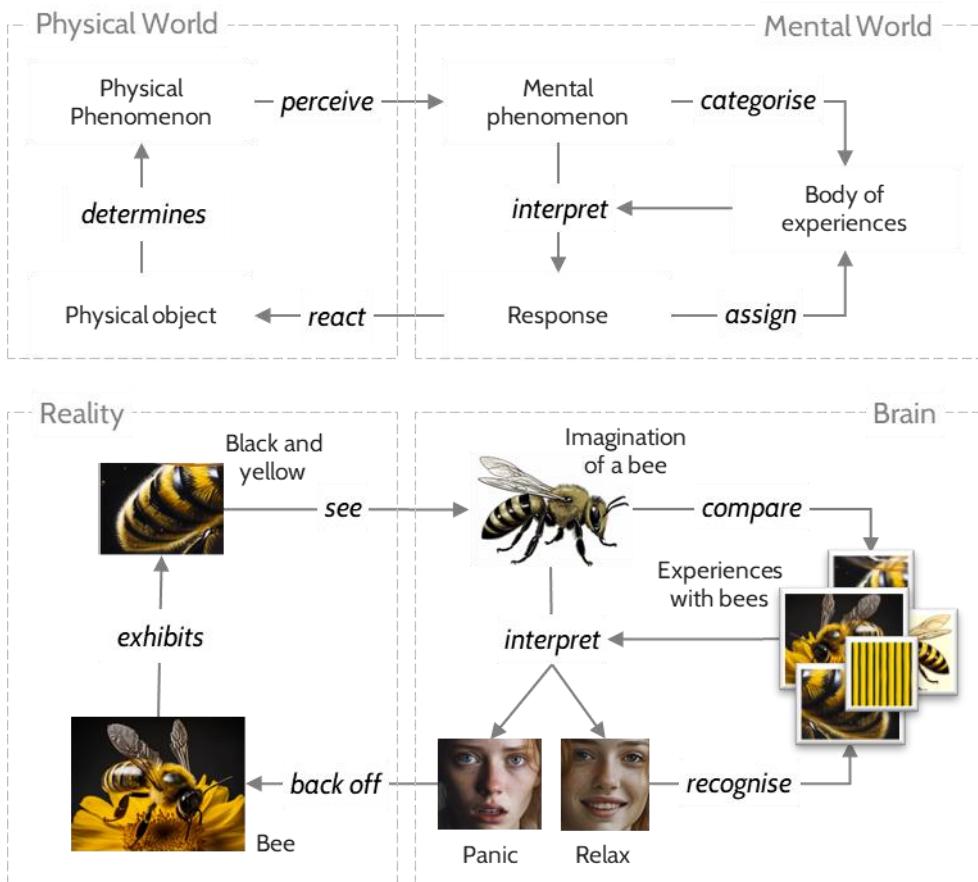


Figure 1.1 On physical and mental phenomena (above) and an example (below).

Although we distinguish here between the physical and the mental world, we should note that it would be misleading to take a singular position by strictly believing in either reality existing or just being mental. Even if we imagine something beyond any physical reality (like when we dream or experience an emotion), it is reasonable to assume our brain is in a particular physical state. A missing link between physical and mental state would be overwhelmingly unlikely. We could now engage in one of the sophisticated debates for and against this mind-body dualism,⁷ but it seems much more reasonable to admit our ignorance of the nature of this link.⁸

Mind-body dualism

⁷ Dualism describes two fundamental (and often opposing) principles or stances (for a comprehensive account on dualism in the philosophy of mind, see Robinson, 2020).

⁸ This is a typical approach of physicists: if you cannot explain a phenomenon, give it a name, accept its existence, and go ahead with your research.

1.3 THE PHILOSOPHICAL PERSPECTIVE

The philosophy of sciences provides us with a framework. Figure 1.2 shows that operational aspects of research (which will be discussed in their context in the other chapters) rely on a philosophical basis of assumptions.

Research	Operational aspects, tools and techniques	Validation Procedure to ensure credible results
		Synthesis Inference on a higher level of abstraction
		Interpretation Approach of reasoning and explanation
		Analysis Procedure to classify and identify relationships
		Sampling Procedure to select objects of investigation
		Instrument Tool used to implement a method
		Method Technique used to conduct research
Philosophical Framework	Beliefs, assumptions, and principles	Methodology Body of principles to investigate
		Epistemology Theory of knowledge creation
		Ontology Perspectives on reality

Figure 1.2 The philosophical framework and operation aspects of research

From the perspective of the philosophy of science, we need to make assumptions for two fundamental questions:

- Do we focus on physical or mental reality?
- Do we believe we can know things just by rationality, or do we always need to experience them first?

The reason for clarifying these questions is that our assumptions will have consequences on the principles of investigation and interpretation.

1.3.1 Ontology – A Matter of Reality

Although we avoided the metaphysical question about the meaning of 'truth', we still need to adopt a position concerning reality. The question

about the nature of reality is a matter of *ontology* (Greek: *ontos*, being), a sub-field of metaphysics dealing with existence.

We can either assume that a real world exists and our senses and thoughts reflect it, or we assume that our mind constructs our reality, independent of whether it exists in the form we perceive it or not. At first sight, this seems like a personal belief. We will see later that it is much more a question of our research objective than just a personal attitude. We begin with distinguishing two fundamental ontological stances: realism and idealism.

Realism holds that the external world exists independently of our perception or knowledge. It has objective properties we can observe and interpret. Nevertheless, realism does not necessarily assume that it exists exactly as we perceive it or that it has a *material reality*.⁹

Idealism is the philosophical stance that reality is fundamentally mental or subjective and that the external world we perceive is a product of our mind. In other words, reality depends on our perception and interpretation rather than existing independently of us.

1.3.2 Epistemology – What Can Be Known

Based on our ontological stance, we can approach the question of what we accept as knowledge and how we justify it: the matter of *epistemology* (Ancient Greek: *epistēmē*, knowledge). Knowledge is understood in this context not just as remembering facts but as the application of the learned to understanding and explanation.

In general, we can distinguish between those things we can know in advance (Latin: *a priori*; the earlier) just by rationality and without an empirical basis and those we derive from sensory experience (Latin: *a posteriori*; the later). That leads to two basic epistemological stances: rationalism and empiricism.

Rationalism The stance of rationalism emphasises the *a priori* or non-empirical approach: the use of reason as a source of knowledge and justification. Rationalists hold that at least some knowledge is innate or inherent in the human mind and that the mind can arrive at truths independent of sensory experience.

Empiricism The stance of empiricism emphasises the *a posteriori* approach, holding that all knowledge and justification require preceding sensory experience.

Ancient empiricists argued that the mind is a blank slate (Latin: *tabula rasa*) at birth and that all knowledge is obtained by interacting with our

⁹ A more rigid stance is *materialism*, which assumes that matter and energy is the ultimate reality and that mental and social phenomena emerge solely from physical processes.

surroundings. However, contemporary philosophy has overcome this rigid view due to insights from the cognitive sciences.

There are further epistemological stances, such as constructivism (knowledge is actively constructed by social actors) or pragmatism¹⁰ (knowledge is determined by practical efficacy), just to name two predominant ones. However, they typically emerge from particular science disciplines, like psychology, education, or economics, and their descriptions tend to get lost in sophisticated details of the admitted subjectivity of our perceptions and understanding. They seem to defend the kind of trivialities that are taken for granted by any reasonable scientists: that knowledge is constructed by humans and, therefore, not necessarily true and that it is typically applied in a real-world scenario. Considering our initial postulate about truth, none of these stances provides enough fundamental differences to incorporate them as demarcating principles and an approach to methodology.¹¹

Other epistemological stances

1.3.3 Methodology – Principles of Research

Our position regarding ontology and epistemology has consequences on the principles we should follow to generate knowledge: the field of *methodology*. The term methodology in its original sense (Ancient Greek: *méthodos*, the way to follow; *logos*, discourse, reason) refers to the study of methods. Contemporary dictionaries also describe it as a body of methods underlying certain principles or assumptions.¹²

To generate knowledge, we can prefer a methodology focusing on logical reasoning (rationalism) or one using observation and experimentation (empiricism) to arrive at knowledge. While many research projects rely on the latter, we use rational arguments in any case, and the methodological differences become less significant. A more pronounced difference stems again from the ontological positions: the realist and the idealist stance.

Methodologies from a Realist Perspective

If we tend to take a realist ontological stance, we assume an independent physical reality. The question of whether reality exists as we perceive it is, in

¹⁰ Pragmatism in contemporary understanding differs from the original idea of a *logical pragmatism* of mathematician Charles Sanders Peirce. Peirce later called it *pragmaticism* to distinguish it from the variants proposed by his contemporary psychologist William James and educational scientist John Dewey; see (Aliseda, 2005).

¹¹ For critical assessments of constructivism, see (Schmidt, 2001), and on pragmatism, see (Rorty, 1980).

¹² An interesting and comprehensive, although not peer reviewed, discussion paper on the notion of methodology is given by (Callaos & Callaos, 2017).

fact, secondary. The main assumption is that reality underlies general principles or laws that we want to find. Such reality would be *objectively* the same for everyone, at least in our contemporary understanding of reality.

Empirical approach To generate knowledge from a realist perspective, we must obtain sensory experience and learn how it affects our rational thinking. To ensure objectivity, we try to control the conditions of our investigation. Although we often have limited control, we keep as much as possible constant or unaltered, leaving a degree of freedom just to the entity under study.

Experimental approach We can also create an artificial environment (a laboratory) and experiment. We do this under rigidly controlled conditions and take advantage of reliable measurement instruments rather than just using our senses. Such instruments add a degree of precision well beyond the capacity of the unassisted human senses.

Methodologies from an Idealist Perspective

A consequence of the idealist ontological stance – our mind creates our reality independent of its real existence – is that we deal with humans or social systems. Another is that interpretation and meaning may differ from person to person (or from society to society) and that multiple interpretations are not just possible but may be of equal value. A consequence is that knowledge is *subjective* since an objective reality is not assumed. Another is that knowledge is relative to the subject under investigation, the observer, and the contemporary understanding of the community.

Dialogic approach In this case, we find evidence by observation and dialogue and by interpreting the meaning of what is said. We use the term *dialogic* to refer to a conversation or discussion between two or more people where each person actively listens and responds to one another in a respectful and open-minded manner. It is an approach to communication that emphasises mutual understanding and the exploration of different perspectives.

Dialectic approach If our goal is to exchange arguments between two or more positions with the goal of defending one argument over another, we call it a dialectic approach. We seek to find the truth through the clash of opposing ideas with the goal of resolving contradictions and achieving a synthesis – a new perspective or understanding of a phenomenon that ideally encompasses both positions.

Hermeneutical approach Dialogic and dialectic approaches rely on the interpretation of written artefacts, such as transcripts from dialogues, field notes, or original texts. The interpretation of written artefacts is in the field of *hermeneutics*.

1.4 THE CONSEQUENCES OF ONTOLOGIES

Epistemology and methodology rely on ontology – the assumptions we make for reality. To explain the consequences of an ontological stance on methodology and results, let us imagine the management of a medium-sized company asking a psychologist and a psychotherapist to independently investigate the reasons for regularly occurring burnout syndromes. Figure 1.3 shows the different approaches that are explained in the following.

	Psychologist	Psychotherapist
Goal	Find patterns	Understand individuals
Ontology	Realism Single reality	Idealism Multiple realities
Method	Survey	Interview
Result	Proportion of professional and personal reasons <small>← although not necessarily contradictory →</small>	Incomparable Individual professional and personal reasons
Application	Propose measures for management	Propose measures for employees
Approach	Nomothetic pattern is identified and generalised	Idiographic pattern may be recognised but is not generalised

Figure 1.3 Example of the consequences of ontologies. Different goals require different ontologies, and the transition from an idiographic to a nomothetic approach requires a change of ontology.

Let us assume the psychologist relies on the realist ontology that a single reality exists for all clients. She conducts a survey and finds that clients more often suffer from burnout syndrome because of professional reasons rather than personal ones. If the sample size represents the population, she can generalise the results and propose company management changes in the work environment.

The psychotherapist will perform individual sessions with each client and does not assume reality is the same for all clients. The idealist ontology guides her to assume that the perception of reality will differ for each client and additionally depends on her personal experience. That does not mean

she rejects a reality outside the client's mind; she merely believes each client brings a personal perception of reality into the session. After each session, the psychotherapist can propose to each client measures to personally deal with the burnout syndrome. She can additionally inform the company management about typical reasons for burnout syndrome.

1.4.1 How the Results Differ

Nomothetic

Since our psychologist produces only a proportion, she cannot propose to each client an individual solution. However, she can find a regularity for the occurrence of burnout syndrome. We call the search for a generic applicable law the nomothetic approach (Greek: *nomos*, rule, *thetikós*, affirmatively).

Idiographic

Our psychotherapist will obtain multiple results, one for each client, but cannot provide the management with a general recommendation since she assumes individual realities. Nevertheless, she can provide the management with a series of individual reasons for burnout syndrome. We call this the idiographic approach (Greek: *idios*, pertaining to self; *gráphein*, write): to describe and understand individuals.

What would happen if our psychologist looked at the individual questionnaire responses? She would have to ask herself whether her assumptions still hold: if she assumes reality is the same for all clients, a single sample does not represent the reality of all employees. That is, individualisation does not make sense to her.

What would happen if the psychotherapist tracked the client's data in a worksheet and calculated the proportion? Again, she would have to ask herself whether her assumptions hold: if each client has its own reality, any new client may have another. That is, a generalisation does not make sense to her.

*Neither contradictory
nor comparable*

A consequence is that the results are not comparable, although they may not contradict. While one result may inform the other, they cannot be confronted since they rely on different ontologies. The investigations support different goals (generalisation and individualisation); they begin with different assumptions (realist vs. idealist), use different methods (survey vs. therapist session), and interpret the results differently.

1.4.2 The Difference Between Theory and Practice

To claim that interpreting an individual's perception is now the only thing our psychotherapist would have to consider would be misleading. In practice, the psychotherapist learned in her education about generalisable laws and subsequently from recurring patterns turning up in her regular practice.

Each education relies on such patterns, and many research problems finally lead to generalisation. If researchers were only interested in individual cases, they could also live in an ivory tower.

On the other hand, a survey barely contributes to comprehensively understanding human behaviour. Without understanding individual cases, we would be unable to decide what allows for generalisation and what does not.

Idiographic research necessarily requires a higher degree of freedom in interpretation and research methodologies. However, scientific studies need to be systematic to compare results among researchers to assess their validity. The tricky part for our psychotherapist is adopting a systematic approach that inherently poses the risk of ending up with a normative¹³ argumentation. While this seemingly creates a contradiction between a systematic approach and idiographic research, we will see later that they are not mutually exclusive. Anyhow, we need to consider different approaches for different research goals.

1.4.3 A Single Approach Does Not Suffice

We can see that we need aspects of both approaches when we look at common university examinations (Figure 1.4).

Method	Methodology	Approach
Written Exam	Lab Experiment	Nomothetic
Oral Exam	Measure knowledge under comparable conditions	
Practical Training	Field Experiment	
Internship	Assess knowledge in real life settings	
Thesis Appraisal	Dialog & Observation	Idiographic
Thesis Defence	Assess knowledge by interpretation and meaning-making	

Figure 1.4 Methodologies underlying typical university examinations. The research objective changes from nomothetic (multiple students) to idiographic (individual students) research.

¹³ Normative: referring to a norm, standard, or law.

A *written exam* can be considered a laboratory experiment since the goal is to measure the knowledge of students under comparable conditions. The *laboratory* is the examination room, and the static conditions are the set of questions, exam period, and allowed tools, such as a calculator. Although we want to identify the proficiency of each individual student, we apply a methodology that is nomothetic and founded on a realist ontology: we assume the individual's response can be measured comparatively due to an underlying objective reality for the assessment.

The same applies to an *oral exam*. Although conducted with individual students and in different rooms, the conditions are held comparable. All these cases are typical for a nomothetic approach, assuming an objectively measurable reality and aiming for generalisation.

The assessment of a student during *practical training* or an *internship* is an example of a field experiment since the investigation takes place in a natural setting under less controllable conditions. In this case, we have already turned away from a nomothetic approach since we deal with a few or just one individual.

However, a supervisor's grading of a thesis already marks a clear transition to an idiographic approach. The supervisor cannot assume a student's perception of a topic is the same for all students. She needs to interpret written statements to assess her thesis appropriately. This applies even more to the thesis defence, where the interpretation of answers, behaviour, gestures, confidence, and many more contribute to the evaluation. A supervisor will also consider her experience with a student from previous lectures or examinations, compare it to experiences with other students, and assess the student's improvement during the studies. But she also needs to stick to university regulations to make the results objectively comparable.

Although a supervisor uses a systematic approach to grading, her assessment is typical idiographic research, assuming the meaning of statements, answers, and behaviour is a subjective measure for grading a student's subjective reality. That is, the established methods to grade students follow two different ontologies.¹⁴

The question is now: can we confront the nomothetic results (like the exams) with the idiographic ones (like thesis defence)? In fact, we cannot. One result might support the other, but in most cases, they do not. A student might achieve a good grade in a thesis, although he is an intermediate performer

¹⁴ While strict advocates of one or another ontological stance attempt to vigorously defend their one-sided ideas through sophisticated rhetoric, they either have never graded students or deviate from their own arguments in their pedagogical practice.

in examinations. On the other hand, being good in examinations does not ensure being good in research and writing.

The consequence is that we never achieve an objective measure to grade students because we tumble between generalisation and individualisation. It depends on the goal: if we want to grade individually, we need an idiographic approach. If we want to make it comparable (what is required at the university), we need the nomothetic one. That is, we should be careful when talking about a mutually exclusive dualism of ontological stances.

1.5 A CRITICAL DISCOURSE

At this point, it is necessary to address some deficiencies of the previously described viewpoints and their consequences. The reason is that students are often confused by ontological stances and their argumentation. In the following, we will critically assess those pitfalls, misused terminology, and emphasise the value of definitions in sciences.

1.5.1 The Issue of Paradigms

We usually find the positions of ontology, epistemology, and methodology embedded in a so-called scientific paradigm, a framework including beliefs, assumptions, and research principles.

The scenario described above is often distinguished by a so-called scientific paradigm: the psychologist follows a post-positivist, and the psychotherapist an interpretivist paradigm. Table 1.1 shows the predominant ones and their characteristics in a simplified form.

Paradigm

If we followed the mainstream, we would address the sophisticated details in paradigmatic stances. However, we decided to refrain from using paradigms as the demarcating principle for the following reasons:

Breaking a rule

- Paradigms change. Something written by the originators of a contemporary paradigm is often outdated within decades, sometimes even shortly after publication when critical reviews occur.
- Paradigms are often differently interpreted in scientific disciplines; this ironically applies particularly to interpretative paradigms.
- Proponents of paradigms often argue with sophisticated details that apply just to specific settings or a discipline.
- Paradigms are regularly defended against seemingly opposing positions that do not exist.

- Finally, the terminology of paradigms is confusing. Anyone who has tried to understand the subtle difference between *constructivism* and *constructionism* (not a typo) knows what we're talking about.¹⁵
- The debate about the scientific value of paradigms and their correct application leads to confusion not just among students but also among practitioners, from which we – the authors – are not exempt. Proponents of a paradigm often emphasise seemingly unique characteristics but often fail to adequately justify their arguments.¹⁶

The issue of rhetoric It becomes worse if the argument is rhetoric. For example, Madison states against the attempt of logical positivists¹⁷ to unify natural and human sciences:

"The interpretive approach rejects this sort of methodological imperialism; it rejects the idea that the human sciences can or ought to be modelled on the natural sciences."¹⁸

Madison uses the word *imperialism* as a rhetorical device to impute to logical positivism a hostile attitude towards interpretivism, which, in fact, does not exist. Moreover, the rejection of "the idea that the humanities can or should be modelled on the natural sciences" seems to express precisely the kind of imperialism against which he is arguing. Madison further claims:

"Let us simply label this the Positivist Ideal. The trouble with this kind of call for intellectual rigour is that it is not nearly rigorous enough. On the one hand it naively accepts positivistic myths as to what natural science is (such as the 'empirical' status of scientific statements; the notion that scientific theories are accepted because they are or can be tested or verified; and so on)."¹⁹

Again, we find these rhetorical devices like *naïvely* and *myths* that do not contribute to a reasonable debate, besides leaving the impression that the author has failed to deal with some of the basics of what he calls *positivistic myths*.

¹⁵ In the same sense, we discourage using the so-called research onions regularly turning up in contemporary textbooks of social science research. They unnecessarily blur the philosophical terminology, causing students more confusion than enlightenment.

¹⁶ For example, we find that interpretivists emphasise the importance of reflexivity, arguing that the researcher's experience, values, and assumptions influence the interpretation of data. However, this is not a definitive criterion for distinguishing interpretivism from other paradigms.

¹⁷ Logical positivism emerged in the early 20th century, emphasising meaningful statements should be either analytic (true by definition) or empirically verifiable. For a summary, see (Hanfling, 2003)

¹⁸ (Madison, 2005, p. 32)

¹⁹ (Madison, 2005, pp. 33-34)

Table 1.1 Characteristics of contemporary scientific paradigms

Paradigm	Ontology	Epistemology	Methodology (Examples)
Positivism	Reality underlies independent laws (Realism)	Knowledge can be gained objectively (Objectivism)	Measurement and natural observation (Experimental)
Post-Positivism	Reality underlies independent laws (Critical realism)	Knowledge can be gained objectively by systematic observation of social action (Critical rationalism)	Observation of social interaction and inquiry (Empiricism)
Interpretivism	Reality underlies mental constructs (Idealism)	Knowledge is gained by interpreting the mental constructs of individuals and observers (Subjectivism)	Interpretation of social phenomena from the perspectives of individuals (Empiricism, Hermeneutics, Phenomenology)
Constructivism	Reality underlies independent laws that cannot be fully known (Model-dependent Realism)	Knowledge is constructed by collaborative consensus and standardisation (Social Constructivism)	Interpretation of the perspectives of social communities (Dialogic, Hermeneutics, Grounded Theory)
Critical Theory	Reality underlies independent social laws that evolve historically (Historical Realism)	Knowledge is mediated reflectively through the perspective of the researcher (Transactional Subjectivism)	Assess implications of human behaviour within its social and political context (Ideology Critique, Critical Discourse Analysis, Critical Hermeneutics)
Pragmatism	(none)	any means	not predefined ('mixed'); often experiment and observation

The rhetoric of debates amongst philosophers reaches a further level of escalation. Slezak writes about the radical constructivism²⁰ of his colleague von Glaserfeld:

“Indeed, such platitudes are characteristic of constructivist instructional advice, though they are typically dressed up in a gratuitous technical jargon which serves only to hide their banality.”²¹

While Slezak provides good arguments for his position, we doubt that such rhetoric is helpful in clarifying conceptual differences.

The paradigm wars

The climax of dividing rhetoric was reached in the so-called *paradigm wars* of the 1970s and 1980s. Even long after the initial storm settled, some authors went as far as to call for it. Amos Hatch writes in his editorial for the *International Journal of Qualitative Studies of Education*:

“Let us engage in the paradigm wars. Let us defend ourselves against those who would impose their modern notions of science on us by exposing the flaws in what they call scientifically-based [sic] research.”²²

While we perfectly understand Hatch’s enthusiasm for his ‘qualitative studies’ in education, it seems unworthy of the profession of a teacher (and he is one) to cynically call for war.

We regularly find examples in the literature where advocates of individual stances try to defend their position against other paradigms. We see endless debates about perceived misunderstandings of paradigms, misinterpretations of their application, and sometimes harsh criticism of rival authors that go far beyond a reasonable discussion.²³

We don’t want to say that the ongoing discussions about paradigms are useless. But we would agree with Hassan:

“The problem with metaphysical paradigms is not epistemology or ontology, which are critical foundations for any effective research; it is the adoption of epistemology or ontology as the paradigm.”²⁴

A fundamental truth of argumentation

At this point, we should remember a fundamental fact: arguing against an opposing position ultimately implies accepting it as a potential alternative.

²⁰ Radical constructivism posits that knowledge is actively constructed, rather than being passively received from an external world. For details, see (von Glaserfeld, 1984).

²¹ (Slezak, 2001, p. 77)

²² (Hatch, 2006, p. 407)

²³ An excellent editorial comment on the rhetoric of positivism and interpretivism can be found in (Weber, 2004)

²⁴ (Hassan, 2013, p. 494)

A new stance always requires first a demarcation from established ones. However, after demarcation, *we must consider at least an attempt to reach a consensus*. If this is not intended, it is just a violent act.²⁵

1.5.2 The Qualitative-Quantitative Debate

We recognise a trend in the social sciences beginning in the second half of the 20th century that reduces the demarcation between paradigms to the terms *qualitative* and *quantitative*. We find literature using these terms to distinguish:

- the type of data typically used (nominal/ordinal vs. interval/ratio)
- the logic employed (inductive or deductive)
- the study phase (exploratory or explanatory)
- the method of analysis (interpretative or logical)
- the underlying paradigm (positivist or interpretivist)

There are more seemingly demarcating criteria. The arbitrary use of *qualitative* and *quantitative* to label words like *research*, *method*, or *technique* seems to have crept into social science culture. Most contemporary textbooks on social science research jumped on that train, and even journals of *qualitative studies* appeared.

However, a closer look at the adjectives reveals that *quantitative* and *qualitative* refer to amounts and states, respectively. Does it mean that *qualitative* research is *stateful* research? Or does it mean that it just uses qualitative data?

The confusion begins with students interpreting survey data as quantitative, although they asked for the respondent's opinions. Survey research, in most cases, collects qualitative data (unless we ask for a number) regardless of whether we transform them later into frequencies or not. Think of it: if we summarise responses from questions addressing affective, cognitive, or conative aspects, our raw data are still qualitative. If we transform them into frequencies, we work with a quantitative representation of qualitative data to aim for generalisation. Is it then qualitative or quantitative research?

Are survey data quantitative?

As natural scientists, we are surprised – to say the least – about such misuse of terminology. Can research – being an activity – be quantitative (numerical) or qualitative (stateful)? We think not. It may take advantage of qualitative data, but that does not even exclude using quantitative ones.

²⁵ It is surprising how often the argumentation of opposing positions aims solely at emphasising their differences, when the subject of the discussion emerges from their proximity.

What is usually meant by *qualitative research* in social sciences is an idiographic approach or one following an interpretivist or constructivist paradigm. In contrast, *quantitative research* primarily refers to nomothetic approaches, a positivist or post-positivist paradigm, and very often just to statistical analysis. H. Russell Bernard appropriately states in his book *Research Methods in Anthropology*:

"By a quirk of English grammar, the phrase 'qualitative data analysis' is delightfully ambiguous. Unless someone spells it out in lots of words, you never know if the phrase means 'the qualitative analysis of data' or the 'analysis of qualitative data.' And, of course, the same goes for 'quantitative data analysis.'"²⁶

Besides such ambiguity, these terms divert from the fundamental methodological difference. Lynne S. Giddings reminds us that:

"the use of the terms qualitative and quantitative as normative descriptors reinforces their binary positioning, effectively marginalising the methodological diversity within them."²⁷

Breaking a rule again We would agree and recommend not following the mainstream but using these adjectives only in combination with *data* and equivalent terms that deserve the distinction between amounts and states. Data can be quantitative (amounts) or qualitative (states). Research cannot.

The dubious mixed-method approach Even more confusing is the so-called mixed method approach, which seems like an attempt to unite *qualitative* and *quantitative research*. One of its originators describes it as:

"An approach to research in the social, behavioral, and health sciences in which the investigator gathers both quantitative (closed-ended) and qualitative (open-ended) data, integrates the two, and then draws interpretations based on the combined strengths of both sets of data to understand research problems."²⁸

Apart from the barely adequate analogy of the terms *qualitative* and *quantitative* with *closed-ended* and *open-ended*,²⁹ the quotation states a triviality: we can use both types of data in research. The argumentation does not become more convincing when its proponents enthusiastically glorify it as a "*third methodological movement*"³⁰ or as "*emerging as a dominant paradigm*"³¹.

²⁶ (Bernard, 2006, p. 451)

²⁷ (Giddings, 2006, p. 195)

²⁸ (Creswell, 2015)

²⁹ The author is probably referring to the response format of surveys, where closed-ended questions provide a limited choice of options, whereas open-ended questions allow the respondent to verbalise an answer. However, a response format is not a data type.

³⁰ (Tashakkori & Teddlie, 2003, p. ix)

³¹ (Doyle, Brady, & Byrne, 2009, p. 175)

From a scientific perspective, there is no doubt that we can use any data and any valid scientific method, provided we adhere to its assumptions and consider the implications of these assumptions in comparing our results.

1.5.3 A Matter of Definition

A similar issue of the misuse of words occurs with other terms, like *inductive*, *deductive*, and *abductive*, which (as we will see later) refer to methods of reasoning and are barely appropriate for qualifying words like *research* or *approach*. In particular, social sciences seem to lack terminological sensitivity and tend to misuse terms from other sciences as metaphors for their concepts. Examples are nominal *scale*,³² data *triangulation*,³³ social *entropy*,³⁴ and social *chaos theory*,³⁵ just to name a few. Before we use or combine any of these terms, we should look at their definitions in the context of their scientific origin. Of course, we need to understand the foundations of the corresponding scientific discipline, and we need unambiguous definitions.

Definitions play a key role in science since they demarcate the meaning of terms or concepts. In linguistics, a lexical definition (Latin: *definitio*; demarcation, specification) describes the meaning of a word to distinguish it from other words. Although words may have a clear definition, their inappropriate use as a metaphor can cause confusion. This even happens in natural sciences.

For instance, defining an electron as negatively charged does not state a reality, let alone truth. Whether an electron exists or not is – at least for a physicist – a pointless question. The term *electron* just describes experimentally observed composite phenomena of charge, spin, orbital angular momentum, and other properties. But as soon as we define an electron as a negatively charged *particle*, we run into the trap of misspecification. We forget that the word *particle* is a metaphor. But soon, we find it in every physics textbook, in the very same book, that a few chapters later, must explain the counterintuitive wave-particle duality, a concept that students still struggle with today. However, wave-particle dualism is not a contradiction but refers to two phenomena that occur due to different experimental settings. The confusion is simply a result of using the metaphors of wave and particle, which – as

Lexical definition

Is an electron a particle?

³² A scale cannot be nominal since the latter applies to a category; see (Sartori, 1970, p. 59)

³³ see, for instance, the comments on triangulation by Morgan (Morgan, 2019), the reply from Maxwell (Maxwell, 2022), and the reply to Maxwell (Morgan, 2022).

³⁴ Not even physicist would claim they have a comprehensive understanding of entropy; see (Schwartzman, 2008)

³⁵ (Kellert, 1995)

any metaphor – cannot replace the phenomenon but merely create an association.

Conceptual definition

An even greater challenge lies in conceptual definitions. Like lexical definitions distinguish words from one another, conceptual definitions require a *contrasted concept*. Otherwise, a demarcation does not make sense. For instance, a conceptual definition of *communication* is useless since a contrasting concept does not exist.³⁶ This is different for *team communication*, which can be distinguished, for instance, from *corporate communication*.

Conceptual definitions require multiple *unique characteristics*; any commonality with the contrasted concept becomes useless as part of a definition. While it is easy to find unique characteristics to distinguish, for instance, idiographic from nomothetic, such a strict approach is barely applicable to paradigms that incorporate ontologies, epistemologies, and methodologies unless the definitions become complicated. But definitions should *improve communication* rather than becoming the primary matter of debate.

1.5.4 A Way Out

In fact, the differences between the paradigms shown in Table 1.1 are not as dramatic as often described. No reasonable scientist would assume that the world is just a matter of facts. Hawking states:

“I take the positivist viewpoint that a physical theory is just a mathematical model and that it is meaningless to ask whether it corresponds to reality. All that one can ask is that its predictions should be in agreement with observation.”³⁷

Unfortunately, Hawking fell into the same trap as many of his colleagues: he used a paradigmatic stance to argue for his position. But that is, in fact, not necessary. It is not about the stance but about the assumptions, which unfortunately blur into metaphysical debates. Even natural scientists are aware of their subjectivity, the inadequacy of their methodology, and the impact that contemporary society's beliefs have on understanding. This is a *generic critical stance* that any reasonable scientist would adopt.

Scientists are not evangelists of truth.

If we accept our initial postulate that we do not search for truth but for facts within a system of acceptable assumptions, we can evade such debate. Rather than just sticking to a rigid position, we derive the most appropriate method from our research objective, from what we want to achieve, or in

³⁶ According to the first axiom of communication there exists no ‘non-communication’ between humans, since every behaviour communicates a message (see Watzlawick, Bavelas, & Jackson, 1969, p. 47).

³⁷ (Hawking & Penrose, 1996, pp. 3-4)

Dharmakīrti's words, from the successful action – whether rational or practical.

That does not mean we can arbitrarily use any method and mix their results.³⁸ You also wouldn't play Mah-Jongg according to chess rules or solve a Sudoku puzzle in the same way as you solve a crossword puzzle. We need to consider the impact of our assumptions on our methodology and our interpretation.³⁹ But we can adopt multiple perspectives and behave – in the words of psychologist Abraham Harold Maslow – like a *healthy scientist*:

"It is possible for healthy scientists to enjoy not only the beauties of precision but also the pleasures of sloppiness, casualness, and ambiguity. They are able to enjoy rationality and logic but are also able to be pleasantly crazy, wild, emotional."⁴⁰

The most important criterion for a scientist is to approach a topic with a clear conceptual design. This is described in the following chapter.

³⁸ A typical misunderstanding found in descriptions of the above mentioned mixed-methods research.

³⁹ For a deeper insight, we recommend Stéphanie Ruphy's book on scientific pluralism (Ruphy, 2017)

⁴⁰ (Maslow, 1966, p. 31)

2 THE PATH TO DISCOVERY

The only way to impress a scientist is to convince him of the conceptual purity of your research approach.

To decide on a methodology, we consider three fundamental aspects: the assumptions we make before we generate new insights, the phase of the research progress in which we investigate, and the complexity of the system under investigation.

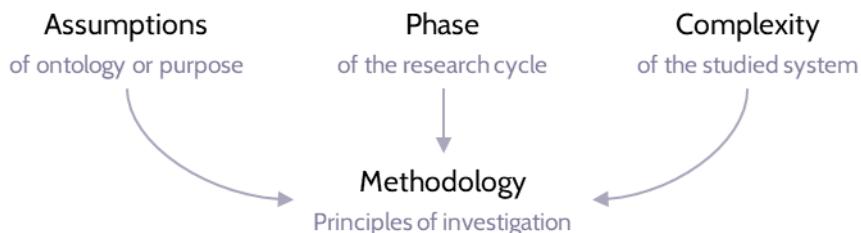


Figure 2.1 Fundamental aspects affecting the research methodology

The assumptions may have ontological origins (such as taking a realism or idealism stance) or depend on the scope and intended level of generalisation (such as a nomothetic or idiographic approach), as explained previously. The following subchapters describe the consequences of the research phase and the system's complexity.

2.1 THE RESEARCH CYCLE

Knowledge generation is a consecutive and cyclic process that happens – independent of the research discipline – in multiple phases. The research

begins with a phenomenon to investigate. The phases differ in the level of existing knowledge and the purpose of the study, as shown in Figure 2.2.

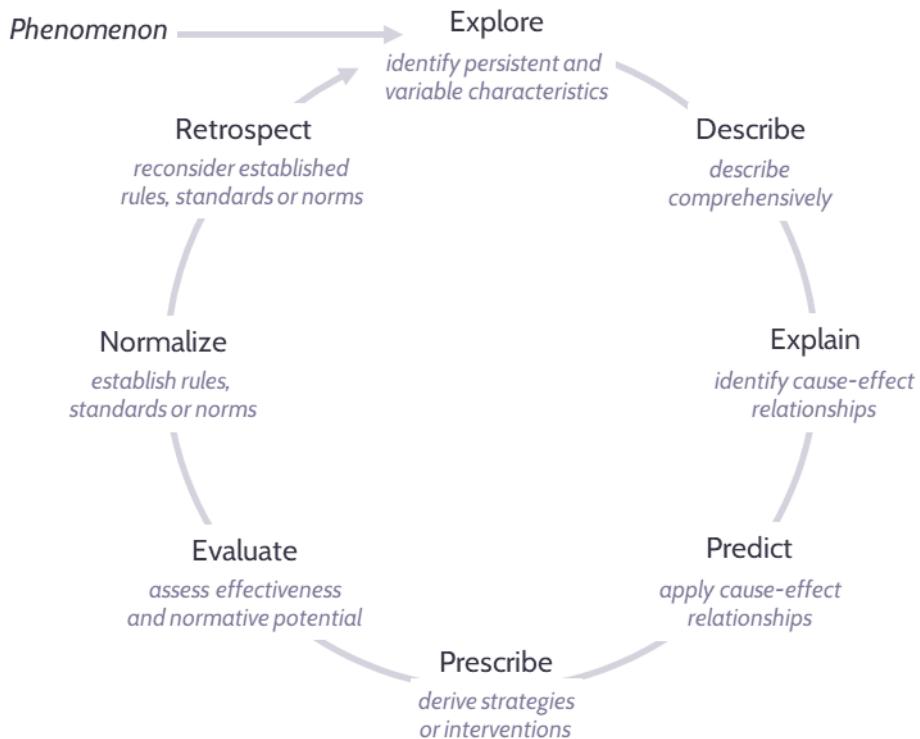


Figure 2.2 A full research cycle

The research cycle begins and ends with exploration. In the *exploratory* phase, we investigate a subject for the first time. We identify characteristics that either are persistent or vary and patterns of their variation. We can also generate *a priori* hypotheses to assess them in subsequent phases.

In the *descriptive* phase, we attempt to describe a subject comprehensively. We use the complete set of characteristics found in the exploratory phase and extend them by metadata, such as codes or descriptive statistics.

In the *explanatory* phase, we identify dependencies between characteristics to model underlying cause-effect relationships. We typically use taxonomies and apply inferential statistics or machine learning to generate a model.

The *predictive* phase applies the found cause-effect relationships to either test hypotheses or forecast yet unknown characteristics.

The *prescriptive* phase focuses on providing recommendations or prescriptions for action. It involves identifying the most effective strategies or interventions to achieve desired outcomes.

The *evaluative* phase involves assessing the effectiveness and impact of the implemented strategies or interventions to achieve the intended goals. This

phase includes applying them to different use cases, monitoring progress, and identifying areas for improvement. We finally assess their normative potential.

The *normative* phase uses successful strategies or interventions and considers their ethical, moral, or value-based implications to establish universally applicable rules, guidelines, policies, standards, norms, or systems, advocating for specific principles to guide decision-making or behaviour.

The *retrospective* phase extends the evaluation by critically reconsidering established norms, practises, or systems in terms of their contemporary validity and value.

Figure 2.3 shows an example of a research cycle for investigating the phenomenon of a flooding scenario.

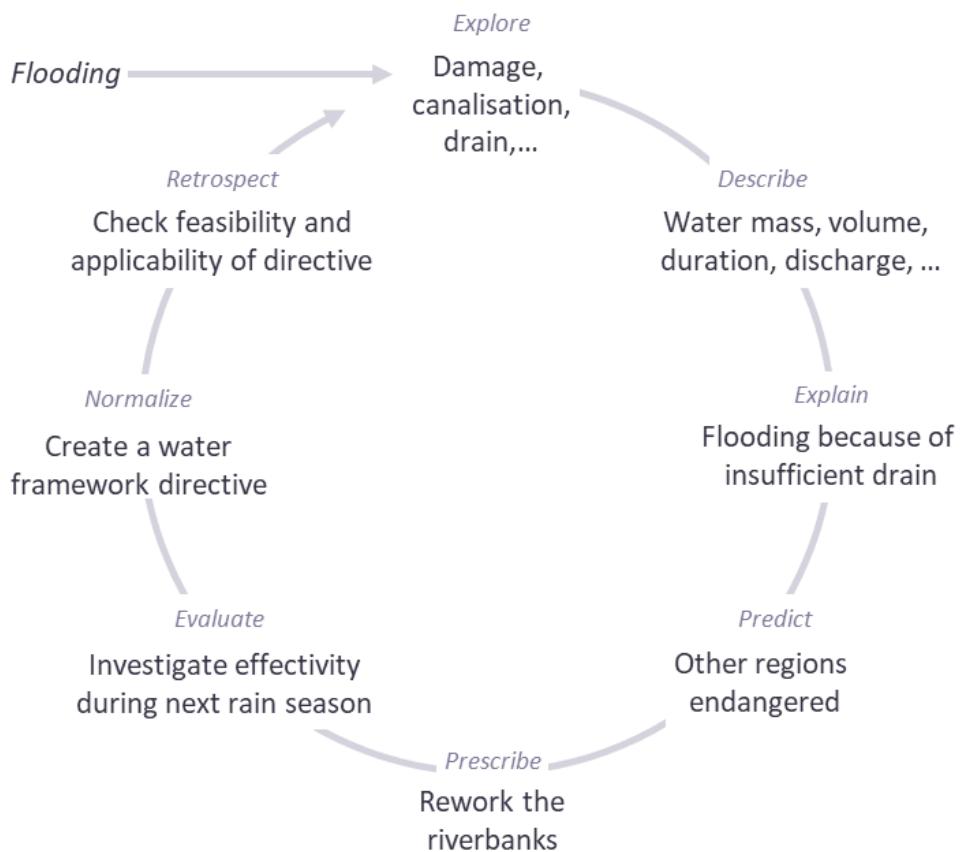


Figure 2.3 Example of a research cycle for a flooding scenario

This sequence encompasses the full research cycle, from initial exploration to reflecting on the established norms. The phases are typically consecutive. Each phase relies on the findings of the previous phases, and each new contribution in one of the phases will trigger the subsequent phase to be reconsidered and updated. Nevertheless, individual research objectives or questions may address different phases of the research cycle.

Besides describing the purpose of a study, the research phase often determines the complexity of the system under investigation.

2.2 SYSTEM COMPLEXITY

System

Research methodologies depend on how difficult it is to understand a system under investigation. When we talk about a *system*, we mean a group of entities that expose certain relationships. Each entity plays a role in the system, and their interactions contribute to the overall behaviour of the system. The behaviour of a system is influenced by stimuli that enter the system. Understanding systems involves examining the relationships, dependencies, and interactions among the entities and with other systems.

Systems exist in various domains, which may be abstract, technological, physical, natural, or social. They can be *simple* (like an electrical circuit), *complicated* (like a computer), or *complex* (like the weather). The systems we investigate in research are usually not simple but either *complicated* or *complex*. Although the terms are often used interchangeably, they have distinct meanings in science.

*Complicated vs.
complex systems*

A complicated system is difficult to understand due to its large number of components and relationships. However, complicated systems can be broken down into simpler parts that can be comprehended. Examples of complicated systems include an airliner, a computer processor, or an industrial robot.

On the other hand, a complex system contains so many elements that its behaviour is not predictable; it involves a high degree of uncertainty. Complex systems exhibit non-linear dynamics that cannot be understood by breaking it down into smaller parts. Examples of complex systems include ecosystems, the weather, the human brain, and social systems.⁴¹

2.3 DECIDING FOR A METHODOLOGY

Although the phase of the research cycle represents the level of existing knowledge, it is not sufficient to decide on a methodology. By defining the type of system under investigation, we can approach a decision scheme leading to a high-level methodology (Figure 2.4). The following paragraphs describe different systems, assumptions, and consequences of the methodology. A summary is given in Table 2.1.

⁴¹ Sometimes, we find that someone claims an airliner being a complex system. In this case, he should better not consider using it.

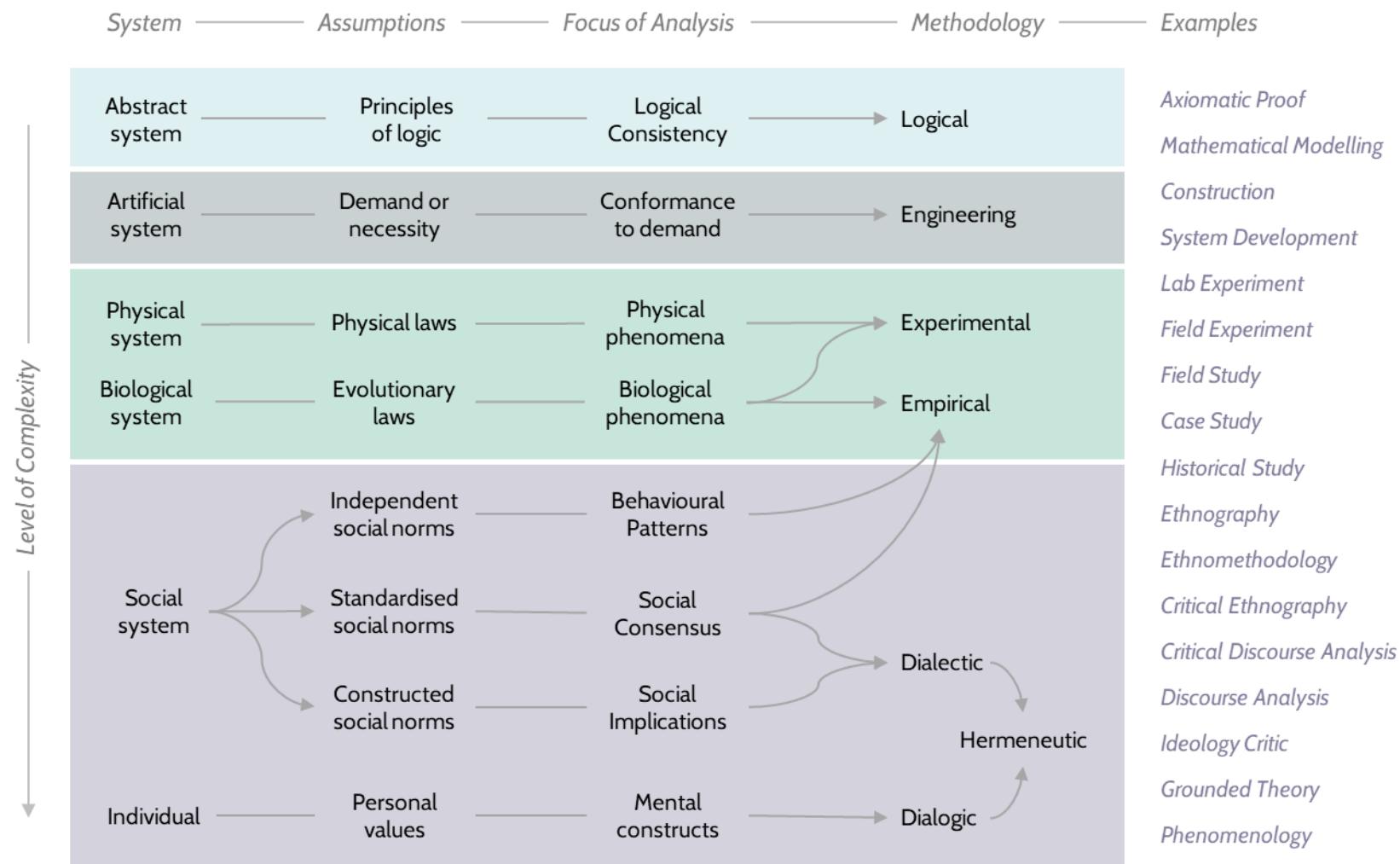


Figure 2.4 Decision tree for identifying research methodologies

Table 2.1 A systematic approach to select methodologies. The research objective might cover multiple goals and may use multiple techniques.

<i>If we want to...</i>	<i>...and we assume there exist...</i>	<i>...we obtain knowledge by...</i>	<i>...using ...</i>
generate or investigate an abstract system	consistent logical models	logical reasoning	deductive inference, axiomatic approach, and mathematical modelling
generate or investigate an artificial system	demands or necessities	finding physical solutions for the demand or necessity	construction and system development techniques
investigate physical systems	independent physical laws	explaining physical phenomena	observation, measurement, and experimentation
investigate biological systems	independent evolutionary and genetic laws	explaining biological phenomena	field observation, measurement, and experimentation
investigate social systems	independent social norms	explaining social behaviour	inquiry and observation of social interaction
investigate social norms	standardised social norms	understanding collaborative consensus and collective standardisation	inquiry, dialectic discourse, and hermeneutics
investigate social implications	historically constructed social norms	assessing implications of human behaviour within its social and political context	critical dialectic discourse, and critical hermeneutics
investigate individuals	personal values	interpreting social phenomena from the perspectives of individuals	personal observation, dialogic discourse, and hermeneutics

2.3.1 Abstract Systems

Abstract systems are conceptual representations of various aspects of the world. Typical examples are formal logic, mathematics, or computer logic. Such systems are complicated; they exhibit many entities and relationships but are predictable.

Although abstract systems seem to be created *a priori*, they usually derive from the observation of complex natural processes. As mathematics has its origins in counting, formal logic derives from the observation of natural cause-effect relationships, and even artificial neural networks are just mimicking part of the behaviour of a human brain.

To work on formal logical problems, we assume we have a *consistent* system, one that is free of contradiction. In solving logical problems, we rely entirely on our ratio. Examples are proofs in mathematics or developing algorithms in computer programming.

Consistency

We can either generate or investigate an abstract system. In the case of generation, we are in the normative phase of our research cycle: generating a standardised system or norm. When investigating, we are in the retrospective phase: reconsidering the validity of a standardised system.

2.3.2 Artificial Systems

An artificial system can either be an artefact, an artificial environment, a technical installation, or a construction. The difference to other approaches is that we begin with a demand or a necessity, leading to requirements rather than searching for an explanation. In this case, we assume we have *consistency* in the requirements, which might be practical, rational, or aesthetical. The outcome would be a prototype or a unique artefact.

The difference from other research approaches is that it is delimited to applied sciences. The knowledge generation does not focus on explanation but on problem-solving and achieving conformance to the demand or necessity.

In contrast to the abstract system, the generation of an artificial system is immediately followed by its investigation. We typically begin in the evaluative phase of the research cycle: we assess the demand or necessity for its normative potential. This typically includes a feasibility study and the elaboration of requirements. The normative phase covers the development, and the retrospective phase is the test or investigation of the system.

Still, we can investigate an existing system by concentrating on the retrospective phase: reconsidering the usefulness of an artificial system.

2.3.3 Physical Systems

A reasonable assumption to investigate physical reality is that reality is observable and underlies independent physical laws. Systematic observation, instrumental measurement, and experiments are then the most appropriate techniques.

We can use laboratory experiments taking place in an artificial surrounding in which the conditions (parameters) are held constant, except for the entities of interest that are allowed to vary (variables). Examples are physical or chemical experiments in natural sciences.

A field experiment takes place in a natural setting, where the conditions are less controllable, but the setting is more realistic. An example is studying the effect of air pollution on atmospheric composition in a specific location.

The investigation of physical systems may cover any phase of the research cycle. The intention is to reach the normative phase by establishing a model or theory, which is continuously scrutinised in the retrospective phase if new insights are obtained.

2.3.4 Biological Systems

When investigating biological systems, we would assume evolutionary or genetic constraints, both of which underlie theories that have not yet been refuted.⁴² We can investigate under laboratory conditions (for instance, with cell lines) or in the field (for instance, with bioreactors).

Studies on animal behaviour (ethology) often take place as a field study in a natural setting, where the conditions are intentionally not controlled, and the research approaches require a higher degree of freedom. They are comparable to studies in social sciences but underlie laws of the physical nature rather than the human one.

Although the investigation of biological systems may cover any phase of the research cycle, it is typically performed in exploratory, descriptive, or explanatory stages. Predictions, strategies, and interventions are rarely of interest, and normalisation is delimited to theory generation, which undergoes the retrospective phase.

⁴² Neither the theory of evolution by natural selection as proposed by Charles Darwin nor gene theory emerging from genome investigation have been refuted or disproved. Although alternative concepts occurred, they significantly lack evidence and conceptual purity of reasoning. For a recent discussion, see (Clatterbuck, 2022).

2.3.5 Social Systems

Investigating how humans reflect a reality (whether it exists or not) would require an empirical approach based on observation and dialogue. In this case, we need to distinguish different assumptions which determine the focus of the otherwise completely covered research cycle.

Independent Social Norms

If we assume that social phenomena are subject to at least contemporary and universal social norms, we can expect humans to respond to their environment in a predictable way. In this case, we want to find the underlying rules. This strategy also assumes that we can investigate humans independently of the observer and that we can create settings that minimise undesired influence. Consequently, we would prefer an experimental approach, extended – if possible – by analytical instruments. A typical example is clinical studies.

If we cannot conduct a laboratory experiment, we could try to achieve an experiment-like rigidity with a field experiment in natural surroundings. Examples are conflict studies in teams or educational studies in a classroom.

If we feel we might miss some important aspects with a rigid experimental setting, we use empirical techniques of observation and inquiry and subsequently try to interpret social phenomena rationally. Examples are concealed observation of consumers in a supermarket, social network analytics, surveys, or interviews.⁴³

Assuming independent social norms necessarily concentrates on exploratory, descriptive phases, and explanatory phases of the research cycle.

Standardised Social Norms

If we do not believe in independent social norms, we may assume that knowledge is – although personally experienced by individuals – socially standardised by communities. Since we still investigate systems, we would necessarily assume norms exist. However, we consider such norms as being shaped by individuals and societies. They may be standardised as implicit or tacit beliefs and values or may be legal regulations. In contrast to generic social laws, standardised social laws would be subject to social dynamics, changing values and norms. Consequently, part of our approach will be the

⁴³ Concealed observation of consumers raises ethical concerns and may have legal implications, depending on the privacy expectations of the observed individuals and the local law. Concealed observation may be deemed acceptable in public spaces where individuals do not have a reasonable expectation of privacy or if informed consent was obtained. However, the latter case could alter the natural behaviour of the individuals.

ongoing interpretation of social phenomena and their underlying concepts and values.

Ethnography We may focus on describing cultural characteristics in a natural setting (ethnography), focus on investigating forms of actions in cultural systems (ethnomethodology), or comparatively assess ethnographic insights (ethnology or cultural anthropology).⁴⁴

Discourse analysis To elaborate on social norms, we observe social behaviour, use conversation, interpret what is said or written (hermeneutical), and analyse the discourse.⁴⁵ We can also interpret human artefacts, such as writings or artwork, constructed in a particular historical or cultural context.

Due to its focus on standardisation, the normative and retrospective phases of the research cycle receive particular attention.

Constructed Social Norms

Finally, we can approach social phenomena to change an unsatisfactory situation. We then acquire knowledge to find solutions to, for instance, societal inequalities, social marginalisation, corruption, and unethical or criminal behaviour.

In this case, we investigate social practice in terms of interest groups, power structures, and their implications on norms, regulations, and policy. We again assume that social reality is subject to regularities, but in this case, we recognise that they consist of historically conditioned structures. We consider the impact of media, institutions, and societies on constructing and justifying public knowledge. The production of scientific knowledge, therefore, requires continuous critical reflection on those influencing factors that determine social behaviour and their normative potential.⁴⁶

Critical approaches Besides observation, discourse analysis, and critical interpretation (critical hermeneutics), we need to engage in a critical discourse (dialectic) about the political and social status quo.⁴⁷ The focus in the research cycle lies then in the retrospective phase: the critical evaluation of established norms.

⁴⁴ For some useful textbooks, see: cultural anthropology (Nanda & Warms, 2019), ethnography (Atkinson, 2014), and ethnomethodology (Button, Lynch, & Sharrock, 2022)

⁴⁵ A good introduction to discourse analysis and its critical variant is given by (Jørgensen & Phillips, 2002)

⁴⁶ A model of the construction of social norms is provided by role theory (Turner, 2001).

⁴⁷ Examples of textbooks are: critical studies (How, 2017), critical discourse analysis (Fairclough, 2013), critical management studies (Alvesson, Bridgman, & Willmott, 2009)

2.3.6 Individuals

If we want to understand the reasoning and behaviour of individual social actors, we need to find out how they attach meanings to phenomena. In that case, we can barely assume that there are universal facts besides the social setting since individuals have their personal values, perceptions, experiences, and knowledge. That is, we cannot assume facts but only interpretations. Consequently, a single phenomenon may have multiple interpretations or meanings, and these interpretations not only depend on the social actors but also on the interpretation of the researcher, the social group under investigation, and the society. Such investigations are often referred to as interpretative studies, although the term misses a clear demarcation from other approaches.

The study of an individual's experience from interaction with social phenomena is typically covered by phenomenology,⁴⁸ which diverts into multiple discipline-specific methodologies, such as descriptive phenomenology and interpretative phenomenological analysis (IPA).⁴⁹ The methodologies incorporate the observation of the individual's behaviour, dialogue, and hermeneutic techniques, extended by systematic techniques like grounded theory. Examples are found in cognitive sciences, psychiatry, and psychotherapy.

Phenomenology

Although investigating individuals may cover the entire research cycle, the phase of normalisation is usually not intended and would go beyond the capabilities of a phenomenological or interpretative approach. The intention is usually not to generalise normative insights but to provide the foundation for understanding individuals. This allows societal research approaches to achieve normalisation. The retrospective phase is continually applied to the interpretations rather than to a standard or norm.

2.4 FROM DATA TO THEORY

When selecting a methodology, we defined the principles of research. What is left is to transform observations or measurements that provide us with data into knowledge that we can apply to theory or practice. An adapted knowledge pyramid shows this transition (Figure 2.5).

The *data* are the results of observation, experimentation, measurement, or calculation. They are enhanced by *metadata* describing the context of data.

⁴⁸ Phenomenology – like many philosophical terms – can be understood in two ways: as a philosophical movement and as a methodology. We will neglect the philosophical movement here and concentrate on phenomenology as a methodology: the principles for studying conscious experience. For details on phenomenology, see (Smith D. W., 2018).

⁴⁹ (Smith & Fieldsend, 2021)

The transition from data to *information* occurs when we interpret the data in the context of our research objective. This transition usually includes changing the representation of data by creating text, tables, charts, diagrams, or other transforms. This information undergoes a reasoning process to obtain *knowledge*, such as understanding cause-effect relationships. Further abstraction leads to an explanatory model of the found relationships. If the model applies to a domain, we can establish a *theory* which explains relationships beyond the research context.

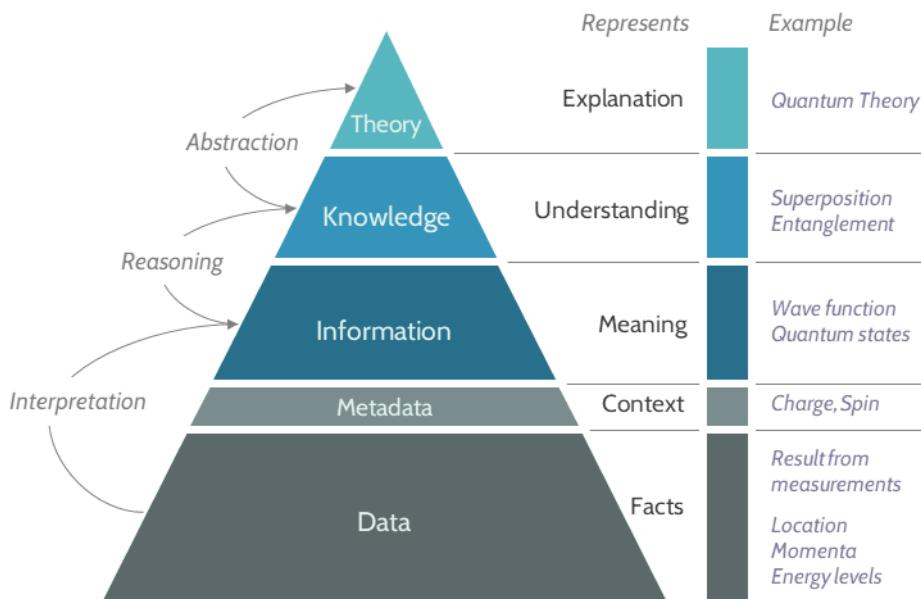


Figure 2.5 A knowledge pyramid for sciences⁵⁰

Since we will follow our initial postulate that truth is only valid in our system under investigation, we refrain from a metaphysical discussion of the topic of knowledge, which is closely related to the perception of ultimate truths.⁵¹ However, we would like to address a remarkable difference existing in the transition between *information* and *knowledge*.

While data processing and information generation methods change marginally (mostly with technology), the knowledge and the resulting theories can change significantly with increasing knowledge. Every paradigm shift in sciences, such as the introduction of quantum theory in physics or the

⁵⁰ The origins of the knowledge pyramid are unclear, but it is typically found in works on information theory and is usually described with the categories data, information, knowledge, and wisdom (DIKW pyramid). Although ‘wisdom’ represents the highest level, we refrain from using such an imponderable term in our scientific context.

⁵¹ For the interested reader, Linda Zagzebski presents an interesting approach (Zagzebski, 2017) and a full account is given by Duncan Pritchard (Pritchard, 2023).

emergence of cognitive psychology, affects the understanding of reality with consequences on social norms and values, which in turn affect the constitution and acceptance of new knowledge.

The principle of the knowledge pyramid applies not only to sciences. Our daily reasoning works similarly. In fact, the main difference between our ordinary decisions and those of a scientist lies in the systematic and comprehensive approach, as the following excursus shows.

Excursus: Scientific Grocery Shopping

Let's say we want to buy pasta at the supermarket. How do we decide which product to buy? There are several criteria: some conscious and some unconscious. An unconscious decision happens if we don't have time and grab the pasta that first catches our eye, maybe because of its availability, its placement, the attractiveness of the package, or because we remember the brand.

When we have more time and shop a little more consciously, we compare prices, read the list of ingredients, consider previous experience with the product, what we read or heard about it, or follow a friend's recommendation.

Nevertheless, the way we decide as a consumer follows the same logic that we use in sciences. A difference lies in the thoroughness of the investigation. As a consumer, we only consider partial information for the sake of convenience. As scientists, we try to obtain a complete picture. We consider, for instance:

- *Package*: look and feel, colour, shape, material, touch, weight
- *Product*: absolute price, price per weight, ingredients, origins, food processing details, nutrition scores, certificates
- *Comparative data*: price relative to similar products, relative product placement and appearance
- *Context information*: affordability, preparatory effort, cultural norms, social influences, environmental aspects
- *Secondary information*: advertisement, brand reputation, product reviews, price comparison reports, product test results, product recommendations, experience reports, scientific studies

In a scientific investigation, we even include subconscious factors, such as our emotional setting, intuition, aesthetic perception, and feelings of dissonance. If we visit multiple supermarkets, we do this under comparable conditions, like the same time of day, similar lighting, similar feelings of hunger, and so on. Ideally, we keep those conditions constant that are not of interest to us, leaving just room for the variables of interest to change.

While for consumers, it takes just a few minutes to decide, a scientific investigation takes weeks, months, or even years.

The necessity for a scientist to obtain the complete picture lies in the impact of the results. As a consumer, we often neglect the consequences of our decisions since our personal well-being stands in the foreground. We also do not publish our results to a larger community. As scientists, we generate new knowledge not just for personal use but for the public. We are aware of what our results have on society. That requires a more responsible strategy. The following sections describe the path we take from data to theory.

2.4.1 Data and Metadata

Primary and secondary data A study produces new *primary data*, whereas *secondary data* are those already existing.⁵² For instance, a literature review provides secondary data. While secondary data may be included in any step of the research procedure, they usually serve as the basis for using the primary data. We can also say the new primary data extends the existing secondary ones.

The primary data include the *raw data* and the unaltered data we acquired by sampling or measurement. For instance, a questionnaire response might be quantitative (such as an answer to age) or qualitative (such as level of agreement). The raw data are enhanced by *metadata* that describes the context of the raw data. This allows for structuring raw data, sorting or ordering them, or assigning them to categories. Examples are units, time of measurement, scales, or details about an interview partner.

Parameters and variables Metadata includes *parameters*, those quantities or qualities held constant during an investigation. Examples are experimental settings, measurement wavelength, or parameters such as mean or standard deviation for an assumed probability distribution. Defining parameters delimits the degree of freedom for the variables.

Variables are the quantities or qualities that change during the investigation and are the ones of primary interest. When changing independent variables, we observe their effect on dependent variables. For a single investigation, the chosen set of independent variables becomes a parameter.

2.4.2 Derived Data

Derived data We use the primary data to derive additional data by applying a particular procedure or mathematical technique. For instance, we can transform qualitative responses of a questionnaire into frequencies and later into statistics,

⁵² Not to be confused with the sources of information in library sciences, which distinguish primary sources (original works), secondary sources (meta-studies), and tertiary sources (used to identify and locate sources).

such as mean and variance. We can also reduce a qualitative statement from a text to a code, a shorter form of the central meaning of the statement. Since the transformation is purposive, it again delimits the interpretation.

The derived data undergo an initial assessment that leads to transforming data into a different representation. We usually begin with deciding on a visualisation that supports achieving our research objectives. For instance, we represent a series of measured temperatures in a scatterplot that shows how temperature evolves over time. Such visualisation helps us to identify *features*: characteristics of interest, like peak temperatures.

Features

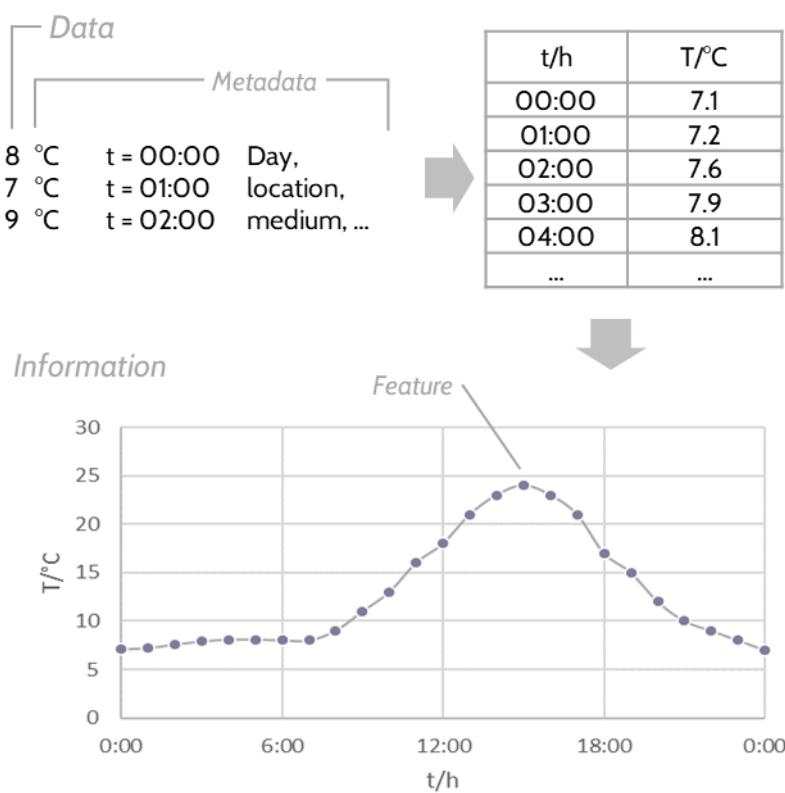


Figure 2.6 The transition from data to information

We may use more sophisticated techniques to change the domain of data. An example is integral transformations, such as a Fourier transformation from a signal in the time domain (like a sound wave) into the frequency domain (like a spectrum). This leads to an alternative representation that emphasises features that are not easily seen in the original signal. The goal of transformation is to emphasise features and thereby reduce the amount of data to the ones relevant to our research objective. Such features can undergo various transitions (Figure 2.7).

Integral transformation

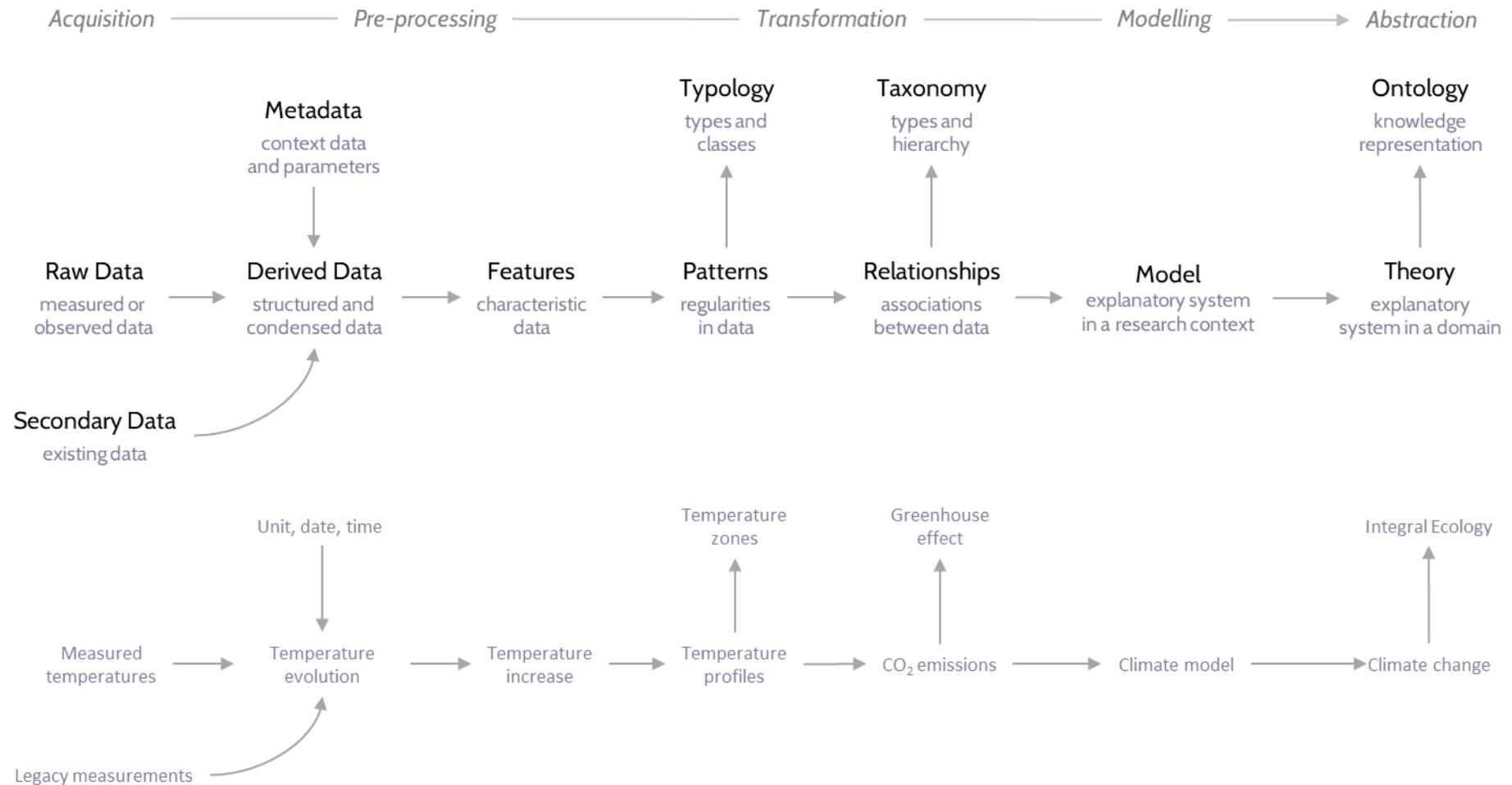


Figure 2.7 Transitions from data acquisition to abstraction. Above the theoretical approach and below is an example of climate change

2.4.3 Patterns and Relationships

If we identify multiple features, we may find *patterns*: regularities turning up in parts of our data. At this point, we try to categorise our data according to those patterns and relate the categories by identifying their *relationships*. If we achieve a comprehensive and replicable set of relationships, we arrive at a model (see Figure 2.8).

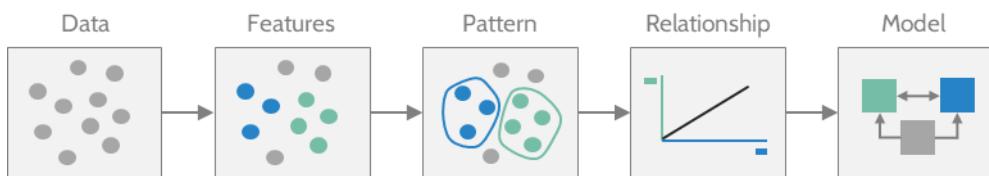


Figure 2.8 From data to model

Patterns and relationships can undergo further transformation to generate a classification, a typology, or a taxonomy.⁵³

2.4.4 Categories and Classes

The simplest way to distinguish two entities is to find one attribute in which they differ. In such a case, we create two categories: *data* and *information*. Categories do not necessarily clearly demarcate. They divide the entities into meaningful groups but may overlap and may not cover all cases.

Category

A class is formed if the categories exhibit two additional properties.⁵⁴ For instance, data can be either *numerical* or *non-numerical*. These attributes clearly demarcate since they are:

Class

- *mutually exclusive*: data are not both numerical and non-numerical.
- *jointly exhaustive*: all data are either numerical or non-numerical.

The underlying demarcating principle is called the *fundamentum divisionis*, or basis of division. In our case, we could choose the word *depiction* to describe the fundamentum. Table 2.2 shows examples of fundamenta (plural of fundamentum) and attributes that further demarcate the concept of data, information, and knowledge. We see that not all fundamenta are mutually exclusive and jointly exhaustive. The more complex the concept is, the harder it is to generate a class, and we must be satisfied with a category.

⁵³ A detailed description of classification, typology, and taxonomy is found in (Marradi, 1990), which is the basis for the following discussion.

⁵⁴ A thorough linguistic discussion of the term classification is provided by (Hjørland, 2017).

Table 2.2 Examples of fundamenta and their attributes for data, information, and knowledge. Potential classes are indicated with an asterisk. Other examples are categories, being either not mutually exclusive or not jointly exhaustive.

	Fundamenta	Attribute	Examples
Data	Appearance*	<i>analogue</i> : continuous <i>digital</i> : discrete	Tone, sound Maximum amplitude
	Depiction*	<i>quantitative</i> : amounts <i>qualitative</i> : states	Number Symbol, word
	Structure	<i>structured</i> : highly organised <i>semi-structured</i> : partially organised <i>unstructured</i> : not or barely organised	Database HTML, XML Document
Information	Origin	<i>immanent</i> : inherent to systems <i>biogenic</i> : generated by biological entities <i>anthropogenic</i> : generated by humans	Crystalline structure Gene expression Fictional novel
	Appearance*	<i>intrinsic</i> : residing within a system <i>extrinsic</i> : between sender and receiver	Mental construct Verbal expression
	Transmission	<i>verbal</i> : spoken or written <i>auditory</i> : acoustic <i>visual</i> : seen	Statement Sound Colour
Knowledge	Conveyance*	<i>explicit</i> : conscious, codifiable <i>implicit</i> : conscious, assumed <i>tacit</i> : unconscious, not codifiable	Theory Expertise Intuition
	Scope	<i>individual</i> : restricted to an individual <i>collective</i> : related to a group <i>social</i> : related to a society	Personal memory Tradition Cultural norms
	Application	<i>procedural</i> : workflow-oriented <i>declarative</i> : normative or standardised <i>strategic</i> : related to long-term goal	Car driving Language proficiency Decision-making

Intension and extension of a class

We call all attributes that constitute the fundamenta of a class its *intension*: the inherent necessary and sufficient conditions of membership.⁵⁵ The intension has a close relationship to a definition, which is a clear formulation of the intension. The *extension* of a class covers the instances or members of a class that suffice the intension.

Classification scheme

We may apply multiple fundamenta in succession to obtain a classification scheme (see Figure 2.10).

⁵⁵ *Intension* in logic is not to be confused with *intention* (the aim or purpose).

2.4.5 Types and Typologies

If we consider multiple fundamenta at a time, we obtain a set of composite fundamenta and attributes. In this case, we talk about a *type* rather than a class. Multiple types in the same context represent a *typology*. The number of types we obtain is the product of the number of attributes in each fundamentum. The simplest typology uses two fundamenta with each of the two attributes to generate four types (cf. Figure 2.9).

Typology

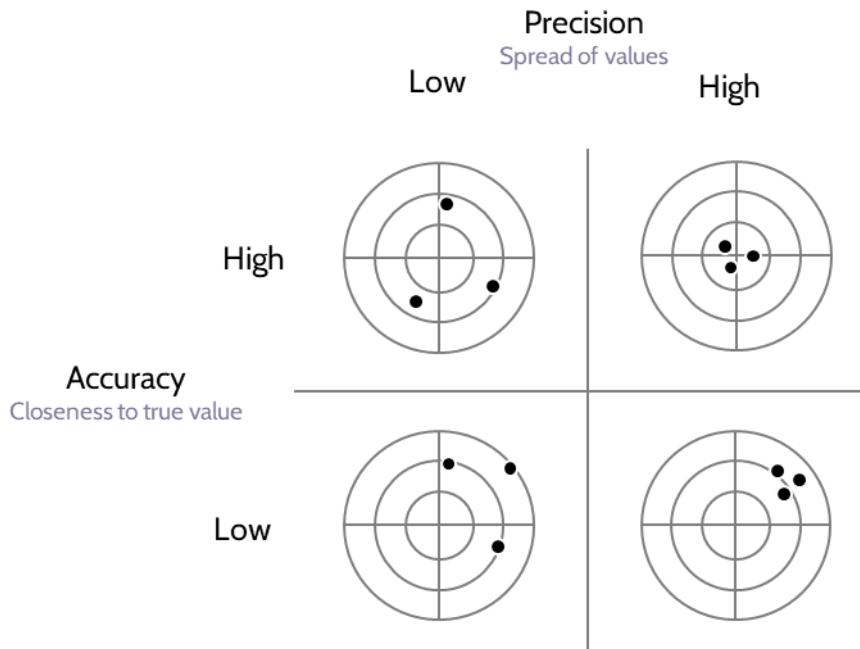


Figure 2.9 A simple typology using the fundamenta precision and accuracy. The centre of the target represents the true result. The distance of a measurement to the centre depicts its accuracy, whereas the spread of data points indicates the precision. The attributes distinguish high and low precision (accuracy) and lead to four types of measurement results.

The order in which fundamenta are considered is irrelevant since they are applied simultaneously. Types are typically abstract (or universals) and do not necessarily relate to real entities.

2.4.6 Intension and Definition

What we have seen until here is what is called an *intensional classification*, defining classes by establishing their intension a priori to achieve the necessary and sufficient conditions of class membership.

Intensional classification

Another way to generate classes is an *extensional classification*: categorising actual instances based on similarities and differences. The instances are sorted in a way that maximises the heterogeneity between classes while maintaining their homogeneity.

Extensional classification

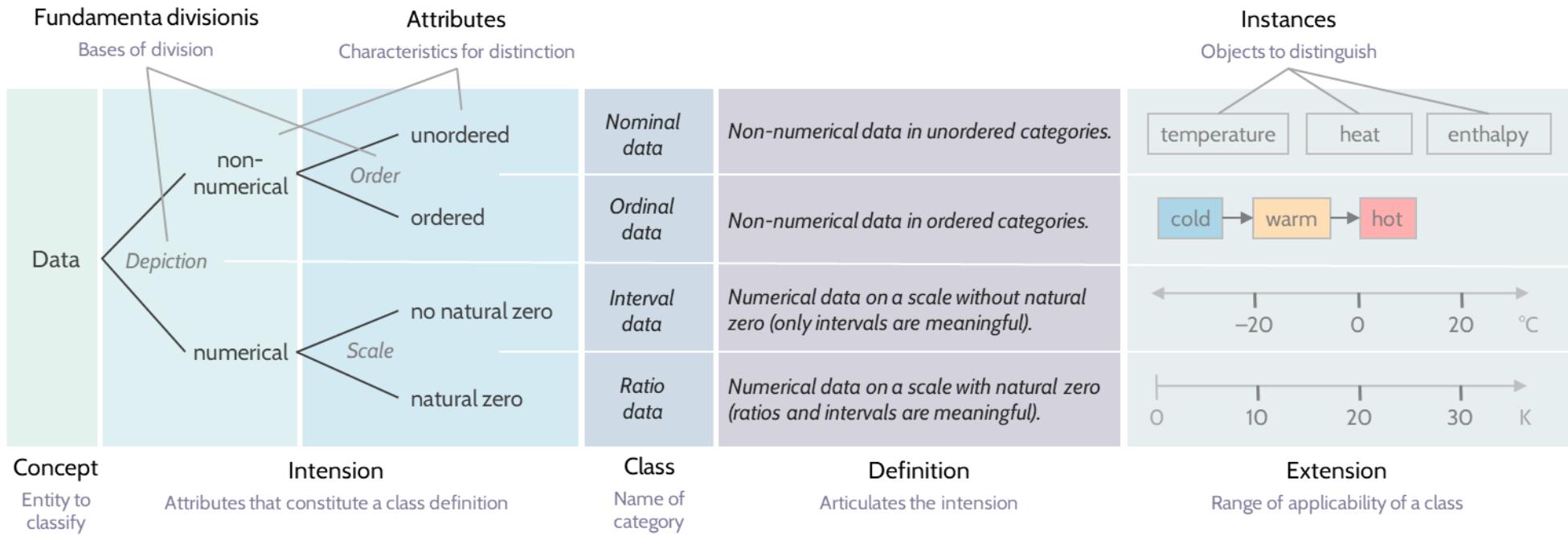


Figure 2.10 A classification to distinguish categories of qualitative and scales of quantitative data.

We usually develop multiple fundamenta with composite attributes that are measurable or assessable.⁵⁶ The close relationship between the intension of a class and its definition allows the use of classification as a tool for defining complicated or complex concepts. In this case, we often use extensional classification with multiple criteria that typically lead to types rather than classes.

Table 2.3 shows examples of composite fundamenta and their derived unique states to distinguish a *project* from a *line process* in business. Such distinction is necessary if we want to argue for differences in leadership styles and management approaches.⁵⁷

In this case, *project* and *line process* are types consisting of four fundamenta, each incorporating two (ideally mutually exclusive) attributes. The intension of each type includes the composite criteria, which allow for deriving a definition: a business project is unique, temporary, targeted, and dynamic, whereas the line process is recurring, indefinite, maintained, and static.

Table 2.3 Fundamenta of business project and line process and their states

Project	Attributes	Fundamenta	Attributes	Line Process
new task; conducted once	unique	Regularity	recurring	known task; repeated
terminated; ends with deadline	temporary	Duration	permanent	not terminated; ends if inefficient
determined by product or service	targeted	Goal	maintained	determined by maintenance
frequent change; exceptions are anticipated	dynamic	Variation	static	ideally no change; exceptions are disruptive

2.4.7 Taxonomies

Applying fundamenta in succession usually generates a classification scheme. If the classification scheme includes a semantic hierarchy and becomes comprehensive, we approach a *taxonomy*.

Taxonomy

⁵⁶ Examples for techniques using extensional classification are the so-called unsupervised learning techniques in machine learning, such as k-mean clustering, principal component analysis, and self-organising maps (Kohonen networks).

⁵⁷ Unfortunately, unique criteria are often neglected in industry standards. For instance, ISO 10006 defines a *project* as an activity that is "undertaken to achieve an objective conforming to specific requirements, including constraints of time, cost and resources" (International Organization for Standardization, 2018, p. 2), where cost and resources delimit any business activity, not just projects.

The semantic hierarchy may indicate priorities, logical or temporal sequence, or logical relations. In contrast to the typology, the sequence of applying the fundamenta becomes relevant since it determines the hierarchy. Although taxonomies are abstract, they typically derive from extensions.⁵⁸

A summary of the terminology is shown in Figure 2.11.

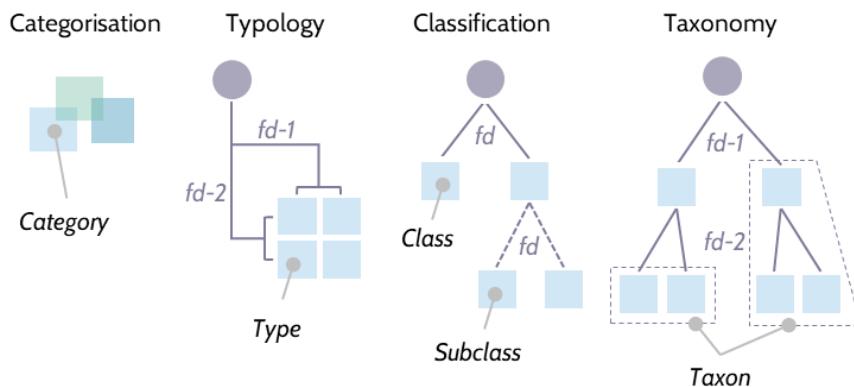


Figure 2.11 A comparison of categorisation, typology, classification, and taxonomy (fd: fundamentum divisionis)

Knowledge ontologies

Taxonomies are a crucial step in visualising and digitally storing knowledge. The knowledge about entities, classes, and relationships we obtain can be formalised in a special type of classification, the so-called *knowledge ontology*. In contrast to the metaphysical meaning, information science uses the term *ontology* to describe a formal representation of knowledge as concepts and their relations within a domain.⁵⁹ Ontology engineering is the first step to digitalising knowledge in software.

2.4.8 Models

Classes, typologies, and taxonomies are potential bases for generating models, which include additional relationships that are relevant to a research context. A model extends relationships by distinguishing causes and effects, the strength of relationships (qualitatively or quantitatively), and includes conditions or limitations (cardinality) of categories or relationships.

⁵⁸ Taxonomy (Greek: *taxis*, arrangement; *nomos*, law) in its original sense refers to the science of classification. However, the term is established in logic to describe the outcome of a taxonomical classification.

⁵⁹ The term is borrowed from the *ontological inquiry* in philosophy, a systematic exploration of the nature of being, existence, and reality. Besides the fundamental entities and categories of existence, this procedure identifies how the entities relate to each other to determine the principles or structures that govern the relationship.

A model is explanatory in the sense that it explains the dependency between entities and is predictive if the dependencies are quantified. Models typically apply to a limited study context. By replacing the abstract entities with specific instances, the model is applied to a specific scenario.

Models may either be of cognitive (*constructs*), mental (*concepts*), or *logical* nature.⁶⁰ In system development, we can even create mind-independent *physical models*, such as prototypes or mechanisms that support the explanation of a phenomenon.

Figure 2.12 shows an example of a so-called structural equation model,⁶¹ describing the quantitative relationships between a construct (student performance), its forming items (participation, engagement, attendance), and its reflective indicators (test scores, evaluation).

Structural equation model

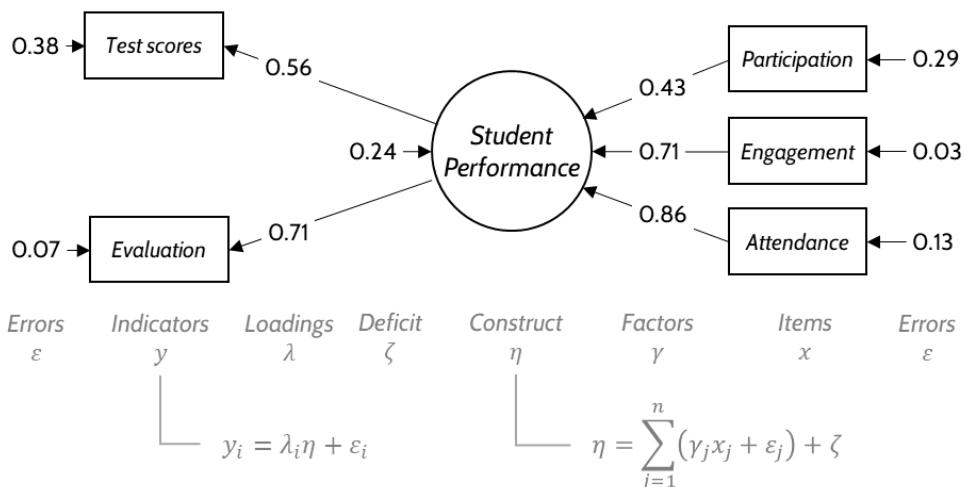


Figure 2.12 Part of a structural equation model for assessing student performance. The construct of interest η in the centre is formed by items (x , right) and reflected by indicators (y , left). The coefficients (λ, γ), errors (ε) and the deficit (ζ , unknown contributions) define the model, shown as equations for the construct and the indicators.

2.4.9 Theories

If we can generalise findings, we can create a model to explain phenomena outside our original study context. A further abstraction of the model leads to a *theory* (Greek: *theōría*, view) that goes beyond the study context and applies to a domain, such as a scientific discipline or a natural environment.

⁶⁰ In cognitive sciences, a concept is measurable entity (like age), a construct results from human interaction and is not immediately measurable (like happiness).

⁶¹ A comprehensive account on structural equation modelling is given by (Bowen & Guo, 2011)

Within its domain, a theory describes the components of a system, explains its phenomena and their mechanisms, and allows for predicting new phenomena. Theories represent the highest level of abstraction in research.

*Generalisation vs.
abstraction*

At this point, we would like to distinguish between generalisation and abstraction. *Generalisation* refers to applying a concept or principle to a broader range of situations in a similar domain. A typical example is a statistical generalisation, whose methods underlie assumptions about a probability distribution or require a particular sampling method.

On the other hand, *abstraction* refers to simplifying complex systems by focusing on their characteristic features and neglecting unspecific details. For instance, intelligence is an abstraction of multiple rational aspects, like consciousness, adaptation, and problem-solving.

3 FOUNDATIONS OF REASONING

The only known animal with just one leg is the grilled half chicken. How to argue against that?

It is obvious that there is something peculiar with the above claim, but what is it? Considering what we learned about definitions and classes, we can easily find that it is not appropriate to assign a food item to the class of animals since it does not possess any living or biological attributes. That is, the patterns we found leading to classes and definitions help us not just in structuring our phenomena but also in judging the value of potential explanations.

The next step is to identify relationships, either between classes or cause-effect relationships, for the phenomenon occurring. Rather than simply assuming a relation, we need an argumentation to defend our assumption, leading to the reasoning process.

In this chapter, we explain forms of reasoning, explicate conditions for justification, and describe characteristics of scientific assertions, like theses and hypotheses. We exemplify applications and cover the fundamentals of statistics and formal logic. The chapter ends with an excerpt of logical fallacies.

3.1 FORMS OF REASONING

Explaining a relationship requires reasoning that depends on the amount of prior knowledge; that is, it depends on the phase of our research cycle.

In the exploratory stage, we don't have enough information to explain an observed phenomenon and its relationship to other phenomena, especially,

Abductive reasoning

if it does not exhibit regularity. In this case, we apply *abductive reasoning*: inference to the most possible explanation.

Inductive reasoning

If the phenomenon is reproducible, we can identify regularities. By repeatedly performing investigations, we can find an increasing probability that an explanation is adequate. In this case, we can apply *inductive reasoning*: reasoning with a certain probability.

Deductive reasoning

Once we obtain enough information, we could create a model that explains the phenomena for the given and similar situations. Whenever we encounter new phenomena in the same context, we would be able to explain them through *deductive reasoning*. The outcome would be certain if the underlying model is adequate. Figure 3.1 shows the relation between abductive, inductive, and deductive inference.

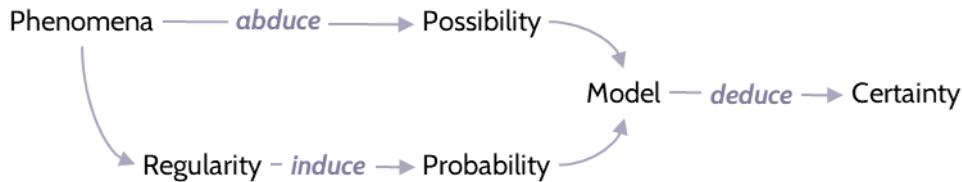


Figure 3.1 Phenomena abductive, inductive, and deductive reasoning

3.1.1 The Inference Procedure

Reasoning as a thought process relies on a logical procedure in which we derive a conclusion from propositions. Such procedure requires:

- Premises: a set of statements that are assumed to be valid.
- Inference: the procedure of argumentation from premises.
- Conclusion: the result of the inference.

Major and minor premise

To explain the difference between the forms of reasoning, let us first distinguish between major and minor premises. A characteristic of the major premise is that it is generic; it covers multiple cases and is universally applicable in the context of an investigation. The major premise is typically a result of numerous studies and might be derived from a model or a theory. The minor premise is either a result of observing an individual case or an assumption.

3.1.2 Abductive Inference

Let us investigate the stable of farmer Smith. The stable seems full of sheep; we assume that because we hear them bleating. One sheep is outside the stable; let's call it Patty. We want to know whether Patty belongs to that stable.

Since we don't have further information, we can only guess as to the best explanation (abductive reasoning). We begin with our major premise that only sheep are in the stable. Our observation of Patty being a sheep becomes our minor premise. Our reasoning could be:

- Premise 1: The stable is full of sheep. (Major premise)
- Premise 2: Patty is a sheep. (Minor premise)
- Conclusion: Patty belongs to the stable.

Such inference results in a potential explanation of our phenomenon that Patty appears outside the stable. But our inference is tricky because Patty could also belong to another stable, to a free-running herd, or be a loner.

Our guess remains mere speculation if we do not compare our conclusion to other explanations. But we can improve its reliability with two arguments: (a) from experience, we know that sheep are flock animals and strongly gregarious, that is, finding a loner would be unusual; and (b) if we don't see another stable or herd nearby. Both supporting arguments make our conclusion the best explanation for the moment.

The issue is that we cannot verify our conclusion by repetitive observation. If we see another sheep outside the next day, the day after, and so on, it does not increase our confidence any of it came out of this stable. That is where inductive inference comes into play.

3.1.3 Inductive Inference

To explain induction, let us modify the situation a bit. We know from Farmer Smith that Patty belongs to the stable, and we ask whether there are just sheep in the stable. We exchange our previous major premise with the conclusion:

- Premise 1: Patty belongs to the stable. (Minor premise)
- Premise 2: Patty is a sheep. (Minor premise)
- Conclusion: The stable is full of sheep.

Our premises are both minor ones: none is generic. The first stems from a particular knowledge and the second from a single observation. The former major premise – the generic statement – is now the conclusion. This is a form of generalisation: we induce a general rule given some knowledge to explain the observation. We call this the principle of inductive inference.

*The principle of
inductive inference*

The result of our inference is now something we could support by observing more similar cases. The more often we see sheep leaving the stable, the higher the probability that our conclusion is true. Each observation combines

the two minor premises for different samples. If all observations are repeatable, our conclusion increases in probability:

- Observation 1: Patty is a sheep and belongs to the stable.
- Observation 2: Mary is a sheep and belongs to the stable.
- ...
- Observation n: Lilly is a sheep and belongs to the stable.
- Conclusion: The stable is full of sheep.

And here is the issue. Suppose our study covers the one hundred animals in the stable of farmer Smith; that is, we are not interested in any other animals. If we see ten sheep out of the population of one hundred animals leaving the stable, we have a 0.1 probability that the stable is full of sheep. With a sample size of fifty, the probability would rise to 0.5. But even if our sample size reaches ninety-nine leading to a probability of 0.99, we still could have missed the last member of the stable, which might be a duck. Consequently, we are not sure about our results unless we cover the entire population.

That is, inductive inference involves a probability rather than a logical truth. To make this conclusion logically true, we would need to investigate not just samples but the entire population. If all sheep left, then our conclusion would be necessarily true. However, in most real scenarios, we often have just probabilistic evidence since we cannot investigate the entire population.

3.1.4 Deductive Inference

We can apply deductive reasoning if we have a confirmed model or theory. If we are sure that the stable is full of sheep (our theory), we could use additional observations of sheep leaving the stable to see whether they fit our theory. Again, we rearrange the statements:

- Premise 1: The stable is full of sheep. (Major premise)
- Premise 2: Patty belongs to the stable. (Minor premise)
- Conclusion: Patty is a sheep.

Apodictic reasoning What is remarkable about this argumentation is that if the premises are valid, there is no degree of freedom for the inference. This is called *apodictic* reasoning: the conclusion is necessarily true if we accept the premises.⁶²

Apodictic reasoning is straightforward: we could still discuss the validity of the premises, but if the premises are accepted, we cannot deny the conclusion anymore. However, there are two issues. Firstly, we need a model or

⁶² The Greek term *apodictic*, meaning ‘to demonstrate’ or is used in philosophy and logic to describe a statement that is self-evident, requiring no further proof or demonstration.

theory to conclude from a specific case. Secondly, we never develop alternative theories if we just try to constantly confirm our theory.

The latter is known as *deduction limitation*: we cannot create insight beyond the information contained within the premises.

Deduction limitation

3.1.5 The Subtleties of Language

While abductive and deductive inference both use major premises, differences are revealed when we rephrase our statements more precisely. We begin with our major premise:

The stable is full of sheep.

This statement comprises two classes (or sets in a mathematical sense), each of which contains instances sharing common characteristics. The term *stable* – as an observable entity – represents our class of interest. The term *sheep* is an abstract class describing a group of individuals sharing the characteristics of a sheep but having no physical existence. With the word *sheep*, we refer to a *universal*, a term describing an abstract class. The universal does not have a meaning beyond the one of a category.⁶³ So, we rephrase our major premise to give it a more precise meaning:

Universal and individual

All members of the class *stable* are also instances of universal *sheep*.

In contrast to *sheep*, Patty is a physically observable *individual* (or particular). If we state that Patty is a sheep, we assign the individual to the universal, thus expressing that it shares the characteristics of the universal. We write more explicitly:

Patty is an instance of universal *sheep*.

The fact that Patty belongs to the stable assigns the individual to our class of interest. Rephrased in formal language, we say:

Patty is a member of the class *stable*.

We now use our more precise statements to distinguish between deductive and abductive reasoning, which have the same major premise:

Major premise: All members of class *stable* are also instances of universal *sheep*.

⁶³ Some metaphysicians even argued that universals have no existence (in contrast to individuals) since universals just serve as a mental construct to categorize individuals. But as always in metaphysics, this is still under debate.

In the case of deductive reasoning, our minor premise and conclusion were:

Minor premise: Patty is a member of the class *stable*.
 Conclusion: Patty is an instance of universal *sheep*.

We can conclude this since all stable members are also instances of sheep. In the case of abductive reasoning, we exchange minor premise and conclusion:

Minor premise: Patty is an instance of universal *sheep*.
 Conclusion: Patty is a member of the class *stable*.

While the minor premise states that Patty has common characteristics with the universal *sheep*, it does not relate to the class *stable*. The link between the major and minor premise is just a characteristic of the abstract universal rather than of the physical class. That is, the minor premise does not support the abductive conclusion.

Then what's the point of abductive reasoning? It provides an explanation if no further evidence is available. The remaining question is how to justify an explanation that does not have inductive or deductive support. One approach is to exclude step by step other less likely causes. Having no other stable nearby could improve the possibility that Patty belongs to the stable.

Falsification

Another way is to falsify our conclusion: if we could prove that Patty belongs to another farmer, we could be sure that our abductive conclusion was false. That would be deductive and, therefore, logically firm reasoning.

Apart from that, we must ensure causality for our inference, as this forms the fundamental basis of our research. It is imperative that none of our findings contradict one another. Additionally, we need to comprehensively describe all pertinent facets of our phenomenon, leaving no stone unturned in our exploration. These insights introduce a range of additional conditions that must be met to justify our conclusions.

3.2 JUSTIFICATION

The importance of justification in science lies in establishing the credibility, reliability, and validity of scientific conclusions. Justification serves as the bedrock upon which the edifice of scientific knowledge stands, ensuring that theories, hypotheses, and findings are supported by robust evidence and rigorous methodologies. There exist multiple conditions that support the justification of an argument.

The exclusion of alternatives. If we can exclude alternative explanations, we can adopt the remaining explanation as the most possible one.

The condition of falsification. If we can find reliable, contradicting evidence, we can safely reject the explanation.

The condition of causality. If we assume a cause-effect relationship, we also need to find the temporal precedence of cause and effect and a correlation. However, correlation does not indicate causality.

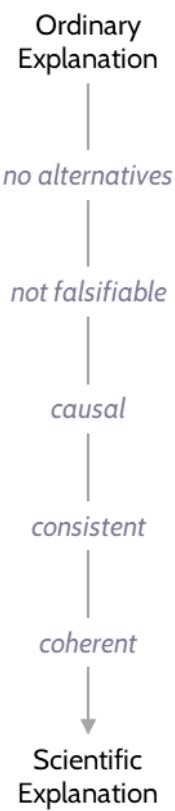
The condition of system consistency. None of the explanations within a system – whether related or not – is allowed to contradict another.

The condition of system coherence. The ideal system should provide a comprehensive explanation for all phenomena and relationships. The model or theory which most effectively reconciles all facts is considered the one with the highest explanatory power.

The main limitation to achieving coherence lies in the human inability to acquire all facts and relationships of a system. Therefore, coherence is difficult to dispute as a criterion of validity.

Although coherence is barely achieved when dealing with natural systems, we at least attempt it by following a systematic process. Ideally, the finding of evidence is *repeatable* (a repeated investigation leads to the same result) and *reproducible* (subsequent investigations using different approaches lead to the same result).

Repeatability and reproducibility



3.3 THESES AND HYPOTHESES

When we explain phenomena, we use assertions that we systematically investigate to find the underlying relationships. These assertions provide the foundation for scientific reasoning, allowing us to construct logical explanations.

We approach scientific assertions again by considering the complexity of our system of investigation. For the remainder of this chapter, we begin with complex systems and gradually narrow them down to complicated ones.

To obtain knowledge in a complex domain, we state assertions about multiple phenomena and their relationships. We first distinguish between theses and hypotheses.

3.3.1 Theses

A thesis (Ancient Greek: *théseis*, proposition) is an assertion on complex composite phenomena appearing in a larger context. It includes so many phenomena that we cannot achieve an understanding by just looking at individual ones. It also does not claim to be part of a model or theory, although it may emerge from or contribute to it. An example is an assertion about generative art:

Generative art, driven by algorithms and artificial intelligence, enhances artistic expression and increases the variety of emotional responses to artwork.

It is obvious that there is no simple answer to whether such an assertion is right or wrong. Although we may have a personal attitude towards such a thesis, there must be a way to identify arguments that count for it. To find arguments, we generate its counter position: the antithesis (Greek: *anti*, against):

Generative art's reliance on algorithms limits the artist's intention and artisanry, resulting in an art form that lacks the emotional depth of traditional art.

While the antithesis negates the thesis, it is usually not a formally contradicting statement, such as 'Generative art does not enhance artistic expression'. It takes a different position and, therefore, may include aspects not occurring in the thesis, such as the human and emotional response. Looking at both positions (and taking the antithesis seriously) allows us to identify arguments for and against them.

We weigh the arguments to accept either of the positions. Ideally, we can resolve their contradiction to achieve a synthesis (Greek: *sýn*, together):

Accepting generative art as a new kind of art neither replaces traditional methods nor diminishes the appreciation for it.

*Characteristics of
Theses*

When we apply the conditions for justification we mentioned in the previous chapter, we find some remarkable differences between theses and other assertions. Since we deal with a complex system, we cannot exclude alternative explanations. In fact, we need an alternative explanation (the antithesis) to judge whether the thesis serves as a better explanation. Using the word thesis assumes that we cannot confirm it in the sense that we can exclude its antithesis; otherwise, it would not be a thesis anymore.

Additionally, we cannot simply falsify the thesis due to the complexity of its context. A single contradicting evidence does not suffice to invalidate the thesis. Finding an instance where generative art did not increase the artist's

expression, or the emotional response does not invalidate the thesis but just delimits its coherence since it is not able to explain all cases.

Nevertheless, we follow the principles of causality (arguments for the thesis must be causal) and consistency (no internal contradictions).

We accept a thesis if it is – compared to its antithesis – of higher relevance, provides more reliable empirical or logical evidence, or contributes more to the understanding of the context. We can summarise the characteristics of theses as shown in Table 3.1.

Table 3.1 Characteristics of theses

Purpose	Establish an explanation for complex composite phenomena
Rationale	Theses must be relevant, concise, unambiguous, and controversial.
Alternatives	Cannot be excluded.
Falsification	impossible
Confirmation	impossible
Acceptance criteria	a) higher relevance than its antithesis b) higher methodological rigour of thesis generation c) more reliable empirical or logical evidence d) higher contribution to understanding e) higher internal consistency f) higher coherence
Outcome of acceptance	The thesis is considered more plausible than its antithesis.

Here, it becomes understandable why the term *thesis* is also used for *academic theses*. Academic theses state one or more assertions and argue for and against them to finally reach an explanation for a complex system. Once the complex system is broken down and simplified, we approach the smaller brother of a thesis: the hypothesis.

3.3.2 Hypotheses

A hypothesis (Greek: *hupó*, under) is a subordinate assertion covering a single or few selected phenomena in a limited context. The key difference is that the hypothesis either serves as an explanation of a single phenomenon or asserts a relationship between two or more phenomena, for example:

Generative art evokes a stronger emotional response than traditional art.

This hypothesis delimits the context of a particular cause-effect relationship within the context of generative art. This makes it easier to assess whether it is true or not: we can record the response of viewers to examples of traditional and generative art and measure their emotional response.

Terminological confusion

Like a thesis, a hypothesis has a counter position. Unfortunately, the naming found in the literature is not always consistent. Although the term anti-hypothesis would be most appropriate, it is unfortunately not established. Another appropriate term would be the alternative hypothesis. However, we run into terminological confusion with the contemporary use of this word. Additionally, the hypothesis of interest is sometimes called the working hypothesis, the research hypothesis, or the alternative hypothesis.

To avoid confusion, we will call our hypothesis of interest the *working hypothesis* and the one contradicting the *counterhypothesis*. Due to the delimited complexity of the context, we can formulate a counterhypothesis in a way that directly contradicts the working hypothesis:

Generative art does not evoke a stronger emotional response than traditional art.

A more general formulation states no cause-effect relationship:

The emotional response of viewers of traditional and generative art does not differ significantly.

Null hypothesis

In statistical terms, this is called a *null hypothesis* since it assumes no cause-effect relationship. Statisticians then use the term *alternative hypothesis* to describe their hypothesis of interest. The reason is that they first assume the null hypothesis is true, which means that anything countering it would support the alternative to the null.⁶⁴

The reason for this seemingly unintuitive approach lies in the condition of falsification, which we initially demanded to justify our reasoning. Testing whether the evidence supports a hypothesis does not confirm it because we can rarely exclude alternative explanations. For instance, finding a higher emotional response with generative art might be due to the picture frame, the lighting conditions, or due to other emotional factors. Since we can never be sure about the coherence of our investigation, we argue the other way around. To explain this further, let us look at a field outside statistics where null hypotheses are commonly used, although under a different term.

⁶⁴ This terminology goes back to works of Sir Ronald A. Fisher, who laid out in the early 20th century the principles of statistical hypothesis testing (Fisher, 1926). Unfortunately, no one ever scrutinised Fisher's terminology.

Hypothesis in Jurisdiction

Crime scene investigation begins with preserving evidence, such as fingerprints or DNA, by interviewing witnesses and by supporting forensic experts who analyse the collected evidence in a laboratory to link it to the crime. Investigators follow up on leads to identify potential suspects. At that point, they generate a working hypothesis (H_1) about the relationship between the suspect and the crime. If they believe they have enough evidence, they present the case to the prosecution.

The prosecution will review the evidence and decide whether it would stand a charge against the accused under given legal conditions. When they decide to proceed with the case, they adopt the working hypothesis of the crime investigators and initiate a trial. In the trial, the judge (or a jury) will scrutinise the evidence to either accept or reject the working hypothesis.

The problem is that the evidence is rarely unique. Finding a person's DNA at the crime scene does not prove the hypothesis that the person committed the crime. The DNA may have been found because of:

- the accused committed the crime.
- coincidence (e.g., the accused left his DNA during a previous visit).
- erroneous investigation (e.g., DNA tests were confused).

To approach the case objectively (and for ethical reasons), the judge presumes innocence (adopts the null hypothesis H_0) and assesses how likely it is that the evidence occurs if the accused were innocent. If it is unlikely, he may reject the null hypothesis.

However, rejecting the innocence presumption does not necessarily prove the accused committed the crime. The suspect might be involved but not be the delinquent. On the other hand, whether the accused is innocent (H_0 is true) also cannot be conclusively answered. In this case, a falsification of the evidence helps.

Rather than trying to verify the guilt by increasing confidence with each new piece of evidence, we try to falsify it. A simple example of falsification in a police investigation is asking a suspect for an alibi. If the alibi is trustworthy, it confirms the suspect's innocence, at least in a judicial sense.

In the same way, we work in sciences. We empirically or rationally state a working hypothesis, typically an assumed relationship or effect. The found data may either support our hypothesis because of:

- the relationship exists,
- random bias, or
- systematic error.

To distinguish between these cases, we assume no effect (tentatively accept H_0) and determine how likely it is to obtain such a result if there are no effects. If the likelihood is repeatedly small, we may reject H_0 .

The only logical way to achieve certainty is to exclude alternative explanations. Or as Conan Doyle's Sherlock Holmes stated:

“How often have I said to you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth?”⁶⁵

An example from Agatha Christie's famous *Murder on the Orient Express*, where detective Poirot tries to find the murderer of Mr. Ratchett among the passengers on the train, exemplifies this in the following excursus.⁶⁶

Excursus: Finding the murderer on the Orient Express

American businessman Samuel Ratchett, one of the passengers of the Orient Express, is stabbed to death at night while the train is stalled in a snowdrift. Among the passengers are the director of the railway line and his friend, the famous detective Hercule Poirot, whom he commissions to investigate the case.

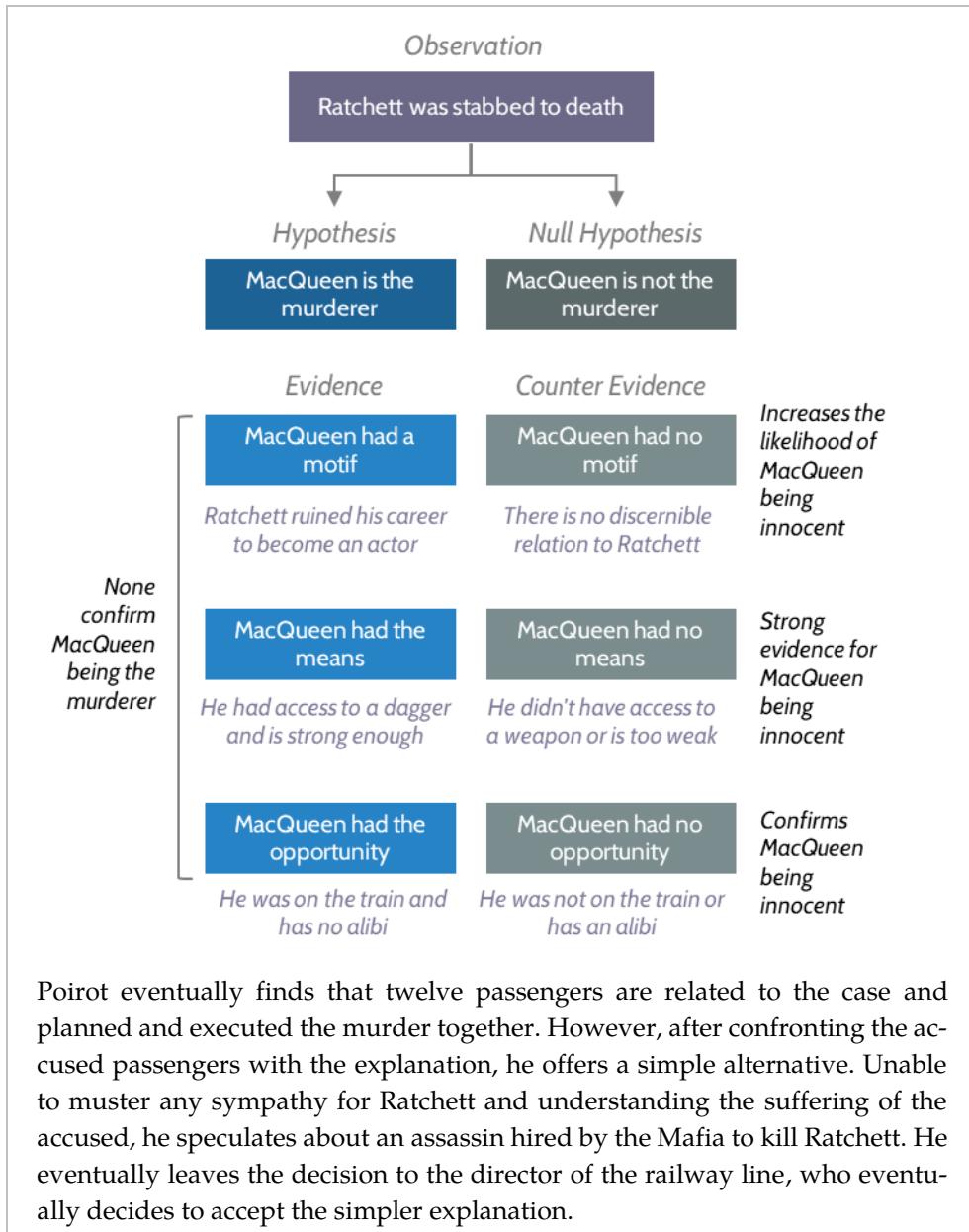
As Poirot begins his investigation, he discovers that Ratchett is actually a criminal named Cassetti, who is responsible for the kidnap of Daisy Armstrong, the young daughter of a rich American family, in the wake of which Daisy, her parents, and several other people die or commit suicide.

When interviewing the passengers, Poirot discovers that Ratchett's secretary, Mr. MacQueen, is involved as his father was the district attorney in the Armstrong case. While the murderer was sentenced to death, his boss Cassetti got off by leaving the country. During the trial, Mrs Armstrong took an interest in MacQueen and his ambition to become an actor, and she became kind of a mother to him. However, as a result of the tragic situation, she died when giving birth to a stillborn child. Poirot guesses that MacQueen makes Ratchett responsible for it.

As an experienced detective, Poirot tries to identify the motif, the means, and the opportunity for committing the murder. While neither the motif, the means, nor the opportunity could confirm the hypothesis that Mr. MacQueen is the murderer, counterevidence would either increase the likelihood of the null hypothesis being true or even ascertain it.

⁶⁵ (Doyle A. , 1890, p. 169)

⁶⁶ (Christie, 1934)



The Origins of Falsification

The concept of falsification of hypotheses goes back to critics of induction. Francis Bacon, a philosopher of the 17th century, was probably the first to describe induction comprehensively. One of his contemporary critics, David Hume, objected that empirical induction could not explain a cause-effect relationship without deductive justification. Hume, therefore, postulated that hypotheses must be inherently disprovable before they are accepted.⁶⁷ Karl Popper seized this argument in the 1950s⁶⁸ and elaborated further on the falsification principle. Popper recommended collecting data with the best

⁶⁷ (Hume, 1748)

⁶⁸ (Popper K., 1959)

chance to contradict (falsify) the hypothesis rather than verifying it. He argued that whereas data in line with the hypothesis only allows one to conclude that there is not enough evidence to reject the hypothesis, a falsification would be deductively true and thus logically valid. However, Popper admitted that a single conflicting instance might be insufficient to falsify a theory since every observation introduces bias.

Quine-Duhem thesis At the same time, Willard Quine questioned the possibility of falsifying (or verifying) hypotheses using Pierre Duhem's insights on indeterminate experimental criteria in physics. What is known as the Quine-Duhem thesis states that neither verification nor falsification of individual hypotheses is possible since they always include auxiliary hypotheses (or assumptions). That is falsification of a hypothesis either questions the hypothesis or one of the accompanying auxiliary hypotheses.⁶⁹

Characteristics of Hypotheses

Explanatory hypothesis A hypothesis can explain the properties of one or more entities. We will call these *explanatory hypotheses* and distinguish three types (Figure 3.2).

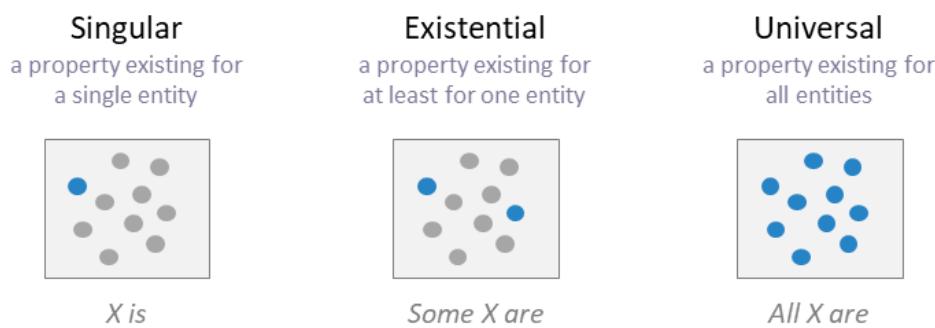


Figure 3.2 Types of explanatory hypotheses

Singular hypotheses state a property or relation of a single entity:

MacQueen is a passenger.
MacQueen had access to a dagger.

Existential hypotheses state that at least one property or relation exists:

Some passengers are related to the Armstrong family.
At least one of the passengers is a murderer.

⁶⁹ An extensive account is given by (Mitchell, 2020)

Universal hypotheses state that all entities of a class have a property or relation:

- All passengers don't have an alibi.
- All passengers committed the murder.

Besides explaining discrete relationships, we can formulate a *probabilistic hypothesis* that expresses the probability of a phenomenon occurring. Those hypotheses stem from inductive inference:

The more passengers are found related to the Armstrong case, the higher the probability that they are all involved with the murder.

Well-formed hypothesis underly similar conditions. However, there are remarkable differences between explanatory and probabilistic hypotheses, as shown in Table 3.2.

Table 3.2 Characteristics of explanatory and probabilistic hypothesis

	<i>Explanatory hypothesis</i>	<i>Probabilistic hypothesis</i>
Purpose	Establish a singular, existential, or universal causality	Approximate a universal probability
Rationale	Logical or empirical evidence	Reproducibility
Falsifiability	Finding contradicting evidence must be possible.	The corresponding null hypothesis must be testable.
Falsification	A single contradicting evidence suffices to falsify. Falsification challenges the underlying assumptions or explanatory model.	A single contradicting evidence does not suffice to falsify. Falsification challenges the assumed probability distribution or model.
Confirmation	a) No falsifying evidence b) No alternative explanations Confirmation supports underlying assumptions or explanatory models.	a) Rejection of null hypothesis b) Alternative explanations are less probable Confirmation supports the underlying probability distribution or model.
Acceptance	The hypothesis is considered the most plausible explanation of a property or relation.	The hypothesis is considered the most probable explanation of a relation or effect.

It is important to note that confirming hypotheses does not prove anything beyond the corresponding assumptions, auxiliary hypotheses, models, or theory they are derived from.

3.3.3 A Taxonomy of Theses and Hypotheses

Theories, theses, and hypotheses are closely related. Although a thesis is not necessarily part of a theory, it is often related to it. Table 3.3 shows an example of a thesis and hypothesis in the context of the theory of evolution.

Table 3.3 Example of a theory and related scientific assertions. While the hypothesis is stated in the context of the theory of evolution, the thesis does not claim to be part of it.

<i>Assertion</i>	<i>Description</i>
Theory	A substantiated and comprehensive explanation to explain phenomena in a natural or logical domain: <i>The theory of evolution states that species undergo gradual changes over time through variation, natural selection, and genetic inheritance.</i>
Hypothesis	A claim that seems plausible or probable in a particular context, a model or theory: <i>An organism inherits characteristics from its parents.</i>
Thesis	An assertion on composite phenomena. It does not claim to be part of a rule, general law, or theory but is part of a reasoning process: <i>There is life on other planets.</i>
Antithesis	A thesis opposing another thesis: <i>There is no life on other planets.</i>
Synthesis	The result of resolving a thesis and its antithesis: <i>Life on other planets differs from life on Earth.</i>

Figure 3.3 shows the relationships beginning with phenomena in complex and complicated systems. The following examples are shown in Figure 3.4.

Thesis
If we want to make an assertion about a phenomenon in a complex system, we generate a thesis, for instance:

Climate change is due to anthropogenic effects.

We construct an opposing position – the antithesis:

Climate change is due to natural effects.

and attempt a synthesis that unifies both positions:

Climate change is due to both natural and anthropogenic effects.

To generate hypotheses, we need to isolate a single phenomenon or reduce the number of phenomena of a complex system to obtain a complicated one:

The CO₂ concentration in the atmosphere influences the global temperature.

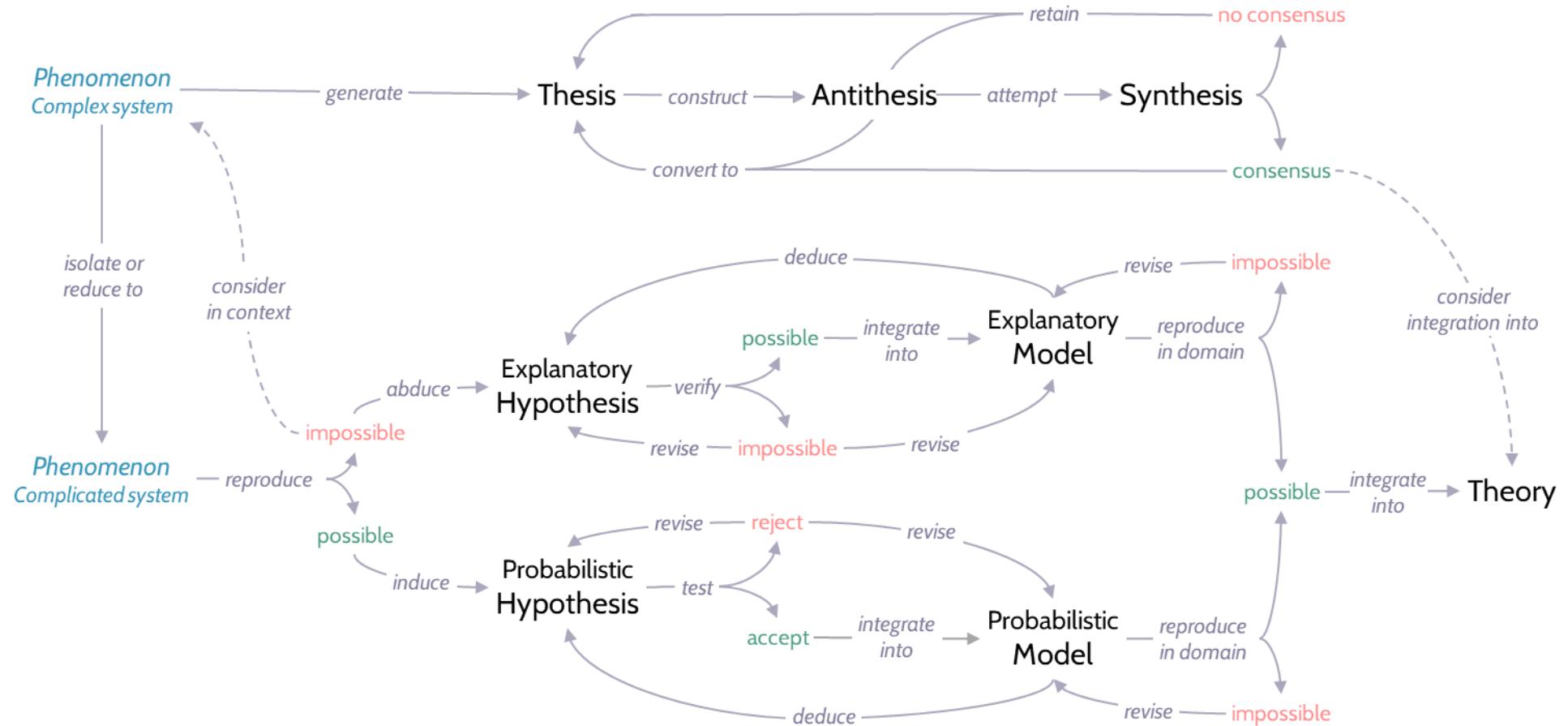


Figure 3.3 A taxonomy of thesis and hypotheses

Explanatory hypotheses

If the phenomenon is not immediately reproducible, we can make an educated guess and generate an explanatory hypothesis by abductive reasoning – an evidence-based or logical explanation of the phenomenon occurring:

CO_2 decreases the reflection of sunlight.

We try to confirm the hypothesis by excluding contradicting evidence and alternative explanations. If impossible, we need to revise the hypothesis. Otherwise, we can accumulate other verified hypotheses in the same context:

Methane, nitrous oxide, and water vapour decrease the reflection of sunlight.

to generate or support an explanatory model:

The greenhouse effect explains the rise in global temperature on the earth that results when gases in the atmosphere reflect radiation from the sun.

If our model correctly explains the phenomena in our research context, we can predict further explanatory hypotheses and verify them deductively:

The synthetic hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, and nitrogen trifluoride have the same effect.

Probabilistic hypotheses

If the phenomenon is reproducible, we can induce a probabilistic hypothesis – an explanation based on the likelihood of the phenomenon occurring:

The concentration of CO_2 correlates with a rise in atmospheric temperature.

We test the hypothesis by assuming the null hypothesis:

The concentration of CO_2 is not related to a rise in atmospheric temperature.

If we cannot reject the null hypothesis, we need to revise the working hypothesis. If we can reject the null hypothesis, we can accumulate multiple accepted hypotheses in the same context:

The concentration of methane and nitrous oxide correlates with a global rise in atmospheric temperature.

to generate or support a probabilistic model:

A climate model explains the increase in atmospheric temperature with an increase in the concentration of greenhouse gases.

If our model correctly explains the probabilities of phenomena in our context, we deduce further probabilistic hypotheses and test them deductively:

The industrial production of synthetic fluorinated gases correlates with global warming.

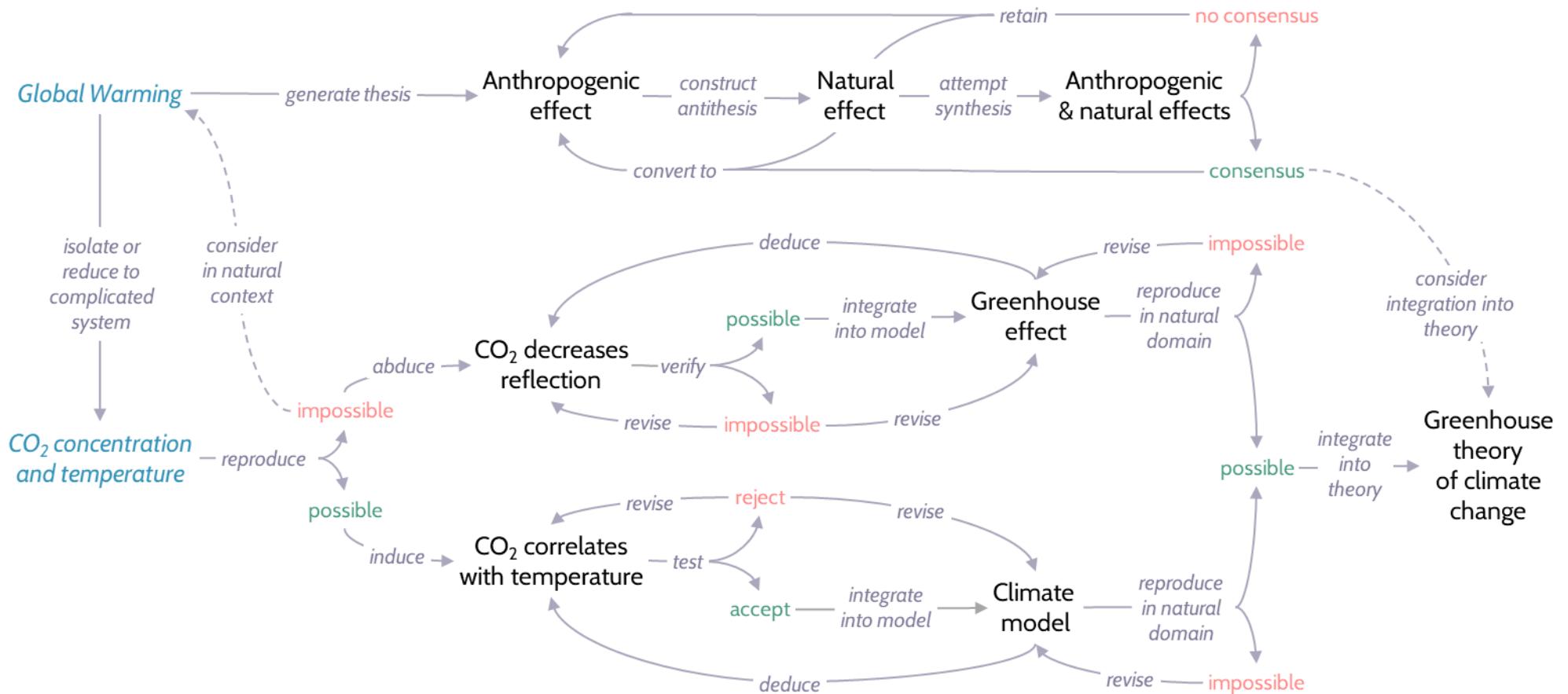


Figure 3.4 Example of thesis and hypotheses in the context of climate change

If we can reproduce any of the models in a larger logical context (like mathematics), in a real domain (like nature), we can integrate them into a theory:

The greenhouse theory of climate change states that the climate system is in an equilibrium of the surface-troposphere and the stratosphere temperature.⁷⁰

3.4 ABDUCTIVE REASONING IN PRACTICE

The idea to introduce abductive reasoning beneath induction goes back to the works of the American mathematician and philosopher Charles Sanders Peirce in the late 19th century, which underwent several changes. Peirce originally intended to use abductive reasoning to generate hypotheses. Nowadays, it is commonly understood as a means of justification: as an inference to the *best explanation* rather than the most probable one (as with induction).⁷¹

The value of abductive reasoning

Peirce found that there are cases where deduction does not work, for instance, if we don't have any model or theory (a major premise). This is typical if we are in the exploratory stage of research. To develop a model, we need to use induction: observing enough individual cases to generate a high probability for a general rule. However, induction may not work if we have insufficient cases to form a representative sample size. The resulting probability would be too small to increase our confidence in such cases. Additionally, induction is not suitable if generalization is not intended.

The creative leap

Here is where abductive reasoning comes into play. It is the creative leap for explaining phenomena based on incomplete or uncertain information. Abductive reasoning can generate new insights and discoveries that may not be achievable through deductive or inductive approaches. We accomplish this by evaluating the plausibility of multiple competing hypotheses. It can generate reasonable assumptions, fill knowledge gaps, and create explanations that can be further investigated. Two typical examples of studies that use abductive reasoning are medical diagnostics and grounded theory.

3.4.1 Medical Diagnosis

Medical diagnostics encompass a process of identifying diseases, conditions, or ailments through a variety of tests, examinations, and technologies. It enables healthcare professionals to make informed decisions regarding treatment and patient care.

⁷⁰ See also (Mikhaylov, Moiseev, Aleshin, & Burkhardt, 2020)

⁷¹ For details on the history of abductive reasoning, see (Douven, 2021)

The typical workflow of medical diagnostics is described, for instance, by Rejón Altable:⁷²

1. Identify symptoms.
2. Create a link to a likely physiological domain (organ or system) that seems to be the source of the manifestation.
3. Create a link to a disorder, i.e., an abnormality in the structure or function of a physiological domain.
4. Identify the underlying pathological process.
5. Reason with pathological evidence and causal relationships.

Let us apply this technique to a patient showing symptoms of icterus (jaundice): yellowing of the skin and eyes due to increased bilirubin levels in the blood.⁷³ Since each symptom appears with multiple diseases, our physician would follow the approach of differential diagnostics. He first collects more context information (metadata) by asking the patient about other symptoms, previous diseases, living conditions, and other things.

The physician knows from his education that icterus may be pre-hepatic (before the liver, for example, due to haemolytic anaemia), hepatic (due to liver dysfunction), or post-hepatic (for example, due to obstruction of the bilirubin passage through the gallbladder).

Abductive reasoning begins when the physician creates a link between the icterus and the liver as a potential domain of the disease. He may have done this because of his knowledge and his experiences with other patients. Our physician generates a hypothesis abductively:

- | | |
|----------------|--|
| Major premise: | One symptom of liver dysfunction (a universal) is icterus
(characteristic of a universal) |
| Minor premise: | The patient (an individual) shows signs of icterus (a
characteristic of the universal) |
| Hypothesis: | The patient (an individual) may suffer from liver dysfunction
(a universal) |

To clarify whether the hypothesis identifies the physiological domain appropriately, our physician needs to exclude alternative explanations.

To exclude two of the three domains, he can order a full blood count (test kind and number of blood cells) to exclude haemolytic anaemia (an abnormal reduction of red blood cells), use ultrasound imaging to exclude obstructive pathology and use further laboratory evidence to exclude unlikely cases.

⁷² (Rejón Altable, 2012, p. 345)

⁷³ An overview on alcoholic liver disease and its diagnostic indicators is described by (Seitz, et al., 2018)

If the hypothesis that the liver is the origin turns out to be the best explanation, the physician utilises further abductive reasoning to create a link to liver dysfunction. The physician knows, for instance, that portal hypertension (increased blood pressure in the liver veins) could be an indicator of liver stiffness, which he can interpret to derive the stage of liver fibrosis (excessive accumulation of extracellular matrix proteins)⁷⁴ or even liver cirrhosis (deterioration of liver cells)⁷⁵. Step by step, he will exclude alternative explanations to support the hypotheses.

The challenge for our physician is the priority. What should he test first to avoid endless trial and error? His decision is mostly a matter of experience, and that is one reason for his extensive practical education in medical sciences. But our physician does not have another chance than to use abductive reasoning: deduction is not possible since there is not enough evidence that a single symptom necessarily stems from a single physiological domain, and inductive generalisation is not a goal of an individual's diagnosis.

3.4.2 Grounded Theory

Grounded theory

An example of a research methodology using abductive reasoning is the grounded theory approach for text analysis. Its original focus was to understand how meanings and concepts are produced during a social event.⁷⁶

Grounded theory studies such events by continually sampling text passages – often from interview transcripts and field notes – that are encoded and form the model's basis (or ground). Researchers use grounded theory to generate a model of the meaning of texts (here called a *theory*) based on qualitative data for describing the perceived realities of actors in real social situations. The generic approach is:

- identify text passages relevant to the research objective and assign them a unique code,
- generate conceptual categories, assign the found codes, and
- identify relationships between categories.

The interrelated categories form a model that would describe the text's meaning and its potential social implications.

Theoretical saturation

The procedure continues as long as the researcher obtains new information. Since each step adds to the understanding, either new data may be required (for example, new interviews) or new insights may change the codes, cate-

⁷⁴ (Bataller & Brenner, 2005, p. 209)

⁷⁵ (Tsochatzis, Bosch, & Burroughs, 2014, p. 1749)

⁷⁶ (Glaser & Strauss, 1967; Corbin & Strauss, 2015)

gories, or assignments. We consider the procedure finalised if further information no longer changes the model, indicating theoretical saturation.⁷⁷

Recognizing patterns and generating conceptual categories is an abductive reasoning process, considering the most plausible explanation rather than the most probable one.

Since grounded theory focuses on text, the synthesis step in the literature review can take advantage of the procedure. Rather than using transcripts and field notes, we could use phrases from articles as raw data. We will address this in more detail in chapter 14.6.3.

3.5 INDUCTIVE REASONING

Inductive reasoning involves drawing conclusions based on individual observations or evidence. Unlike deductive reasoning, which proceeds from general principles to specific conclusions, inductive reasoning starts with individual observations and uses them to generalise. Below, we explain different forms of inductive reasoning.

3.5.1 Eliminative Induction

Eliminative induction covers methods to investigate whether the presence or absence of boundary conditions leads to the occurrence of a phenomenon. It originates in *Mill's canon of induction*.⁷⁸

Let's say we want to determine the most probable cause for Patty sleeping. We implicitly assume that the body of boundary conditions represents potential causes of our phenomenon:

	Boundary conditions <i>B</i>	Phenomenon <i>Ph</i>
<i>b</i> ₁	It is night.	
<i>b</i> ₂	It is warm outside.	
<i>b</i> ₃	Patty played all day.	→
<i>b</i> ₄	Patty grazed all day.	Patty sleeps.

⁷⁷ In this sense, the procedure is closely related to ontology engineering in information science (see Keet, 2018), where ontology – in contrast to its metaphysical meaning – refers to the representation of concepts and their relations within a domain. However, the underlying assumptions and objectives diverge.

⁷⁸ (Mill, 1886).

We can now apply tests for *coincidence* or *divergence* of boundary conditions with the phenomenon's occurrence.⁷⁹

Coincidence: The boundary condition b_i that occurs in all tests together with the phenomenon is the most probable cause:

	b_1	b_2	b_3	b_4	Ph
	Night	Warm	Played	Grazed	Patty sleeps.
Day 1	+	-	+	+	+
Day 2	+	-	-	+	+
Day 3	+	+	+	-	+
Day 4	+	-	+	+	+

Conclusion: Night is the most likely cause for Patty sleeping.

If B covers all potential causes and b_i is the only cause, this type of inference would be even deductively valid.

Divergence: If in any test, all boundary conditions lead to the phenomenon (day 2), and in any other test, the phenomenon disappears together with a single boundary condition b_i (day 4), b_i is the most probable cause:

	b_1	b_2	b_3	b_4	Ph
	Night	Warm	Played	Grazed	Patty sleeps.
Day 1	+	-	+	+	+
Day 2	+	+	+	+	+
Day 3	+	-	+	-	+
Day 4	-	+	+	+	-

Conclusion: Night is the most likely cause for Patty sleeping.

In other words: the remaining boundary conditions are insufficient to cause the phenomenon.

By combining coincidence and divergence, we can find whether a boundary condition is both a necessary and sufficient cause of the phenomenon. If two or more tests in which the phenomenon occurs have only one condition b_i in common (days 1 and 2) and two or more tests in which the phenomenon

⁷⁹ We refrain from using Mill's originally proposed terminology of methods of *agreement* and *difference* (Mill, 1886, p. 429), which seems inappropriate in the general case.

does not occur have only the absence of b_i in common (day 3 and 4), b_i is the most probable cause:

	b_1	b_2	b_3	b_4	Ph
	Night	Warm	Played	Grazed	Patty sleeps.
Day 1	+	+	+	+	+
Day 2	+	-	-	-	+
Day 3	-	-	+	-	-
Day 4	-	+	-	+	-

Conclusion: Night is the most likely cause for Patty sleeping.

The logical tests all rely on the change of a boundary and its effect on a phenomenon. A boundary condition b_i is causally relevant for a phenomenon if it changes with b_i , and causally irrelevant if not.

In contrast to other forms of induction, eliminative induction does not test a hypothesis. It identifies a superior set of causal conditions responsible for an event. Such conditions are ideally independent of each other and form a composite indicator. Each new piece of evidence may lead to conditions extending our knowledge about causation.⁸⁰

3.5.2 Analogical Induction

Analogical induction is a form of inductive inference where multiple observations exhibit a set of common properties. If a new case shares all properties except for one, the missing one is assumed:

- Observation 1: Patty is white, fluffy, and grazes (common properties)
- Observation 2: Mary is white, fluffy, and grazes (common properties)
- Observation 3: Lilly is white, fluffy, and grazes (common properties)
- Observation 4: Maggie is white and fluffy (partial properties)
- Conclusion: Maggie also grazes (exhibits all common properties)

This requires an evidential connection between the common properties to confirm the analogy of the new case.

3.5.3 Enumerative Induction

Enumerative induction consists of multiple equivalent premises stating that the same characteristic always occurs. Assuming a regularity exists, the

⁸⁰ In that sense, eliminative induction shares similarities with Bayesian inference (see also Hawthorne, 1993).

conclusion states that in a subsequent case, the characteristic occurs, too. The following inference shows an example:

Observation 1: Patty is white.
 Observation 2: Mary is white.
 Observation 3: Lilly is white.
 ...
 Observation n: Maggie is white.
 Conclusion: The next sheep will be white.

Here, the inference just applies to a single subsequent observation. For a generalisation, a more robust form of inference is required, like:

Conclusion: All sheep might be white.

The difference is that such a more robust inference applies to an abstract universal rather than an observable individual. At this point, we can begin to quantify our statements, leading us to the field of statistics.

3.5.4 The Transition to Statistics

Statistics closely relates to inductive reasoning since it quantifies the probabilities of inductive inferences.

A *statistical generalisation* can be seen as a special case of enumerative induction. It uses a statistic of a sample distribution (such as the arithmetic average \bar{x}) as a point estimate for the corresponding parameter in the assumed population distribution (such as the mean μ). For instance:

Premise: 80% of the sampled sheep are white.
 Conclusion: 80% of all sheep are white.

assumes the probability distribution underlying the 80%-premise of the sample applies to the probability distribution of the population.

Statistical inference presupposes a statistical generalisation as a major premise to infer characteristics given a minor premise. For instance:

Premise: 80% of all sheep are white. (major premise)
 Premise: Patty is a sheep. (minor premise)
 Conclusion: Patty has an 80% probability of being white.

Statistical generalisation is possible if we find an underlying probability distribution telling us about frequent frequencies of particular results that can be expected.

The Meaning of Probability Distributions

Statistical probability only makes claims about the probability distribution of equivalent or at least similar phenomena. In descriptive statistics, we describe data in terms of their *central tendency* (like the mean), *dispersion* (like the variance), and *probability distribution* (like the Gaussian distribution). We then use statistical tests to verify the assumptions that must hold for the expected probability distribution. After validation, we can use observed data to test hypotheses or predict new data. The probability density function (PDF) expresses the location (central tendency), scale (dispersion), and shape (symmetry), as shown in Figure 3.5. A typical probability density function is the Gaussian (or normal) distribution:

$$P(x; \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{x-\mu}{\sigma})^2}$$

$P(x; \mu, \sigma)$ is the probability of x , given the location parameter μ and the scale parameter σ , both of which stay constant for a given distribution. In this case, a shape parameter does not exist since the function is symmetric in any case.

In the exponent, we divide the difference $x - \mu$ by the standard deviation σ to achieve a difference relative to the scale of the function. The same happens in the normalisation term $1/\sqrt{2\pi} \approx 0.4$, which ensures the unity of the area under the curve.

What happens if the function value x reaches μ is that the exponential term becomes 1, and the likelihood (the probability y at the discrete value x) becomes about 0.4σ in the normalised form. If x approaches $\pm\sigma$, we reach an inflection point with a likelihood of about 0.24. With $x = \pm 2\sigma$, the likelihood reduces to about 0.05 (see Figure 3.6).

To simplify the term, we can transform our x -values (scores) into z-scores

$$z_x = \frac{x - \mu}{\sigma}$$

z-score

which express the number (or magnitude) of standard deviations of x . With the variance being the squared standard deviation, we can also write:

$$z_x^2 = \left(\frac{x - \mu}{\sigma}\right)^2$$

If we transpose our x values to $\mu = 0$ and scale them to $\sigma = 1$ we arrive at the simplified form of the *standard normal distribution*:

$$P(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2}$$

Standard normal distribution

In contrast to the likelihood, which applies to a discrete x -value, the probability refers to an interval and is represented by the cumulative likelihoods occurring in that interval; that is, the area under the curve (see Figure 3.7).

Likelihood vs. Probability

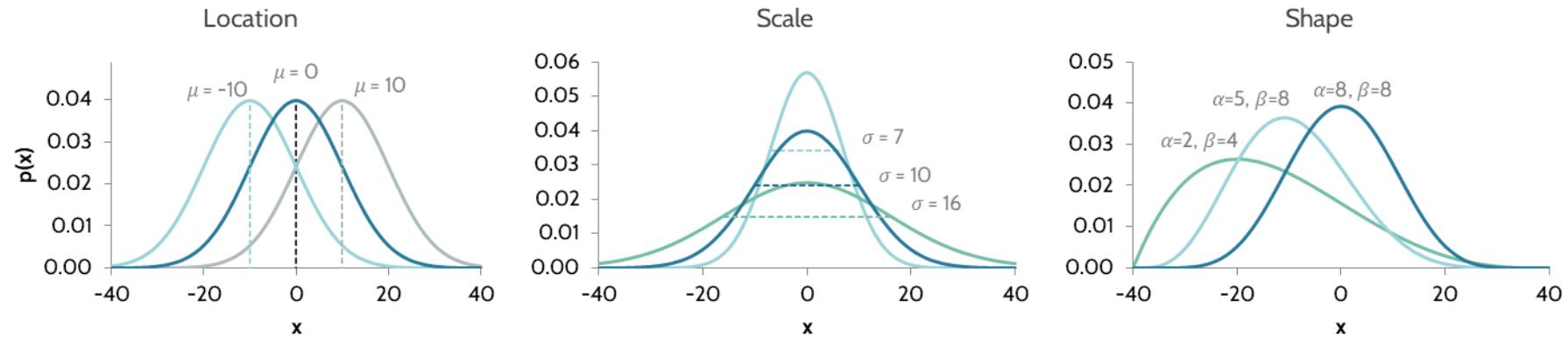


Figure 3.5 Location, scale, and shape of Gaussian distributions (left and middle) and beta distributions (right).

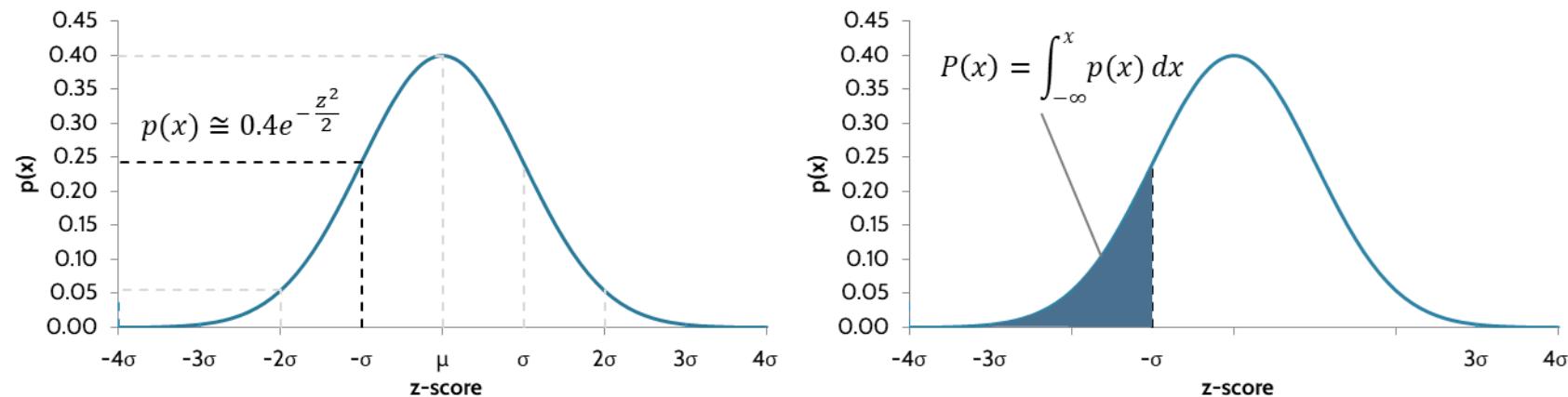


Figure 3.6 Likelihoods (left) and probabilities (right) of z-scores in a standard normal distribution.

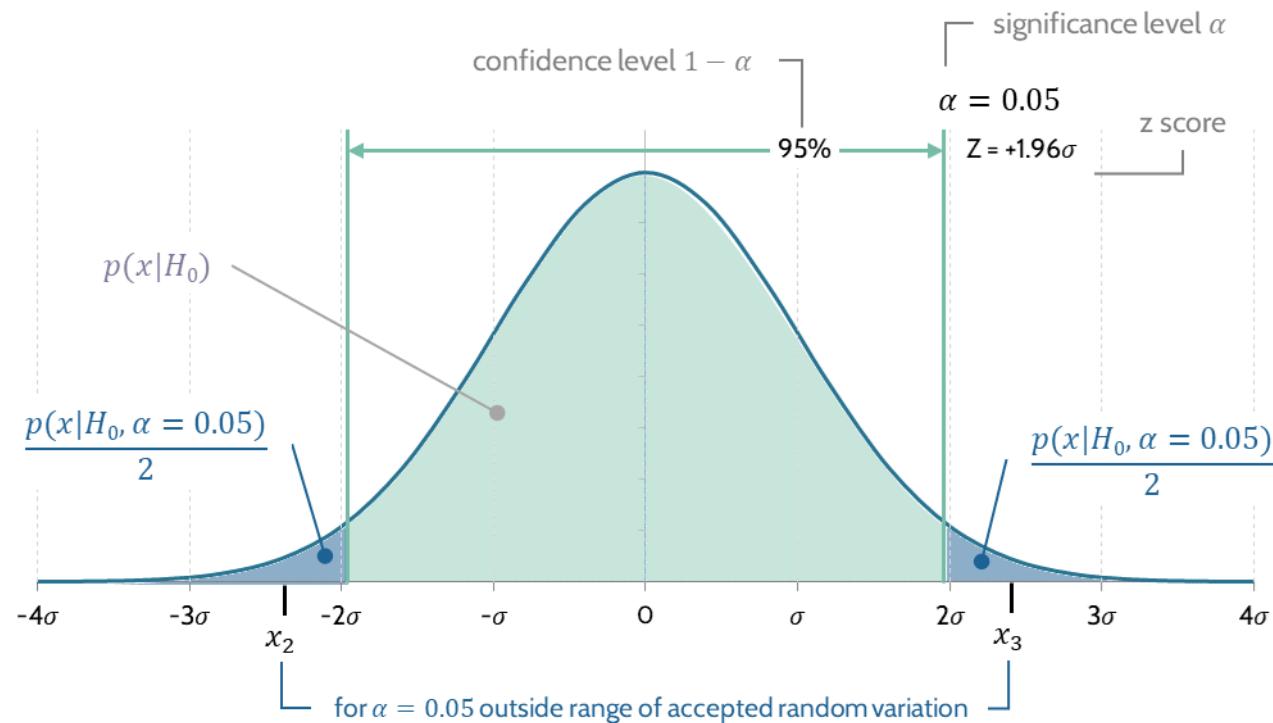


Figure 3.7 Confidence levels, significance levels, and Z-scores for a standard normal distribution. Assuming we choose $\alpha = 0.05$, the results x_2 and x_3 are outside the 95% confidence interval.

For instance, the probability of obtaining a value less than x is the integral over all likelihoods $p(x)$ on the interval $[-\infty, x]$:

$$P(x) = \int_{-\infty}^x p(x) dx$$

Since we have a symmetric function, the same applies to the probability of obtaining values larger than x with the interval $[x, \infty]$. This probability is what is called the P-value of x .

Inductive argument

The inductive argumentation is now that if we measure a value x that is far away from the mean, the likelihood of obtaining that value is small. This might either indicate an outlier of our expected distribution or a member of another distribution.

Depending on our knowledge of a probability distribution, we distinguish between parametric and non-parametric statistical tests.

Parametric

Parametric statistical tests make assumptions about the parameters of the data distribution. A critical assumption in probability theory, statistics, machine learning, and related disciplines is that randomly sampled data are mutually *independent* and *identically distributed* (the so-called IID assumption). Further assumptions include normality and homogeneity of variance.

Non-parametric

If these assumptions are not met or the underlying distribution is unknown, nonparametric statistical tests are an alternative. They just assume a similar dispersion in compared data sets. Although non-parametric statistical tests are less likely to detect a significant effect if one exists, they are more appropriate when ordinal or ranked data are used.⁸¹

The Mysterious P-Value

The *Cochrane Handbook for Systematic Reviews of Interventions*, one of the comprehensive guides for conducting systematic reviews in healthcare, states:

“A P value is the standard result of a statistical test,[sic] and is the probability of obtaining the observed effect (or larger) under a ‘null hypothesis’.”⁸²

This is a pretty abstract formulation for whether a result falls into a random variation (bias) or another effect induced it.

While the likelihood of obtaining any value in a normal distribution is never zero since the curve reaches out to infinity at both ends, the probability (the

⁸¹ For instance, the median may represent the central tendency better than the mean. In particular, skewed distributions show inadequately high means and correlation coefficients if we add samples that contribute to the long tails of the probability distribution.

⁸² (Schünemann, et al., 2022, ch. 15.3.2)

aggregate likelihood) of obtaining a value far from the centre decreases dramatically. Therefore, we can define a *significance level* (α) that marks an arbitrary limit to accept a value belonging to the range of random variation. We deem any value beyond such limit unusual and question whether it belongs to our distribution.

However, since there is always a probability greater than zero, we cannot logically derive any conclusions. That is, the P-value cannot confirm any of our hypotheses. It is the conditional probability of obtaining a result of at least x beyond the mean if there is no particular reason other than the random variation (accepting a null hypothesis H_0 and a significance level α):

$$p = P(x|H_0, \alpha)$$

The P-value cannot confirm a hypothesis.

It does not state the conditional probability that the null hypothesis $P(H_0|x)$ or an alternative hypothesis $P(H_1|x)$ are true given the result x . To assess the P-value appropriately, we need to remember:

- We select the level of significance (α) arbitrarily, depending on an informal assessment of what is an acceptable bias and what counts as unusual. In psychology, it is typically 0.05 ($z = 1.96$), whereas in particle physics, it is 0.000000287 ($z = 5$).
- By stating a significance level, we deliberately ignore random outliers without any logical reason.
- We assume a normality of the residuals, which requires random sampling. Any form of biased sampling, like convenience or purposive sampling, invalidates this assumption.

What is then the value of calculating P ? The value is: if such an extreme value occurs *multiple times*, our doubts will increase that they belong to the same distribution. To understand this, let us look at the original publication.

Significance testing with a P-value goes back to a publication by Ronald Fisher from the 1920s. Fisher intended the P-value to establish whether further research into a phenomenon is justified. He stated the significance level:

"A scientific fact should be regarded as experimentally established only if a properly designed experiment rarely fails to give this level of significance."⁸³

That is, a P-value less than the significance level was a reason for Fisher to repeat the experiment. If multiple experiments gave the same result, he concluded that the observed effects were not just a matter of outliers.⁸⁴

⁸³ (Fisher, 1926, p. 504)

⁸⁴ A detailed description of impact of sampling on p-value interpretation is given by (Hirschauer, Grüner, Mußhoff, Becker, & Jantsch, 2020)

In 1933, Neyman and Pearson extended this concept to hypothesis tests and seemingly replaced Fisher's interpretation with a hard rule, which was probably derived from the following excerpt:

"Here, for example, would be such a 'rule of behaviour': to decide whether a hypothesis, H , of a given type be rejected or not, calculate a specific character, x , of the observed facts; if $x > x_0$ reject H , if $x \leq x_0$ accept H ."⁸⁵

However, if we read on:

"Such a rule tells us nothing as to whether in a particular case H is true when $x \leq x_0$ or false when $x > x_0$. But it may often be proved that if we behave according to such rule, then *in the long run* [emphasis added] we shall reject H when it is true not more, say, than once in a hundred times, and in addition we may have evidence that we shall reject H sufficiently often when it is false."⁸⁵

That refers to Fisher's repetition of experiments and emphasises the meaning of a significance level as an informal limit; in this case, less than 0.01. However, it was quickly interpreted as a hard rule for accepting a hypothesis. Regina Nuzzo reminds us of our misunderstanding:

"The P value was never meant to be used the way it's used today."⁸⁶

In summary, multiple small P-values are one of the hints suggesting the data do not belong to the random variation.⁸⁷ But a single P-value does not prove anything, is no evidence, and does not allow for inference. Statisticians, therefore, recommend reporting the absolute P-value (like $p = 0.032$) rather than a relative one posing evidence based on an alpha level (like $p < 0.05$) and implying a statistical significance.⁸⁸

*Statistical significance
is not scientific
relevance.*

The issue arises if we mistake *statistical significance* for *scientific relevance* while at the same time choosing the *significance level* informally. Such dichotomous interpretation is no longer considered acceptable in the statistical community since even a small probability is not zero. There are even recommendations for retiring the notation of statistical significance as dichotomous argumentation for acceptance or rejection of the hypotheses.⁸⁹

*Why everything seems
normally distributed*

Statisticians often assume a normal distribution for sample means or residuals in regression. A simple reason is that calculations such as regression and analysis of variance rely on minimising the deviations from the data points

⁸⁵ (Neyman & Pearson, 1933, p. 291)

⁸⁶ (Nuzzo, 2014, p. 151)

⁸⁷ (Goodman, 2008)

⁸⁸ for a more recent discussion, see (Muff, Nilsen, O'Hara, & Nater, 2022)

⁸⁹ See, for example, (Amrhein, Greenland, & McShane, 2019; Haaf, Ly, & Wagenmakers, 2019)

symmetrically (method of the least squares). That is, we assume a similar distribution of data points above and below a regression line. Typical parametric tests, such as the F-test for the equality of variances, the t-test for comparison, and the P-value, only make sense if we can assume a normality of residuals.

Measurement results of natural phenomena show apparently normally distributed frequency distributions. One reason might be that the measurement is usually a result of multiple additive-independent phenomena.⁹⁰

To elaborate on this, we use the central limit theorem (CLT) that describes a convergence in distribution for additive averages. It states that if we draw samples of size n , their means $\bar{x} = \sum x_i / n$ approach a normal distribution:

$$\bar{x} \sim \mathcal{N}\left(\mu_x, \frac{\sigma_x}{\sqrt{n}}\right)$$

the so-called *sample distribution of the mean*. That is, if we measure phenomena that stem from additive effects (and the error term is not significantly greater than the cumulative effect y), the CLT will tell us that we deal with a normal distribution of averaged measurement results, even the underlying non-averaged quantities are not normally distributed.

We use the CLT, for example, in statistical process control by taking groups of samples from a production line, calculating their average, and using this average to demonstrate the variation in the production process.

The CLT appears to be an underlying premise for discovering approximate normal distributions in natural phenomena. However, if we examine how we conduct experiments and sampling, we see that we intentionally perform them so that their samples are independent and identically distributed. In addition, we experimentally try to minimise sampling or measurement errors to reduce the variability (or amount of information in a distribution). That is, we often select the phenomena we investigate and conditions to measure them so that they necessarily suffice the normal distribution.

It might be much more a matter of experimental conduct than of natural law. Kac wrote (attributing the statement to Henri Poincaré):

“...there must be something mysterious about the normal law since mathematicians think it is a law of nature whereas physicists are convinced that it is a mathematical theorem.”⁹¹

⁹⁰ The same applies to the error term, which is a sum of individual errors.

⁹¹ (Kac, 1959, p. 52)

Central limit theorem

In fact, most natural phenomena are not additive but multiplicative, meaning that a log-normal distribution often describes the distribution of measurements from natural systems more adequately.⁹²

Regression and Relation

Regression is one of the techniques used to analyse relationships. We begin with having a reason to believe in a relationship (our working hypothesis). For instance, we believe that increasing demand will increase a product's price. Our belief can simply stem from our experience with the market. The null hypothesis would state that demand and price are not related. We quantify the demand by a relative increase in orders and examine how the price changes.

A typical output of a regression analysis includes the *regression statistics*, an *analysis of variance* (ANOVA) for testing assumptions, and the coefficients defining our *regression model*. Let us look at the underlying details, beginning with the regression model.

The Regression Model

A regression table contains essential information about our assumed relationship (see Figure 3.8). The table shows the dependent variable (price) and the parameters of our model:

$$y = b_0 + b_1 x + \varepsilon$$

consisting of an intercept b_0 and the coefficient b_1 of our independent variable x . The coefficient b_1 shows the individual contributions to the slope of the regression line. The slope represents the effect that our cause (demand, x) has on our response variable (price, y). If the slope is zero, there is no effect. The intercept is the constant we obtain if our cause (demand) equals zero. That is, it explains the price if we don't have an increase in demand.

The standard errors represent the variation of our coefficients (slope and intercept). The *t stat* is the ratio of the coefficient and its standard error, thus expressing the magnitude of the coefficient relative to its error.

The effect of price on demand is 7.92, with a standard error of 2.15 (see Figure 3.8). With 68% confidence, we could express this as:

$$b_1 = 7.92 \pm 2.15 \text{ (68%)}$$

The coefficient is about four times higher than its error, indicating that there seems to be an effect of demand on a price beyond the random variation.

⁹² for a more detailed discussion, see (Lyon, 2014)

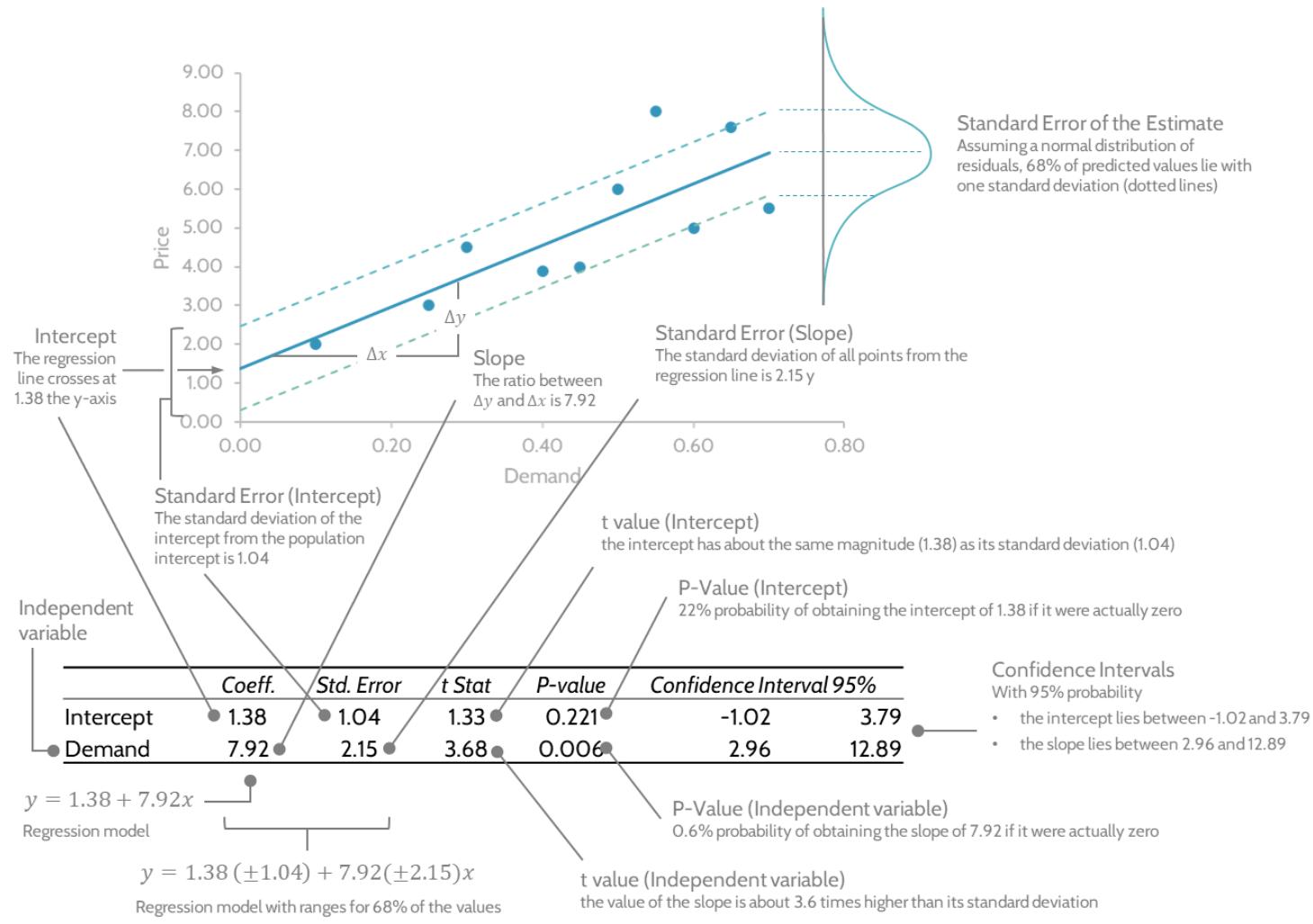


Figure 3.8
The regression table and its interpretation

The meaning of the absolute numbers of these coefficients depends on their scale; a small coefficient does not necessarily mean a small contribution if the change of the corresponding dependent variable has a higher magnitude.

The price without demand is 1.38, with a standard error of 1.04. With 68% confidence, we could express this as:

$$b_0 = 1.38 \pm 1.04 \text{ (68\%)}$$

The null-effect price is about the same magnitude as its random error, indicating that we could not clearly distinguish between random error and the null-effect price.

The corresponding P-values tell us the probability of obtaining such coefficients if they were actually zero. We have a 0.6% probability that the demand increases a price 7.92 times if the demand would not be the cause. Since this probability is comparatively small, we could assume that the demand might have an effect of such magnitude on the price. Still, there is this 0.6% chance that the coefficient is meaningless.

If we are not convinced, we will further investigate the issue. We could increase the sample size to make the result more reliable. However, if we forgot about another variable that causes a higher price, then – although the P-value would decrease – we would still rely on a wrong assumption (see the discussion of the P-value above).

The confidence interval tells us the range of our coefficient with a 95% probability. That is, with a 95% probability, our price will increase about 3 to 13 times with an increase in demand of 1.

The Analysis of Variance

The analysis of variance provides a summary of the bias of the regression model (see Figure 3.9). The regression line allows us to use any demand x_i to predict a price \hat{y}_i using the coefficients from the regression model. Ideally, our data points would all lie on the regression line. However, our actual data points spread around the regression line due to

- *random errors*: a natural variation in the sampling or
- *systematic errors*: something affecting our result that we didn't account for in our model.

The ANOVA table expresses the random errors with the sum of squared errors (SS) for the regression line and the residual. The table begins with the degrees of freedom (df), a concept explained in the following excursus.

Excusus: Grading Freedom

The degree of freedom describes the number of components in a mathematical function that are allowed to vary (i.e., variables in the original sense) to determine the function value. For instance:

$$y = a + b + c$$

has four variables, of which only three (a, b, c) can vary since the function value y is determined by the variables. If we know the variables

$$y = 2 + 3 + 5$$

there is no freedom left for y being 10.

That is, the degree of freedom of a function is, in any case, always one less than its number of variables v , since the function value y has no freedom left:

$$df(\text{Function}) = v - 1$$

Those function components we hold constant become a parameter, for instance:

$$y = 2 + 3 + c$$

the degree of freedom reduces to the number of remaining variables – 1. In general, the degree of freedom of a function is the number of components reduced by the number of parameters and the function value:

$$df(\text{Function}) = c - p - 1$$

A single linear regression model:

$$y = b_0 + b_1 x + \varepsilon$$

has five components. Three of them (intercept b_0 , slope b_1 , and error term ε) are constant for a given set of data and represent the parameters of our model. Two variables, y and x , may vary. However, since y is determined by x , only x has the freedom to vary.

A multiple linear regression model:

$$y = b_0 + b_1 x_1 + b_2 x_2 + \varepsilon$$

has seven components, four of which are parameters ($b_0, b_1, b_2, \varepsilon$), one is the function value (y), leaving freedom to two variables (x_1 and x_2).

You will easily find out that for a regression model, the degree of freedom always equals the number of independent variables.

The sum of squares of the regression model are the summarised differences between the predicted price \hat{y}_i at point i and the mean price \bar{y} :

$$SS(\text{Regression}) = \sum_{i=1}^n (\hat{y}_i - \bar{y})^2$$

Since the mean price \bar{y} is constant, only \hat{y}_i can vary ($df = 1$).

On the other hand, the summary error term ε is expressed by the sum of squared differences of the residuals and is calculated using the actual data point y_i and the point on the regression line \hat{y}_i :

$$SS(Residual) = \sum_{i=1}^n (y_i - \hat{y}_i)^2$$

That is, \hat{y}_i (the point on the regression line) can vary, and the distance to the actual data points y_i varies with each sample. With n samples, the degree of freedom is now:

$$df(Residual) = n - 2$$

In general, for k independent variables:

$$df(Residual) = n - k - 1$$

In our example, we have 10 samples and one independent variable, so our degree of freedom for the residuals is 8.

If we include more samples, the degree of freedom for the regression model does not change – however, the degree of freedom for the residual sum of squares increases with the number of samples.

The total sum of squares is consequently:

$$SS(Total) = \sum_i (\hat{y}_i - \bar{y})^2 + (y_i - \hat{y}_i)^2 = \sum_i (y_i - \bar{y})^2$$

and the total degree of freedom is:

$$df(Total) = df(Regression) + df(Residual)$$

To calculate the mean squares (MS), we divide the individual sum of squares by their degrees of freedom. Since our example includes just one independent variable, SS and MS for the regression show the same value.⁹³

The mean squares represent two parts of the total variation:

- *explained* variation of y with x due to the slope of the regression line (MS Regression)
- *unexplained* variation of y with x due to the spread of the data points around the regression line (MS Residual)

The F-Value is the ratio between explained and unexplained variation. The larger it is, the higher the explanatory power of the model. In our case, the explained variation is about 13 times greater than the unexplained one.

⁹³ Unfortunately, there are two commonly used sets of abbreviations for sums of squares (SS). Either SSR (SS regression) + SSE (SS error) = SST (SS total) or ESS (explained SS) + RSS (residual SS) = TSS (total SS). To avoid confusion, we will adopt the terminology used in the ANOVA table: SS(Regression) + SS(Residual) = SS(Total)

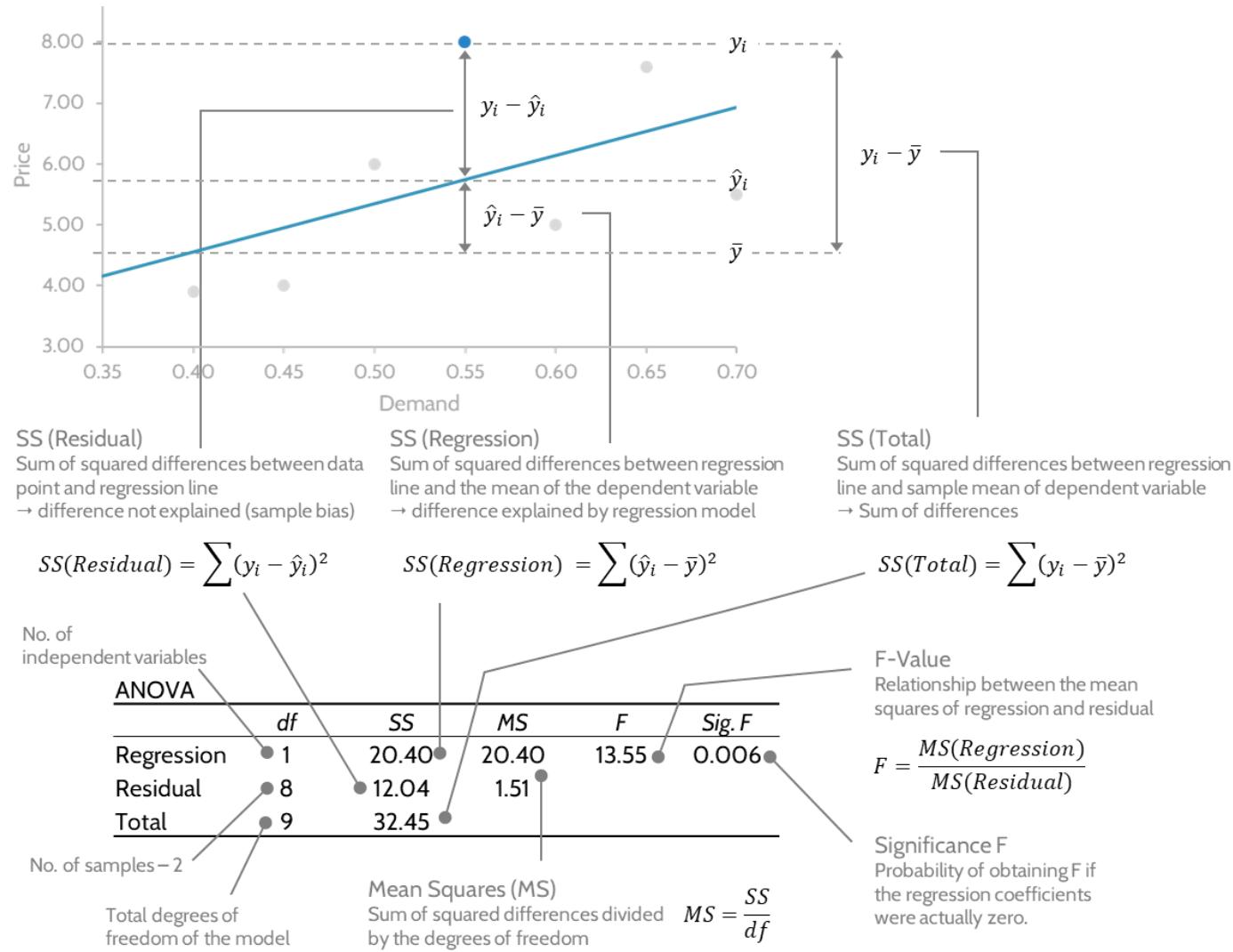


Figure 3.9
The analysis of variance for a regression and its interpretation

Therefore, we can assume that the ability of the slope to explain the change in price is higher than its bias. The significance of the F-Value shows the probability of obtaining such an F-Value if the regression coefficients of our model were actually zero (our regression line was identical to the x-axis).

The Regression Statistics

The table of the regression statistics (Figure 3.10) provides a summary, including the Pearson correlation coefficient (Multiple R) and the coefficient of determination (R^2).⁹⁴

Correlation Coefficient

Ration between the covariation and individual variation of x and y
→ magnitude of relationship between x and y

$$r = \frac{s_{xy}}{s_x s_y} = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \cdot \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}}$$

Regression Statistics

Multiple R	0.793
R Square	0.629
Adjusted R Square	0.582
Standard Error	1.23
Observations	10

Coefficient of Determination

Ratio between model variation and total variation
→ proportion of explained variation in y by variation in x

$$R^2 = \frac{SS (\text{Regr.})}{SS (\text{Total})} = \frac{\sum (\hat{y}_i - \bar{y})^2}{\sum (y_i - \bar{y})^2}$$

Adjusted Coefficient of Determination

R^2 corrected for the reduced degree of freedom due to additional independent variables.
→ proportion of explained variation for multiple regression

$$R^2 = 1 - (1 - r^2) \frac{n - 1}{n - k - 1}$$

Standard Error of the Estimate

Square root of residual sum of squares normalised by the model degrees of freedom
→ precision of the regression model's predictions

$$S_e = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n - k - 1}}$$

Figure 3.10 Typical output of regression statistics

Whereas R represents the magnitude of the relationship, R^2 represents the proportion of explained variation. The latter is obtained by dividing the explained variation (SS Regression) by the total variation (SS Total).

⁹⁴ r^2 and R^2 are not necessarily the same. In multiple linear regression, R^2 represent the square of multiple correlations. R^2 can even be negative, for instance if a regression does not include an intercept or in non-linear regression.

Adjusted R^2

Since the degree of freedom decreases with each independent variable we introduce, R^2 would increase whether the variable contributes to the explanatory power of the model or not. The adjusted coefficient of determination (Adjusted R Square, \bar{R}^2) corrects for this effect:

$$\bar{R}^2 = 1 - (1 - R^2) \frac{n - 1}{n - k - 1}$$

The term on the right-hand side expresses the ratio of total and residual degrees of freedom and will result in a number larger than 1, which increases with the number of independent variables:

$$\frac{n - 1}{n - k - 1} = \frac{df_{Total}}{df_{Residual}}$$

Multiplying the unexplained variation $(1 - R^2)$ with this number will increase it and decrease the explained variation $1 - (1 - R^2)$. If additional coefficients significantly contribute to the model, the adjusted R^2 increases as expected; otherwise, it decreases.

For single regression (like in our case), the adjusted R^2 is not meaningful. This is because there is only one independent variable in the model, and adjusting for the number of independent variables becomes unnecessary.

The standard error S_e is the square root of the residual's mean square:

$$S_e = \sqrt{\frac{SS(Residual)}{n - k - 1}} = \sqrt{MS(Residual)}$$

It expresses the precision of the predictions. In our case, the equation

$$y = 1.38 + 7.92x \pm 1.23$$

states that our predictions lie with 68% probability within this interval.

Correlation and Causation

The correlation coefficient is a valuable statistic for expressing the strength of relationships. The problem is its interpretation.

Social scientists would celebrate for a week if the correlation coefficient of their linear model is $r = 0.6$; that is, 36% of the variation in the dependent variable is assumed to be a consequence of the independent variable variation. Although sometimes referred to as a *moderate* or *substantial* correlation, it means that 64% of the variation is irrelevant to the assumed cause-effect relationship.

A chemist measuring an analyte concentration from an instrumental signal would not dare to use a calibration with a linearity of less than $r = 0.995$,

meaning 99% of the instrumental signal explains the analyte concentration, accepting a maximum of 1% as measurement error.⁹⁵

Furthermore, correlation can turn up everywhere without a particular reason (causation). Blindly generating correlation tables without having a reason to assume an underlying relationship – without a grounded hypothesis – is about as useless as shaking an apple tree and hoping pears will fall off.⁹⁶

Robert Matthews critically addressed the issue by looking at the correlation between the annual number of babies born and the number of breeding pairs of white storks in 17 European countries. He found $r(15) = 0.62$, $p = 0.008$.⁹⁷

Perhaps the ancient folk tale that storks deliver babies is true? No, it is not because we don't have a reason to believe in such a relationship. Matthews wrote his article to emphasise the misuse of correlation coefficients. Höfer et al. supported him by humorously claiming two contrasting theories:

Two different theories exist concerning the origin of children: the Theory of Sexual Reproduction (ThoSR) and the Theory of the Stork (ThoS).⁹⁸

In fact, the relationship is probably more due to a common cause variable, which might be the size of the countries: the larger the country, the more storks and babies are found. While regression *assumes* a cause-effect relationship (formulated as a hypothesis), a correlation does not *indicate* its existence.

Causality relies on ontological and epistemological assumptions. Regularity theory of causation assumes, besides a correlation, a temporal order between cause and effect and the exclusion of confounding (or extraneous) variables that would lead to the same effect. Probabilistic theories of causation assume that causes do not always (necessarily) lead to effects but provide a probability of an effect occurring. This may include prior beliefs or knowledge about causal relationships. If prior beliefs are combined with observed data, we use Bayesian inference to update the probabilities and make inferences about causal relationships.

That a correlation coefficient can be misleading without visual inspection of the regression model shown in Figure 3.11, where linear models of different data lead to the same correlation coefficient, $r(10) = 0.82$, $p = 0.034$.

⁹⁵ As Einstein would say: everything is relative to the system of reference.

⁹⁶ This is a general issue of studies using exploratory data analysis, where all variables are initially correlated with each other without even attempting to identify cause-effect relationships.

⁹⁷ (Matthews, 2000)

⁹⁸ (Höfer, Przyrembel, & Verleger, 2004, p. 88)

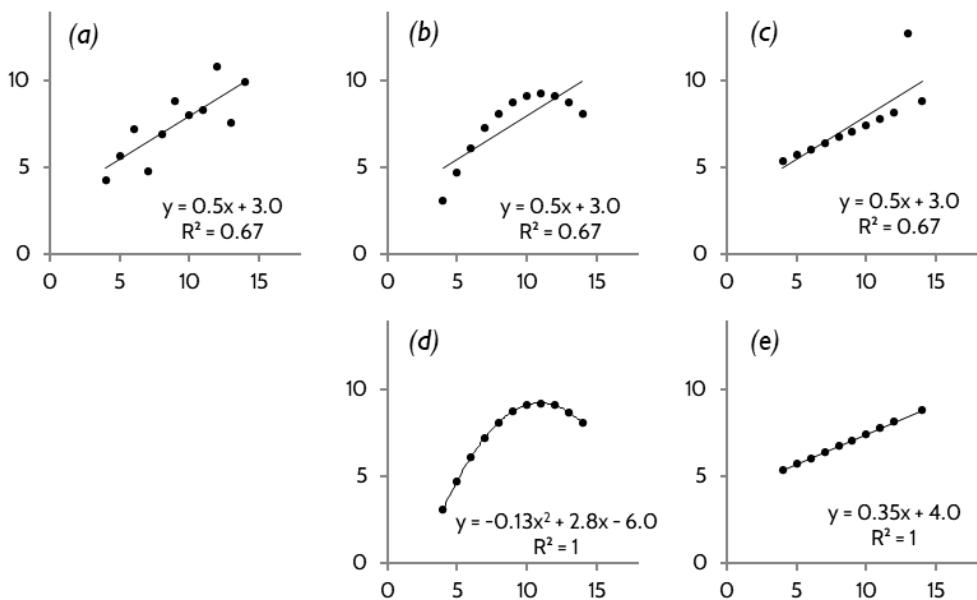


Figure 3.11 Regression models with different data. The upper row (a to c) shows linear regressions resulting in the same regression model. The lower row shows the correct models: (d) a polynomial regression and (e) a linear regression excluding the outlier.⁹⁹

The Bayesian Viewpoint

Until now, we determined the probability of an event by the frequency with which it occurs over many repetitions of an experiment. This is the so-called frequentist approach, assuming that the model's parameters are fixed and the data are random. Typically, we calculate a P-value to obtain a measure of the statistical significance of the rejection of a null hypothesis.

Frequentist approach

Another form is Bayesian statistics. It allows us to update probabilities as we receive new information. The theorem is named after the English mathematician Thomas Bayes. The basic idea of Bayes' theorem is to update a prior probability based on new observations or data to obtain an updated (posterior) probability.

Bayesian approach

In contrast to the frequentist approach, Bayesian statistics defines probability as a measure of uncertainty or belief in a particular event or hypothesis. In Bayesian statistics, we assume that both the parameters of a model and the data are random variables, and we can describe them using probability distributions. Prior beliefs about the parameters of a model or a hypothesis are updated based on observed data to produce a posterior probability for the distribution parameters.

⁹⁹ The idea and data for this example are taken from Edward Tufte's excellent book *Visual Explanations: Images and Quantities, Evidence and Narrative* (Tufte, 1997, pp. 14-15)

For example, the probability (or belief) in a prior hypothesis H being true is $P(H)$. The posterior probability given an evidence x is $P(H|x)$. Bayesian inference assumes that evidence x inductively supports a hypothesis if the probability given the evidence is greater than the prior probability:

$$P(H|x) > P(H)$$

Evidence x disconfirms hypothesis H if and only if $P(H|x) < P(H)$, and is neutral (irrelevant) to hypothesis H if $P(H|x) \cong P(H)$. Since the conditional probability is defined as the ratio of joint intersection and evidence, we can write:

$$P(H|x) = \frac{P(H \cap x)}{P(x)}$$

The theorem of total probability states that the total probability of event x is the sum of all probabilities $P(H \cap x) = P(x|H)P(H)$ leading to the basic form of Bayes' theorem:

$$P(H|x) = \frac{P(x|H) \cdot P(H)}{P(x)}$$

Posterior probability
conditional probability of hypothesis
being true given the evidence

Likelihood
of evidence given hypothesis is true

Prior probability
Unconditional probability of hypothesis
before evidence is considered

Probability of evidence

Figure 3.12 Basic form of Bayes' Theorem

In Bayesian statistics, we obtain statistical significance by comparing the posterior probabilities of the null hypothesis and the alternative hypothesis.

Bayesian statistics updates beliefs, probabilities, and probability distributions based on new evidence and is used in different application scenarios. A typical application is in medical diagnosis to combine patient-specific information with prior medical knowledge to arrive at a more accurate diagnosis. They also help in determining optimal treatments and predicting outcomes. Another field using Bayesian methods is machine learning and artificial intelligence: Bayesian techniques are used in machine learning algorithms, especially for tasks involving uncertainty and probabilistic reasoning, such as Bayesian networks, Naive Bayes classifiers, and probabilistic graphical models.¹⁰⁰

¹⁰⁰ A comprehensive account is given in (Garnett, 2023).

3.6 THE LANGUAGE OF DEDUCTIVE LOGIC

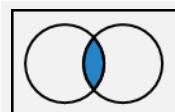
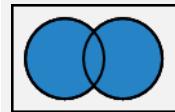
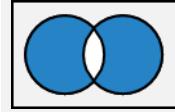
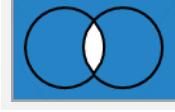
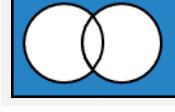
From a logical point of view, it is the only valid reasoning process since it leads to undeniable truth as long as the premises are true. The concept of deductive reasoning (Latin: *deductio*, derivation) is the oldest and goes back to Greek philosophers more than 2000 years ago.¹⁰¹

The examples of reasoning we have seen so far are cases of semantic logic (or propositional logic) where we express logical relationships with terms, such as *is* to express equality, *and* to express a conjunction, *or* for a disjunction, or *if-then* for an implication.

Propositional vs predicate logic

Another way to express logical relationships is predicate logic, which uses mathematical symbols to quantify relationships.¹⁰² Table 3.4 shows typical symbols used in formal logic, which are explained in the following.

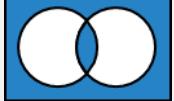
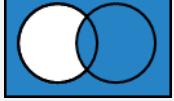
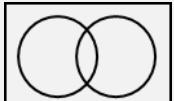
Table 3.4 Common symbols in formal logic

Symbol	Meaning	Read as	Name (Gate)	Venn Diagram
\wedge	and	... and ...	Conjunction (AND)	
\vee	inclusive-or	... and/or ...	Disjunction (OR)	
\vee	exclusive-or	either ... or ...	Disjunction (XOR)	
\neg	not	not ...	Unary Negation (NOT)	
\uparrow	not and	... and ... not exist simultaneously	(NAND)	
\downarrow	not or	neither ... nor ... exist	(NOR)	

¹⁰¹ An extensive account of the origins and nature of deduction is given by (Dutilh Novaes, 2021)

¹⁰² Predicate logic, also known as first-order logic, is a formal system that uses symbols and rules to represent relationships between objects and to infer conclusions based on those relationships. The term *first-order* refers to the most basic type of logic applied to individual objects rather than to a set of objects (higher-order logic).

Table 3.4 (cont.)

Symbol	Meaning	Read as	Name (Gate)	Venn Diagram
\leftrightarrow \Leftrightarrow	not exclusive-or	... if and only if ...	Biconditional (NXOR)	
\rightarrow \Rightarrow	implies	if ... then ...	Implication (IMPL = NOT A OR B)	
T	unconditionally true	... is always true	Tautology True state	
\perp	unconditionally false	... is always false	Contradiction False state	
\forall	for all	for all ...	Universal	Quantifiers
\exists	there exists	there exists ...	Existential	
\because	because	... because of ...	Cause	Object language
\therefore	therefore	... therefore ...	Consequence	
\vdash	proves	provided that ... proves ...	Syntactic validity	Meta language
\vDash	entails	... proves ...	Semantic validity	

3.6.1 Definitions

Formal logic views truth as an undeniable state (or predicate) of an object under investigation. An object might be a proposition (or conjecture) that is proven to be true or false. Formal logic uses binary states. Other forms of logical reasoning use probabilistic statements, such as statistical inference, or uncertain states, such as fuzzy logic.¹⁰³

Logical approaches always rely on premises. We may either accept an initial proposition or define something as being true. The basis for assumptions depends on using a language consisting of a unique syntax (grammatical symbols) and semantics (truth assignments). Using such syntax allows us to phrase propositions and deductive arguments uniquely.

¹⁰³ Fuzzy logic considers vague or imprecise expressions occurring in natural language. Rather than assigning a binary state, like true and false, fuzzy logic uses a degree of certainty (or uncertainty) to describe the tendency to approach a unique state.

If we express a subject and a predicate in semantic form like *Patty is a sheep*, we turn it around and write in predicate logic:

Sheep (Patty)

Usually, an uppercase character (P, Q, and R) indicates a generic predicate, and a lowercase character indicates the generic subject variable (x, y). In the following, we use the initial characters of our predicate and subject to ease the understanding of the expression:

$S(p)$

meaning that our individual *Patty* (p) is a member of the universal sheep (S). A negation, like *Patty is not a sheep*, is expressed with a logical not (\neg):

$\neg S(p)$

meaning it is not true that *Patty* is a sheep.

3.6.2 Implication

A semantic if-then construct, like

If *Patty* is a sheep, then it is an animal.

is expressed in predicate logic as an *implication* (\rightarrow):

$S(p) \rightarrow A(p)$

where $A(p)$ stands for *Patty is an animal*. We call $S(p)$ the *antecedent* and $A(p)$ the *consequent*.

Antecedent and consequent

The truth value of the implication is false only if the consequent contradicts the implication; that is if a sheep would not be an animal. We show this in the following truth table that states all potential combinations of binary states for the two definitions.

p is a sheep.	p is an animal.	p being a sheep implies p being an animal.
$S(p)$	$A(p)$	$S(p) \rightarrow A(p)$
True	True	True
True	False	False
False	True	True
False	False	True

The latter two cases are so-called vacuous truths since they negate the antecedent and, thus, are meaningless for the implication. In other words, whether *Patty* is a duck or a plant – meaning $S(p)$ is false – is irrelevant for an implication based on the antecedent that it is a sheep.

3.6.3 Biconditional

If we state an *if and only if* (iff) condition, like

Patty is a lamb if (and only if) it is less than one year old.

we express it as biconditional (\leftrightarrow):

$$L(p) \leftrightarrow O(p)$$

The truth table is as follows:

p is a lamb.	p is less than a year old.	p is a lamb if p is less than a year old.
$L(p)$	$O(p)$	$L(p) \leftrightarrow O(p)$
True	True	True
True	False	False
False	True	False
False	False	True

The biconditional is true only if both propositions have the same state.

3.6.4 Logical Operators

A connective expression combines two propositions with a semantic operator (*and*, *or*, *either or*). Assuming Patty (p) and Lilly (l) are sheep, we use the *and* operator (\wedge):

$$S(p) \wedge S(l)$$

The above statement is true only if both premises are true. With an *or* operator (\vee):

$$S(p) \vee S(l)$$

the statement becomes true if Patty is a sheep, Lilly is a sheep, or both are sheep. Since it includes the latter case, it is called an *inclusive-or*. If we want to say that *either* Patty *or* Lilly is white (but not both), we use an *exclusive-or* ($\vee\!\!\vee$):

$$W(p) \vee\!\!\vee W(l)$$

The generic truth table for these operators is:

a	b	$a \wedge b$	$a \vee b$	$a \vee\!\!\vee b$
True	True	False	False	False
True	False	False	True	True
False	True	False	True	True
False	False	True	True	False

In contrast to propositional logic, predicate logic requires a so-called *truth functionality*: truth values must be solely determined by the truth values of component propositions rather than other conditions. Otherwise, statements may become ambiguous or lead to misunderstandings in logical relationships.

Since the truth value of the exclusive-or is not solely determined by the truth values of its component propositions (in fact, it evaluates true when an odd number of component propositions are true), it is replaced in predicate logic by more precise statements, such as:

$$\begin{aligned} p \vee q \\ \equiv \neg(p \leftrightarrow q) \\ \equiv (p \vee q) \wedge (\neg p \vee \neg q) \\ \equiv (p \wedge \neg q) \vee (\neg p \wedge q) \end{aligned}$$

Truth functionality

Exclusive-or is not truth-functional.

3.6.5 Quantifiers

For a major premise, like *All sheep are white*, we use a *universal quantifier* (\forall):

$$\forall x(S(x) \rightarrow W(x))$$

meaning that for all instances of x being a sheep implies it being white.

To state that *Some sheep are white*, we use the *existential quantifier* (\exists):

$$\exists x(S(x) \wedge W(x))$$

meaning there exists (at least) one instance x for which the condition of being a sheep and being white is true.

The negation of the major premise

Not all sheep are white.

is equivalent to

Some sheep are not white.

and can be written as:

$$\neg(\forall x(S(x) \rightarrow W(x))) \equiv \exists x(S(x) \rightarrow \neg W(x))$$

3.6.6 Logical Arguments

We distinguish between three basic forms of categorical, disjunctive, and conditional arguments. They distinguish the major premise and the inference procedure (see Table 3.5).

Table 3.5 Formal types of argumentations

	<i>Categorical</i>	<i>Disjunctive</i>	<i>Conditional</i>
Affirmative	Major premise	All A's are B's	Either A or B
	Minor premise	C is an A	Accept A
	Conclusion	C is a B	Reject B
Negative	Major premise	No A's are B's	Either A or B
	Minor premise	C is an A	Reject A
	Conclusion	C is not a B	Accept B

We achieve formal validity if the argument conforms to the logical rules explained in the following.

Categorical Argument

In categorical argumentation (Figure 3.13), we have arguments consisting of three terms, each occurring twice but only once in each premise. At least one premise must be affirmative. The middle term must be universal (a model or theory).

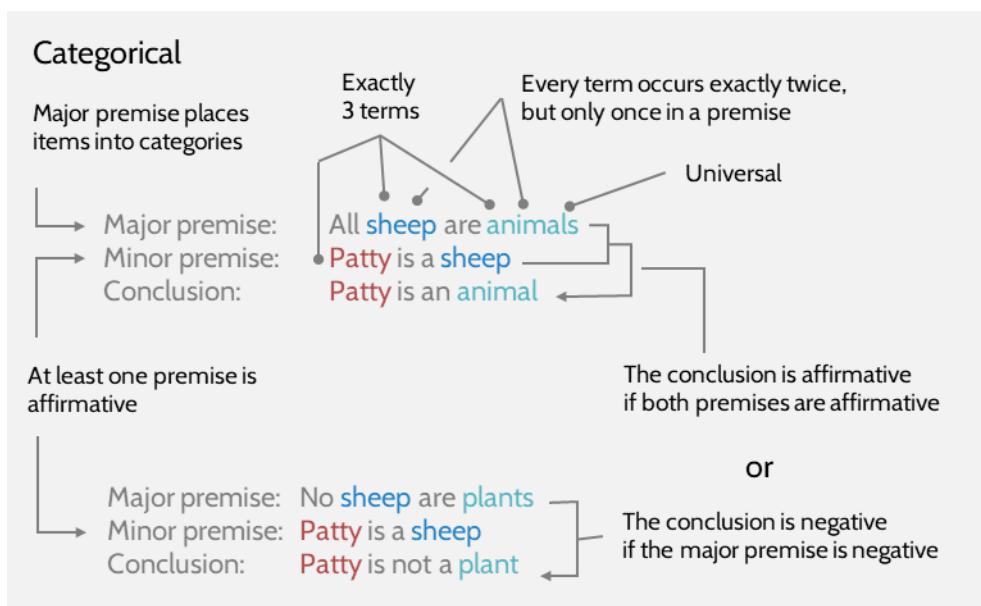


Figure 3.13 Validity requirements for the categorical argument

The major premise

$$\forall x(S(x) \rightarrow A(x))$$

is combined with the minor premise to obtain the affirmative categorical argument for Patty as:

$$(S(x) \rightarrow A(x)) \wedge S(p) \rightarrow A(p)$$

In the negative approach, the major premise states that there does not exist an instance of a sheep being a plant:

$$\neg \exists x (S(x) \wedge P(x))$$

Combined with the minor premise, we obtain the negative categorical argument:

$$\neg (S(x) \wedge A(x)) \wedge S(p) \rightarrow \neg P(p)$$

Conditional Argument

In conditional arguments (Figure 3.14), the major premise implies a consequent from an antecedent. The minor premise affirms the antecedent (thus the consequent) or denies the consequent (thus denying the antecedent).

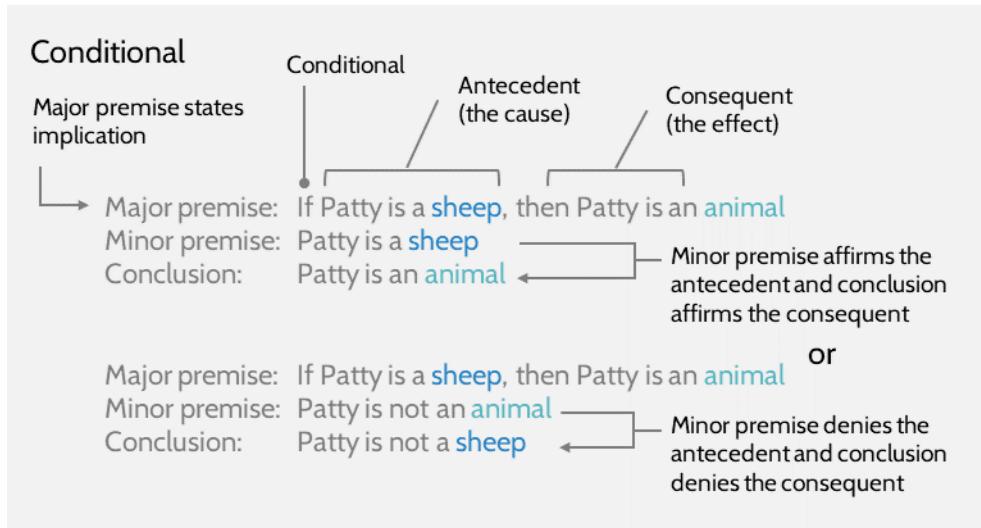


Figure 3.14 Validity requirements for the conditional argument

The major premise expresses the implication:

$$S(x) \rightarrow A(x)$$

which we can either combine with a minor premise by affirming the antecedent $S(x)$:

$$(S(x) \rightarrow A(x)) \wedge S(x) \rightarrow A(x)$$

or by denying the consequent $\neg A(x)$:

$$(S(x) \rightarrow A(x)) \wedge \neg A(x) \rightarrow \neg S(x)$$

Disjunctive Argument

In disjunctive argumentation (Figure 3.15), the major premise presents one or more alternatives. The minor premise either accepts one alternative (rejecting all others) or rejects all but one (accepting the remaining ones).

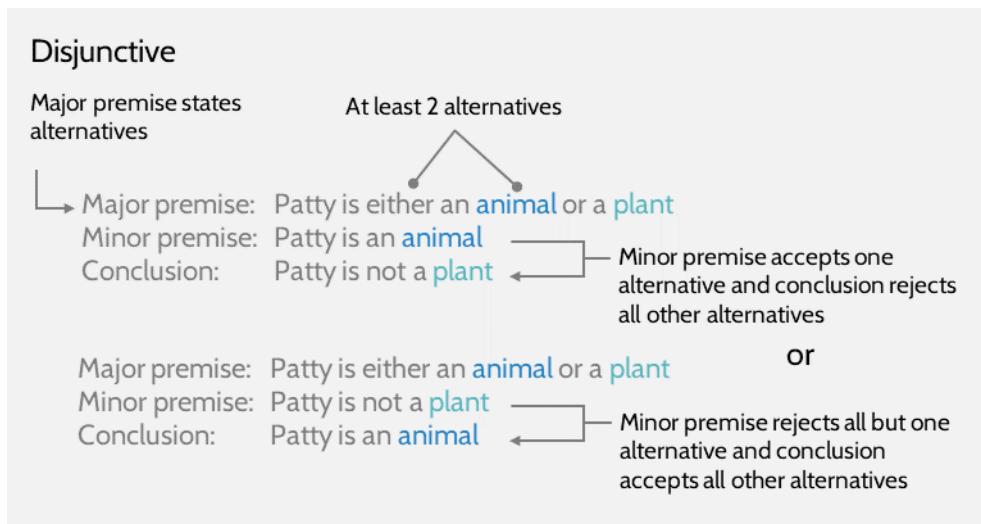


Figure 3.15 Validity requirements for the disjunctive argument

The combination of the major premise

$$A(p) \vee P(p)$$

with the minor premise can be evaluated by accepting the first alternative and reaching a negative conclusion for the second alternative

$$(A(p) \vee P(p)) \wedge A(p) \rightarrow \neg P(p)$$

or by rejecting the second alternative to reach a positive conclusion for the first alternative. Note that this case reverses the alternatives:

$$(A(p) \vee P(p)) \wedge \neg P(x) \rightarrow A(p)$$

Hypothetical Syllogism

Suppose a sequence of implications is inherently connected in a way that the consequences of previous premises become the antecedents of the following premises. In that case, we talk about a pure hypothetical syllogism (Figure 3.16). The pure hypothetical syllogism is a logical argument form that deals with hypothetical or conditional statements, demonstrating relationships between premises and conclusions by employing if-then propositions without specific reference to real situations or facts.

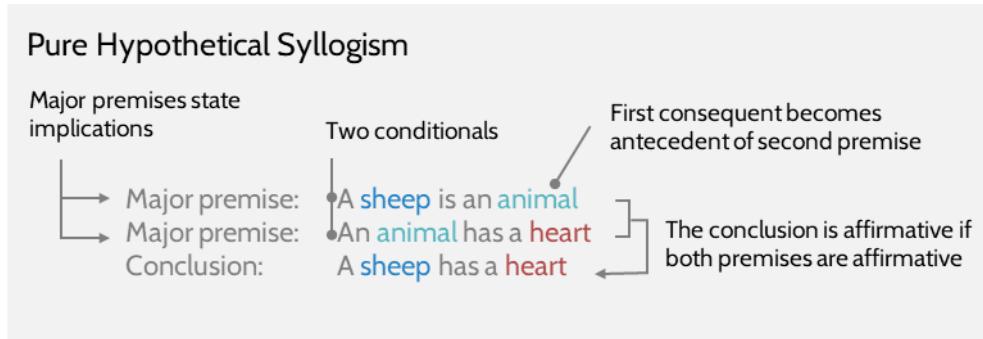


Figure 3.16 Validity requirements for the pure hypothetical syllogism

The two major premises

$$\forall x(S(x) \rightarrow A(x))$$

$$\forall x(A(x) \rightarrow H(x))$$

are combined: if a first proposition implies a second, and the second implies the third, then the first proposition also implies the third:

$$((S(x) \rightarrow A(x)) \wedge (A(x) \rightarrow H(x))) \rightarrow (S(x) \rightarrow H(x))$$

3.6.7 Axioms, Postulates and Theorems

The more we can narrow down a complex system to a complicated one, the more we can isolate individual phenomena and encounter logical relationships between phenomena. In this case, *definitions* receive particular attention. They ascribe names to a logical or mathematical meaning, such as the definition of even and odd numbers. Definitions support axioms or postulates.

Axioms (Latin: *axioma*, worthy) are self-evident unquestioned assumptions that do not require proof since no evidence opposes them. For example, that two parallel lines do not intersect in Euclidean geometry cannot be proven, but there is no need to prove it considering the definition of *parallel*.

Axiom

A *postulate* (Latin: *postulatum* request) is an assumption we can question. While mathematics does not distinguish between a postulate and an axiom, this small difference becomes vital in other sciences. For instance, the first postulate in quantum mechanics assumes the state of a quantum mechanical system is thoroughly described by a wave function¹⁰⁴ $\psi(\mathbf{r}, t)$ of the system's coordinates \mathbf{r} and the time t . In this case, it is not an undeniable axiom but a

Postulate

¹⁰⁴ In quantum mechanics, the wave function is a mathematical function that describes the quantum state of a particle or system. It contains information about the position, momentum, and other physical properties of the system.

demand to the science community to accept it as the mathematical basis to describe quantum systems.

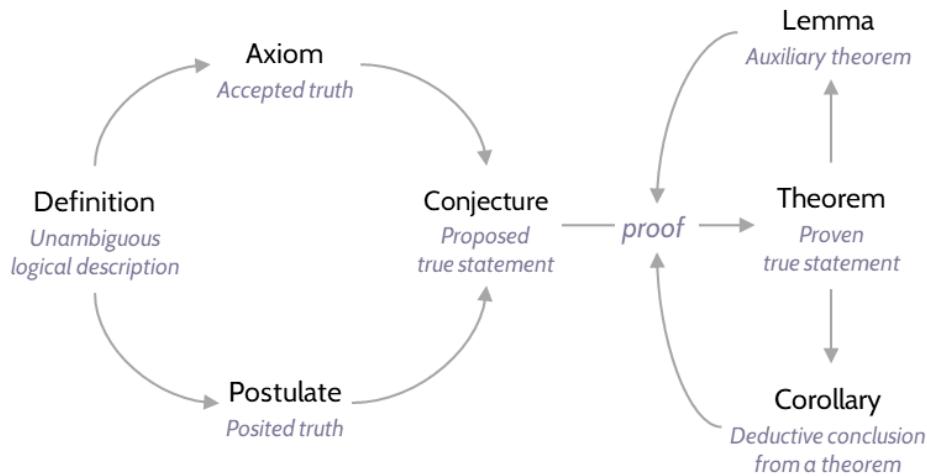


Figure 3.17 Terminology of the axiomatic approach to reasoning

Conjecture

A *conjecture* is an assertion that appears to be correct and has not been unproven.¹⁰⁵ It converts after proof into a theorem. The *proof* provides the logical explanation to achieve a state of an undeniable logical truth, assuming we accept the underlying axioms or postulates. In the mathematic proof, a so-called *mathematical induction* may occur, which uses an intermediate inductive inference that is immediately proven (making it a deductive step again).¹⁰⁶

Theorem

We can derive a *theorem* (Latin: *theōrēma*, consideration) from axioms, postulates, definitions, and other theorems. For instance, there exists a maximum possible speed in the universe. The theorems of space and time quantization state that any system will exhibit at least an elementary space Δr_0 and an elementary time interval Δt_0 . An identical elementary speed $v_0 = \Delta r_0 / \Delta t_0$ must, therefore, exist in all frames of reference.

Lemma and corollary

Both *lemmata* (Greek: *lēmma*, premise) and *corollaries* (Latin: *corollarium*, garland) support the proof of a theorem. A *lemma* is an auxiliary theorem that combines steps in a proof that repeatedly turns up in a simpler logical expression.¹⁰⁷ The *corollary* is a subordinate theorem, usually a simple de-

¹⁰⁵ In this sense, it resembles the a hypothesis, but is not necessarily testable.

¹⁰⁶ A mathematical induction is used in a logical series of n terms. It is done by proving the first term in the sequence ($n = 1$), and then proving that if any particular term ($n = k$) is true, the next term ($n = k + 1$) is true. This leads to the conclusion that all terms in the sequence are true. Although termed as induction, it is different from inductive reasoning.

¹⁰⁷ The *dilemma* is the consequence of two opposing lemmata.

ductive consequence of a theorem. Whether a supporting theorem is considered a lemma or corollary depends on the chain of argumentation.

We can develop a logical theory out of a set of theorems. Such a theory describes a logical domain and allows for generalisation within that domain. Examples are number theory, set theory, group theory in formal mathematics, and game theory in applied mathematics.

While we usually find this terminology in mathematics and logic, they are not limited to formal sciences. We can find them in natural and social sciences, although the logical proofs are far more complicated and less formalised. Table 3.6. shows examples in communication theory.

Table 3.6 Example of the use of logical terms in communication theory

Term	Description
Postulate	The demand for accepting a logically unprovable claim: <i>Social action is defined by the subjective meaning attached to it by the acting individual.</i> ¹⁰⁸
Axiom	A claim which cannot be proven or deduced but is seen to be true without any need for proof: <i>One cannot not communicate.</i> ¹⁰⁹
Corollary	A trivial conclusion deduced from an axiom, theorem, or definition: <i>One cannot not influence.</i> ¹¹⁰
Lemma	An auxiliary theorem used to prove other theorems: <i>The interpretation of social action is subjective and influences reality.</i>
Theorem	A principle derived deductively from an axiom or postulate: <i>"If humans interpret situations as real, they have real consequences."</i>

3.6.8 Formal Proof and Meta Language

The axiomatic approach is a basic method of deductive reasoning in axiomatic proofs.¹¹¹ In this case, we find that the logical statements we expressed before in *object language* are now written in the so-called *meta-language* using some additional symbols. Formal proofs use a meta-language to provide a clear syntactic structure of explanations rather than a semantic one.

We distinguish between proofs that consider truth assignments and those that do not. We say that a premise *semantically entails* a conclusion:

$$S \models A$$

¹⁰⁸ (Schutz, 1962)

¹⁰⁹ (Watzlawick, Bavelas, & Jackson, 2011, p. 30)

¹¹⁰ (Griffin, Ledbetter, & Sparks, 2019, p. 167)

¹¹¹ An overview of mathematical proof is given by (Rossi, 2006)

Semantic entailment means if any valuation of S is true, it makes A true. Semantic entailment is the formal proof of an implication. If A would be true in any case, it becomes a theorem, and we write this as:

$$\vDash A$$

A premise *syntactically* entails a conclusion if a formal proof exists without interpreting a state or an instance. In this case, we write:

$$S \vdash A$$

We use the term *logical tautology* when we can prove the conclusion to be true in any case:

$$\vdash A$$

If Shakespeare had been a fan of logic, he would have expressed the syntactic entailment of Hamlet's famous "To be, or not to be" as:

$$\vdash (B \vee \neg B)$$

meaning that $(B \vee \neg B)$ is always true, and proof exists without assigning B a truth value.

Sound and Complete Arguments

We talk about a *sound* argument if its syntactic entailment (formal proof) involves the semantic entailment (truth-based proof):

$$S \vdash A \Rightarrow S \vDash A$$

Meaning: a formal proof of sheep being animals implies that, in any case, the term sheep semantically entails being an animal. In this case, we need to look out for contradicting evidence (falsification). If we cannot falsify it, we can accept the implication.

We obtain a *complete* argument by finding a formal proof for all semantic entailments:

$$S \vDash A \Rightarrow S \vdash A$$

Meaning: if the term sheep semantically entails all instances of sheep being an animal, we can imply that we can formally prove a sheep being an animal. This is harder to achieve since we have to find logical proof for the entailment.

Arguments should ideally be sound and complete:

$$S \vdash A \Leftrightarrow S \vDash A$$

Meaning: We have formal proof of a sheep being an animal if and only if the term sheep semantically entails all instances of sheep being animals and vice versa.

In propositional terms, we can always prove a major premise (or theory) by individual instances, and the major premise (or theory) always explains any instance we prove. This results in a sound and complete theory.

The double-barred arrows for implication (\Rightarrow) and biconditional (\Leftrightarrow) are often used in meta-language. However, the literature is inconsistent.

Proof Terminology

Formal proofs often use Latin terms to describe the mode of inference (*modus*) by affirming (*ponendo*) or negating (*tollendo*) a premise to affirm (*ponens*) or negating (*tollens*) a conclusion. We show the formal inferences described above in metalanguage.

Disjunctive proof

Modus tollendo ponens (MTP): One of two states is true; one state is false; the other state must be true:

$$((a \vee b) \wedge \neg a) \vdash b$$

Modus ponendo tollens (MPT): Two states cannot exist simultaneously; one state is true, and the other must be false:

$$(\neg(a \wedge b) \wedge a) \vdash \neg b$$

Conditional proof

Modus ponendo ponens (MPP): An antecedent implies a consequent; the antecedent is true; the consequent must be false:

$$((a \Rightarrow b) \wedge a) \vdash b$$

Modus tollendo tollens (MTT): An antecedent implies a consequent; the consequent is false; the antecedent must be false:

$$((a \Rightarrow b) \wedge \neg b) \vdash \neg a$$

Categorical proof

The categorical proof uses a universal instantiation and a conditional proof, either MPP:

$$(\forall(a \Rightarrow b) \wedge a) \vdash b$$

or MPT:

$$(\neg \exists x (a \wedge b)) \wedge a \vdash \neg b$$

Hypothetical syllogism

Hypothetical syllogism relies on a first state implying a second and the second implying the third, entailing the first state implying the third:

$$((a \Rightarrow b) \wedge (b \Rightarrow c)) \vdash (a \Rightarrow c)$$

All examples form syntactic tautologies (or semantic theorems using \models) because they can be derived deductively from the premises.

Formal Hypothesis Testing

A universal hypothesis (H):

$$H: \forall x(S(x) \rightarrow A(x))$$

is confirmed by positive instances (evidence E) that suffice:

$$E: S(x_i) \wedge A(x_i)$$

and disconfirmed by any negative instance:

$$E: S(x_i) \wedge \neg A(x_i)$$

This requires the antecedent $S(x)$ being observable and is called the *instantial confirmation*.

A famous paradox that may occur is Hempel's paradox (originally with ravens and therefore also called the raven paradox). The idea is that an equivalence exists between a positively and negatively stated universal hypothesis:

$$\forall x(S(x) \rightarrow A(x)) \equiv \forall x(\neg A(x) \rightarrow \neg S(x))$$

A consequence is that, for instance, a stone – not being an animal – would confirm the equivalent hypothesis in that it implies that it cannot be a sheep. But it would also confirm the original hypothesis. For sure, something that is not a sheep cannot verify that a sheep is an animal. The issue is due to the different domains of living and non-living beings.

Therefore, in the same way as experiments require experimental conditions to hold or statistical analysis rely on independent and identically distributed random variables, we introduce auxiliary hypotheses that suffice:

$$(E \wedge H_A) \models H_{|\text{dom}(E)}$$

meaning that evidence E and auxiliary H_A entail the hypothesis H evaluated in the domain E .

Hypothetic-deductive models require auxiliary hypotheses, which are typically about experimental conditions or assumptions in the form:

$$((H \wedge H_A) \rightarrow E) \wedge E \rightarrow (H \wedge H_A)$$

While evidence E may inductively support H, E being true does not exclude H being false. Also, if E is false, we can only conclude according to the conditional argument:

$$((H \wedge H_A) \rightarrow E) \wedge \neg E \rightarrow \neg(H \wedge H_A)$$

which means that if either the hypothesis or the auxiliary hypothesis or both are false, the right-hand statement results in true, but not which of these conclusions applies. That is, single counterevidence does not disconfirm the hypothesis but only both the hypothesis and the auxiliary hypothesis.

3.7 THE TRAPS OF REASONING

Deductive, inductive, and abductive reasoning provide us with a framework to conclude from evidence with certainty, probability, or possibility. Still, we can run into logical fallacies: errors in reasoning that can deceive or mislead into accepting flawed or invalid arguments. These fallacies occur in various forms, such as in language, in the structure of an argument, or in the way evidence is presented. Logical fallacies can be intentional or unintentional, and individuals or groups can use them to influence or manipulate others.

3.7.1 Ignorance of Alternatives

We can commit a deductive fallacy when not considering alternative explanations:

If I sleep, I'm unconscious. I am unconscious; therefore, I sleep.

$$A \Rightarrow B; B \therefore A$$

Affirming the consequent

The conclusion assumes unconsciousness is the only reason for sleep. Similarly, the conclusion:

If I sleep, I'm unconscious. I do not sleep; therefore, I am not unconscious.

$$A \Rightarrow B; \neg A \therefore \neg B$$

Denying the antecedent

assumes sleep is the only reason for being unconscious. And finally:

I'm unconscious because I sleep or because of a low blood sugar level. I have low blood sugar levels; therefore, I do not sleep.

$$A \vee B; B \therefore \neg A$$

Affirming the disjunct

assumes sleeping and low blood sugar levels are the only alternatives for unconsciousness.

The literal *or* is an inclusive-or since either or both reasons may apply: We could sleep and still have a low blood sugar level. If we replace the inclusive-or with an exclusive-or, we emphasise it by using the word *either*:

Either I am asleep, or I am awake. I am awake; therefore, I do not sleep.

$$A \vee B; B \therefore \neg A$$

The conclusion is logically true since alternative explanations do not exist. However, this is rarely the case in research.

3.7.2 Argumentative Fallacies

We can quickly run into logical fallacies when we interpret the meaning of information. As an example, let's attend a discussion between an advocate and a critic of the existence of extraterrestrial life. The abbreviation behind the statements refers to typical logical fallacies, which are addressed in the following paragraphs. But before you look at the explanation, try to find out on your own what is illogical with the arguments.

Excusus: A lively debate

Advocate:	I believe we are not alone in the universe. The universe is too vast to be empty of other intelligent beings.	BQ
Critic:	I believe we are alone. If the universe is so vast, we would never have a chance to find such life. And without finding evidence, I have no reason to dismiss my belief.	CC
Advocate:	However, scientists discovered microbial life in extreme conditions on Earth. There may be planets with even more extreme conditions that could support life.	PH
Critic:	Either we are alone in the universe, or aliens already contacted us. Since there is no evidence of alien contact, we must conclude that we are alone.	FD
Advocate:	But most people believe in life on other planets. It's been featured in countless movies and TV shows, and even scientists are starting to believe it.	BW
Critic:	People who believe in aliens are just conspiracy theorists who wear tinfoil hats and believe in all sorts of nonsense.	AH
Advocate:	But if we assume that aliens do not exist, then we are alone in the universe. That would be a sad thought.	AP

Critic:	Look, there is simply no evidence of extraterrestrial life, therefore, you cannot really believe what you said.	AI
Advocate:	But we have explored only a small fraction of the universe. There must be more.	NS
Critic:	Life cannot exist on other planets because the conditions on those planets do not allow for carbon-based life forms.	EV
Advocate:	However, the US government started the SETI program to search for extraterrestrial intelligence. Do you think they are all wrong?	AA
Critic:	We should focus on solving problems on Earth instead of wasting resources searching for extraterrestrial life.	RH
Advocate:	But imagine how amazing it would be if we discovered intelligent life on other planets. We would no longer be alone in the universe, and it would expand our understanding of the cosmos in ways we can't even imagine.	AE
Critic:	Just as there are no unicorns or dragons in the world, there is no extraterrestrial life in the universe.	WA
Advocate:	It seems you don't believe in nothing. Why should I believe you?	SM

Begging the Question (BQ): an argument relying on a premise equivalent to the conclusion. The premise that the universe is too vast to be empty of other intelligent beings is a paraphrase of the conclusion that we are not alone.

Circular Claim (CC): similar to BQ but involves two or more arguments generating a closed loop. This argument is circular because it assumes we are alone because we will not find life and, therefore, have no evidence that we are not alone.

Post Hoc (PH): assuming that an event is a cause for another. The argument that microbial life was found in extreme conditions does not provide evidence for the existence of extraterrestrial life, although it increases its probability.

False Dilemma (FD): presenting two mutually exclusive options as the only possibilities when there are more. The two positions, *we are alone*, and *aliens would contact us*, offer only two options, ignoring other possible explanations for the absence of alien contact.

Bandwagon argument (BW): appeal to an argument that (supposedly) everyone else believes. The argument appeals to the popularity of the idea of life on other planets rather than providing evidence to support the claim.

Argumentum ad hominem (AH): an attack on an opponent's person or stance instead of the argument itself. That someone believes in aliens or wears a tinfoil hat does not necessarily mean their argument is invalid.

Appeal to Pity (AP): attempts to persuade a listener by triggering an emotional response of feeling sorry for something. Being alone has a negative connotation and raises doubts about following the critic's argumentation.

Appeal to Ignorance (AI): persuading a critic by arguing with missing evidence. The attempt to fall back to a factual argument should release the emotional strain of the previous argument. However, missing evidence (a null hypothesis) does not prove anything.

Non Sequitur (NS): drawing a conclusion that does not logically follow from the premise. The fact that humans have explored only a small fraction of the universe is logically not related to the existence of alien life forms.

Equivocation (EV): sliding between two or more meanings of a word or phrase important to the argument. The term *life* is equated with *carbon-based life*, ignoring the possibility of other grounds for life.

Appeal to Authority (AA): attempt to persuade based on the expertise of established authorities. The US government established the SETI program because they took the possibility of discovering intelligent life into account. It does not prove they exist.

Red herring (RH): raising a side issue to distract the audience from the original issue. Addressing other Earth problems does not contribute to the question of extraterrestrial life's existence.

Appeal to Emotion (AE): generating emotional response by addressing anticipated desires of the audience. The argument presents an inspiring vision eliciting a positive emotional response rather than providing evidence to support the claim.

Weak Analogy (WA): referring to a (seemingly) similar case to strengthen one's own argument. The reference to legendary creatures should emphasise the insubstantiality of the claim of alien life forms existing.

Straw Man argument (SM): attempt to intentionally misrepresent or exaggerate an opponent's stance to make it easier to refute. Assuming the critic holds no belief is used as an argument to take the same position against him.

We call the latter a *killer argument* since it is apodictic if the premise is true. More examples of fallacies are given in several sources.¹¹²

¹¹² For instance, more examples are found in (Van Vleet, 2021) and a philosophical treatment is given by (Hamblin, 2022).

A final hope is that intelligent algorithms may detect such fallacies automatically in the future.¹¹³

3.7.3 Overtgeneralisation

When we look for patterns in our results, we often assume that a few similar events provide evidence for a general pattern. That is, we overgeneralise based on limited observations:

When conflicts occurred in the teams, the projects were delayed. Thus, conflicts should be prevented in teamwork.

Should they? For sure, we must manage conflicts in project teams in a way that prevents them from affecting the project outcome. However, preventing conflicts increases their potential and delimits creativity for better solutions.

An issue occurs if such a conclusion affects inquiry. We search for a particular reason for delays rather than investigating what other reasons might apply. The tendency to overgeneralise increases with increasing pressure for action: since delays are expensive, we need to find reasons, and conflicts offer an easy explanation.

Another risk of overgeneralisation is that it can lead to selective observation. Once we have concluded that a particular pattern exists, we tend to focus on events that fit the pattern and ignore those that do not. Rather than asking how we can prevent conflicts, we should ask about the contribution of conflicts to project delays. If it is small, we must find other reasons.

Selective observation

Another example of inadequate selectivity is removing the non-response in a questionnaire. One effect of removing incompletely filled questionnaires is that it reduces the sample size and, thus, the precision. However, the more severe impact is inappropriate selectivity, which occurs if we remove samples representing a specific group. For instance, leaving out respondents who did not fully answer questions about their religious affiliation may lead to missing a particular religious group. If these groups behave differently from the rest of the sample, it causes our estimators to be biased.

3.7.4 Overcomplication

More straightforward explanations are generally more likely to approach a valid value than more complicated ones. In Bayesian terms, hypotheses with

¹¹³ A nice overview with argumentation and additional literature is given in (University of North Carolina at Chapel Hill, 2023). A recent approach for textual fallacy detection is presented by (Jin, et al., 2022)

fewer adjustable parameters have an enhanced posterior probability. This is called the principle of parsimony.¹¹⁴

All assumptions introduce possibilities for error. If an assumption does not improve the accuracy of a result, its only effect is to increase its bias.¹¹⁵ The following excursus shows this.

Excursus: Why is your cat gone?

You come home, and your cat is gone. What is the best explanation?

- a) You hadn't seen her sneaking out when you left your flat.
- b) Your cat ended your relationship because you bought the wrong cat food.
- c) You don't have a cat. You are just hallucinating.
- d) Your neighbours are aliens and stole your cat.
- e) Catnesty International has confiscated your cat since you infringed fundamental cat rights.



If we look at the assumptions for the different explanations, we find their number and complexity increasing:

- a) a sneaking cat; your inattentiveness
- b) you bought food your cat does not like; you can offend your cat; your cat is able to end the relationship and can decide to leave your home.
- c) you suffer from psychosis; you lived a considerable time in a false reality, and neither your family nor friends realised it.
- d) aliens exist; they mastered space travel and can enter your house unnoticed; they are interested in your cat for unknown reasons.
- e) Catnesty International exists; they are watching over cat rights; they have the right to confiscate your cat; they intended not to inform you; they were able to remove the cat unnoticed.

We prefer the less exotic interpretation among competing ones. This aligns with the goal of abstraction, generating a higher-level perspective that simplifies finding universal laws. This does not mean simplifying things beyond recognition. There are cases when a more complicated explanation is more

¹¹⁴ Colloquially referred to as Occam's razor, although William of Ockham, a 14th century English theologian and philosopher, seem to never state it explicitly (cf. Tornay, 1936).

¹¹⁵ Typical for conspiracy theories

universally applicable. However, some critics see a trend to accept more complex explanations as more scientific. For instance, Mazin believes:

“What is at work here and now is a more pragmatic assumption - that a more exciting interpretation can get your paper published in a high-profile journal.”¹¹⁶

3.7.5 Appeal to Authority

Authority can assist human inquiry. We do well to trust the judgment of someone with particular expertise in a given matter. However, experts hinder progress if they speak outside their realm of expertise.

We must scrutinise experts' statements even more than those of laypeople, as they have a greater impact. We are especially careful when someone argues with experience. Experience may help in making decisions faster, avoiding pitfalls, or being more relaxed in critical situations. However, experience is not an adequate argument for maintaining established behaviour or procedures.

The advertising industry plays heavily on the *authority* of popular testimonials. They use an appeal to an authoritative figure instead of evidence to support an argument. And it seems to work, although we all know that a celebrity advertising a product is rarely an expert.

Authority may also lead to a transfer of responsibility. Stanley Milgram showed this in 1961 in a series of social psychology experiments on obedience to authority.¹¹⁷ Milgram measured the willingness of study participants to obey the instructions of the scientific experimenter (the authority) in a learning experiment. The participants were (seemingly by chance) given the role of a *teacher* who was instructed to apply electric shocks to *students* if they answered questions incorrectly. The *students* were members of the institute and played the role of the tortured, but the participants did not know that. It was surprising that two-thirds of participants were willing to apply electric shocks to the student well beyond a fatal voltage level just because they shifted the responsibility to the experimenter's authority.¹¹⁸

3.7.6 Conservatism and Common Beliefs

Knowledge is cumulative, and an inherited body of information and understanding is the starting point for developing further insights. However,

¹¹⁶ (Mazin, 2022, p. 367)

¹¹⁷ (Milgram, 1963).

¹¹⁸ A simplified summary of the original and further experiments can be found in (McLeod, 2023).

conservatism and tradition may also hinder scientific progress. If we no longer try to question established knowledge, we lead the concept of continuous improvement – a fundamental principle of nature and evolution – ad absurdum. Or, as Karl Popper stated:

"I hold that orthodoxy is the death of knowledge since the growth of knowledge depends entirely on the existence of disagreement."¹¹⁹

A principle of sciences is, therefore, to ask for the origins of knowledge and to scrutinise whether it is still valid. If we forget about the origins of knowledge, we run the risk of uncritically accepting assumptions that may not hold anymore. French sociologist Pierre Bourdieu named it the *amnesia of genesis* and stated (in his admittedly complicated style):

Only the anamnesis allowed by historical work can liberate us from the amnesia of genesis, which is almost inevitably implied by a routine relationship to heritage and essentially converts into disciplinary doxa.¹²⁰

Bourdieu referred to the concept of *doxa*: beliefs and values taken for granted and unquestioned in society.¹²¹ Doxa stem from a culture's collective unconscious or common sense, which shapes how people think and interact. Thus, a *doxa* is a culturally contingent common belief, the counterpart to *episteme*, the justified belief consistent with universal observation and rationality.

According to Bourdieu, doxas are passed down from one generation to another through socialisation, education, and other cultural institutions. Bourdieu's concept of doxa emphasises the importance of understanding the underlying cultural and social structures that shape people's beliefs and values. Uncovering the hidden assumptions and unspoken rules that govern society makes it possible to challenge and transform the status quo. And that is one of the primary goals of research. Identify your own doxa by judging the statements in Table 3.7 (we do not provide answers; find out on your own).

3.7.7 Paradox and Antinomy

The term doxa described above also occurs in the word paradox (Greek: *pará*, against; *dóxa*, opinion). A paradox is a statement that appears to be self-contradictory or illogical.

¹¹⁹ (Popper K. R., 1994, p. 34)

¹²⁰ The original statement is: "Seule l'anamnèse que permet le travail historique peut délivrer de l'amnésie de la genèse qu'implique, presque inévitablement, le rapport routinier à l'héritage, converti, pour l'essentiel, en doxa disciplinaire." (Bourdieu, 1995, p. 3)

¹²¹ (Bourdieu, 1977, pp. 164-169). The term doxa (Greek: *dóxa*, opinion, belief) goes back to Plato's dialogue *Gorgias*, where he related it to unreasoned beliefs (see Hall R. W., 1964).

Table 3.7 Knowledge test on common beliefs

		True	False
Culture & Politics			
1	A red telephone connects the Kremlin directly to the White House.	<input type="radio"/>	<input type="radio"/>
2	Henry Ford invented the automobile.	<input type="radio"/>	<input type="radio"/>
3	Diplomatic missions are the sovereign territory of the represented state.	<input type="radio"/>	<input type="radio"/>
4	You need to wait 24 hours before reporting a missing person to the police.	<input type="radio"/>	<input type="radio"/>
5	Sushi means 'raw fish'.	<input type="radio"/>	<input type="radio"/>
Economics		True	False
6	Controlling and accounting have the same goals.	<input type="radio"/>	<input type="radio"/>
7	Microeconomic theory is a scientific theory.	<input type="radio"/>	<input type="radio"/>
8	Management is about leading people.	<input type="radio"/>	<input type="radio"/>
9	Conflicts should be prevented through teamwork.	<input type="radio"/>	<input type="radio"/>
10	Quality management is about testing product quality.	<input type="radio"/>	<input type="radio"/>
Literature		True	False
11	The forbidden fruit mentioned in the Book of Genesis is an apple.	<input type="radio"/>	<input type="radio"/>
12	In the Bible, three wise men visited and worshipped Jesus in a stable.	<input type="radio"/>	<input type="radio"/>
13	Frankenstein was the name of the monster in Mary Shelley's book.	<input type="radio"/>	<input type="radio"/>
14	William Shakespeare created the story of 'Hamlet'.	<input type="radio"/>	<input type="radio"/>
15	Walt Disney created the story of 'Peter Pan'.	<input type="radio"/>	<input type="radio"/>
Natural Science		True	False
16	Albert Einstein failed in mathematics at school.	<input type="radio"/>	<input type="radio"/>
17	Darwin's 'Theory of Evolution' is just a theory, not necessarily true.	<input type="radio"/>	<input type="radio"/>
18	Information is created by humans only.	<input type="radio"/>	<input type="radio"/>
19	The states of matter are solid, liquid, and gas.	<input type="radio"/>	<input type="radio"/>
20	Heavier objects fall faster than lighter ones.	<input type="radio"/>	<input type="radio"/>
Biology		True	False
21	Margarine is naturally yellow, whereas butter is white.	<input type="radio"/>	<input type="radio"/>
22	Bacteria are animals.	<input type="radio"/>	<input type="radio"/>
23	Antibiotics are designed to kill viruses.	<input type="radio"/>	<input type="radio"/>
24	Chameleons change their colour to match their surroundings.	<input type="radio"/>	<input type="radio"/>
25	Ostriches bury their head in the sand when they are scared.	<input type="radio"/>	<input type="radio"/>

Paradox and Antinomy

The term doxa described above also occurs in the word paradox (Greek: *pará*, against; *dóxa*, opinion). A paradox is a statement that appears to be self-contradictory or illogical.

Table 3.7 Knowledge test on common beliefs (cont.)

Physiology		True	False
26	Drinking alcohol keeps you warm.	<input type="radio"/>	<input type="radio"/>
27	Schizophrenia describes a multiple personality disorder.	<input type="radio"/>	<input type="radio"/>
28	Exposure to a vacuum causes the body to explode and the blood to boil.	<input type="radio"/>	<input type="radio"/>
29	Humans have five senses.	<input type="radio"/>	<input type="radio"/>
30	Humans use just 10 per cent of their brains.	<input type="radio"/>	<input type="radio"/>
Physics		True	False
31	Vitamin C is an effective treatment for a cold.	<input type="radio"/>	<input type="radio"/>
32	Colour is a property of an object.	<input type="radio"/>	<input type="radio"/>
33	Sound and light are both electromagnetic waves.	<input type="radio"/>	<input type="radio"/>
34	A direct lightning strike burns a person instantaneously.	<input type="radio"/>	<input type="radio"/>
35	48 ml of water added to 52 ml of alcohol gives 100 ml of liquid.	<input type="radio"/>	<input type="radio"/>
Astronomy & Geography		True	False
36	Seasons are caused by the earth's distance from the sun.	<input type="radio"/>	<input type="radio"/>
37	The earth revolves around the sun.	<input type="radio"/>	<input type="radio"/>
38	There is a dark side of the moon.	<input type="radio"/>	<input type="radio"/>
39	The Great Wall of China can be seen from space.	<input type="radio"/>	<input type="radio"/>
40	The capital of Australia is Sydney.	<input type="radio"/>	<input type="radio"/>
Computer Science		True	False
41	Mac OS exhibits less vulnerability than Microsoft Windows.	<input type="radio"/>	<input type="radio"/>
42	Computer science is the subject area that studies computers.	<input type="radio"/>	<input type="radio"/>
43	Deleting a file removes it from the hard drive.	<input type="radio"/>	<input type="radio"/>
44	The World Wide Web was developed in the USA.	<input type="radio"/>	<input type="radio"/>
45	Artificial Intelligence is about creating intelligent computers.	<input type="radio"/>	<input type="radio"/>
Mathematics & Statistics		True	False
46	Both precision and accuracy measure a true value.	<input type="radio"/>	<input type="radio"/>

-
- | | | |
|--|-----------------------|-----------------------|
| 47 In Roulette, the more consecutively red comes, the chance of black increases. | <input type="radio"/> | <input type="radio"/> |
| 48 A high correlation implies causality. | <input type="radio"/> | <input type="radio"/> |
| 49 If x is a small number, so is $x + 1$. | <input type="radio"/> | <input type="radio"/> |
| 50 $\sqrt{a^2} = a$ | <input type="radio"/> | <input type="radio"/> |
-

You probably know Carlo Collodi's famous children's novel *The Adventures of Pinocchio*,¹²² where the protagonist – a wooden puppet – has a long nose, which grows longer every time he lies. Let's imagine Pinocchio saying: 'I'm lying'. What will happen to his nose?

If his nose grows, then it is because he was lying. Then his statement 'I'm lying' would also be a lie, so he says the truth and his nose should not grow. If his nose does not grow, then because he was telling the truth, but then his statement would be true, and his nose should grow.

This is an example of an irreconcilable contradiction: The statement 'I'm lying' evaluates to true when it is false and to false when it is true. This is the strong form of the liar's paradox going back to Epimenides, a Greek philosopher born around 500 BCE.¹²³

Liar's paradox

While some paradoxes are, in fact, unresolvable, many just appear paradoxical. An example is the time-travel paradox: If you were to travel back in time and kill your parents before you were born, would you disappear at that very moment? The issue is that even if you travel back in time, the standard time that you left is still running. Even if you kill your parents, you were born in standard time. Ultimately, you will find that this is, in fact, not a paradox, as seen in the following excursus.¹²⁴

Excursus: Time travellers have a hard time

If we want to build a time machine, we first need to define time. In non-relativistic physics, we could define it as a movement of elementary particles. Whenever something happens, particles move. If nothing would move, although we could still assume a metaphysical time exists, a measurement of time is impossible. From a physicist's perspective, considering time in this situation would be deemed unnecessary.

¹²² (Collodi, 2014)

¹²³ (Beall, Glanzberg, & Ripley, 2020)

¹²⁴ For a metaphysical discussion on time-travelling, see (Effingham, 2020)

Let us say we build a machine with a container in which we can revert the movement of each elementary particle, that is, would be able to turn back time in that container.¹²⁵ If we ask our parents to sit in the container, we can rejuvenate them to a point in time before our birth. But then we are still outside, alive, and grew older during the experiment. If we sit ourselves in the container, we will become younger, but we cannot reach a point to act before our birth. Our parents would still be outside, alive, and growing older. If we sit together with our parents in the container, we all become younger, but we will again not reach a point before our birth where we could kill our parents. The reason is that we have two frames of reference inside and outside the machine.

If we build a machine that brings us outside the reference frame (the standard time), we need to isolate our particle movement from the reference frame. To kill our parents in the past, we need to re-enter the reference frame. At that point, we would run into a disastrous side effect. Particles of our time frame would suddenly turn up in a space occupied by existing particles. We would merge with the existing matter at the moment we re-enter the past standard frame and most probably die. But even if we find a solution to stay alive, kill our parents, travel back, and enter the standard time frame, we do not run into a paradox. In fact, our parents would be gone, but there is no reason to assume we would not exist. Isolating ourselves from the standard time frame provides us with a different reference frame in which we still exist and grow older.

Whatever we do, we do not end up in a paradox.

Paradoxes occur in many known statements. If someone says: *I don't care what you believe, as long as you don't harm others*, she actually cares. Saying *everything is possible* means that even the impossible is possible.

But there are cases where paradoxes can make sense. If we say *the exception proves the rule*, it is illogical in the sense that an exception would invalidate the rule. However, the statement goes back to a Roman legal principle, suggesting that an exception to a law implies the existence of a more general one.¹²⁶

In the same sense, paradoxes can express a deeper meaning. George Orwell's *Animal Farm*, an allegoric fable on social revolutions, ends with the commandment:

¹²⁵ Unfortunately, it is not possible to revert the state of an elementary particle back to a previous state. While the laws of quantum mechanics allow for deterministic and reversible evolution of particle states, quantum systems are subject to various sources of noise, interactions with their surroundings, and the effects of measurement that prevent us from fully reverting a particle back to its previous state.

¹²⁶ The principle is 'exceptio probat regulam in casibus non exceptis', suggesting that the presence of an exception to a rule (like a non-parking sign) implies the existence of the general rule (parking is allowed elsewhere). See also (Holton, 2010, pp. 369-370).

"All animals are equal, but some animals are more equal than others."¹²⁷

Although a contradiction, the author emphasises, with this paradox, the underlying inequality between the animals and their leaders.

A special case of a paradox is an antinomy (Greek: *antinomia*, against the rule). It occurs if opposing statements are equally well-founded. For instance, we have a direct and undeniable subjective experience of free will: to make choices and decisions that lead to different outcomes. On the other hand, any scientific investigation assumes that events, including human actions and decisions, are determined by preceding causes. This is the antinomy of free will and determinism.

Antinomy

If we imagine an omniscient being, one that knows every course of action, then everything would be determined. Would such a being have free will? What would be its reason for doing something? Could it create a puzzle that it cannot solve?

While such arguments emphasise potential inconsistencies, they do not disprove the existence of free will or determinism. The most plausible explanation (the abductive inference) would be to admit that we lack the understanding of the foundational relationship between degrees of freedom and causality, if any of these concepts is reliable at all.

3.7.8 An Issue of Precision

Finally, we would like to address an issue that regularly turns up in the academic thesis: the issue of numerical precision.

We express the precision of a number either by stating the error or by its decimal places. From a probabilistic perspective, we assume the absolute error of a number – no further information given – to be ± 0.5 in the least significant digit. For 24, it is ± 0.5 , and for 24.5, it is ± 0.05 . Trailing zeros are significant digits; that is, the absolute error of 24.50 is ± 0.005 .

The integer part of a number is considered significant. If the number of digits exceeds the allowed precision, we change to the base ten notation:

$$250 \pm 5 = 25 \cdot 10^1$$

indicating two significant leading digits.

¹²⁷ (Orwell, 1946, p. 123)

In general, the precision of the result of any calculation should not exceed that of the least precise component. For measurement results, there exist two basic conventions.¹²⁸

Rounding rules

When adding or subtracting numbers, we round off the result to the number of *decimal places* of the component of least precision:

$$\begin{aligned} 2.00 + 8.00 &= 10.00 \\ 2.0 + 8.00 &= 10.0 \\ 2 + 8.00 &= 10 \end{aligned}$$

In multiplication or division, we round off the result to the number of *significant digits* of the component of least precision. For instance:

$$\begin{aligned} 2.00 \cdot 8.00 &= 16.0 \\ 2.0 \cdot 8.00 &= 16 \\ 2 \cdot 8.00 &= 2 \cdot 10^1 \end{aligned}$$

However, an exact multiplier has unlimited precision; for instance, if we say that the weight of a package is 4.25 kg, then 4 packages weigh exactly 17.00 kg since we can write $4.25 \cdot 4.000$ (or even add unlimited trailing zeros). The same applies to natural constants that have a precise value, like Avogadro's number, Planck's constant, or pi.

Assumptions can dramatically delimit the precision of results. If an hour ago, a prisoner escaped by foot and the average speed is assumed to be 10 km/h, is the area (πr^2) to be searched for 314.159265 square kilometres? It is not because the uncertainty in the assumption (in the ideal case ± 0.5 km/h) would lead to a range between about 314 and 346 km². The real uncertainty is much larger (from a jogger at about 8 km/h to a sprinter at about 30 km/h).

Context matters

The precision of a number depends not only on its error of measurement but also on the context. For example, if I have exactly 10.00 meters of wall in my room and decide to fill it up with shelves of exactly 3.00 meters in length. Would I have to buy 3.33 shelves? It is obvious that no more than three shelves would fit.

Precision and context both play a role. Consider the following:

You study four participants of ages 22, 23, 25, and 28. What is the average age of your participants?

Calculating the average to 24.5 years seems appropriate since age is a continuous variable. However, the ages are not exactly determined. If each participant has their birthday the next day, the result would be close to 25.5.

¹²⁸ For details on the derivation of rounding rules, see (Lee, Mulliss, & Chiu, 2000)

But even if data have a higher precision than expressed, the context may delimit the precision of the result:

You study four classes with 22, 23, 25, and 28 students. What is the average number of students?

Since the numbers are discrete values, they have higher precision than expressed (for example, 22 means exactly 22.00). We would even have a better reason to calculate the arithmetic average of 24.5 students. But what does it mean? 24 students and a dwarf? From a statistical perspective, 24.5 is the arithmetic average. From a context perspective, it has no meaning; there are about 25 students on average in the classes.

If we look at the meaning of percent (of one hundred), it should be obvious that it is useless to talk about a percentage if our number is considerably smaller than one hundred. Does it make sense to talk about 50% of the week if it has only seven days? It would be more appropriate to talk about 4 out of 7 days.

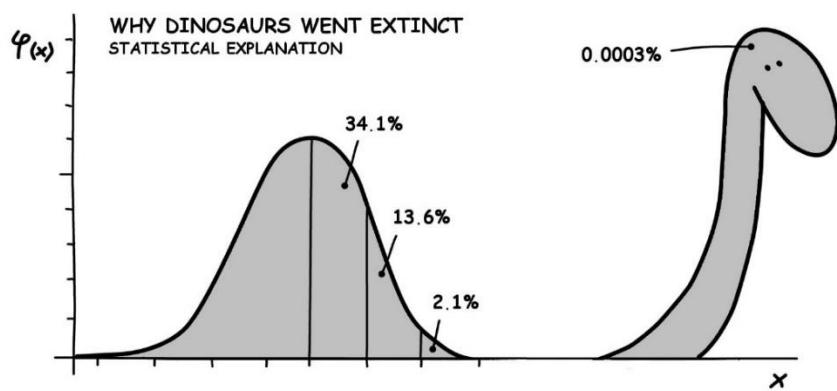
On the other hand, if the number is large enough to justify using percentages, we still need to consider the appropriate precision and the context. For instance, the CIA World Factbook¹²⁹ estimated the surface of the earth to be 510.072 million square kilometres, of which 361.9 million are water. Does it make sense to talk about 70.9507% of the earth being covered by water? In terms of the significant figures, 70.95% would be appropriate (four significant figures); for the purpose of the relationship, 71% or even 70% would be sufficient since the water surface changes every year.¹³⁰

If two studies on sexual orientation report that 6.5% of the respondents in New York City and 12.0% in Boston state their gender identity as non-binary, is it appropriate to report the average as 9.25%? No, it is not. In this context – and given the bias of any survey – it would be sufficient to report that Boston has about twice as many respondents considering themselves non-binary.

We need to consider the precision of measured data, assumptions, and context to arrive at a reasonable statement, or we end with a faulty explanation.

¹²⁹ (Central Intelligence Agency, 2023, 'Area')

¹³⁰ see, for instance, (Yang, Chen, & Wang, 2020)



PART II

THE COMPOSER'S GUIDE



4 ORGANISE TO SURVIVE

While you must write a thesis to finalise your studies, you don't need an antithesis to give it up.

Writing a thesis can be overwhelming and daunting, but it is a necessary step towards completing your academic studies. Researching, writing, and organizing your thoughts can be time-consuming and stressful, and it is common to experience periods of frustration or writer's block.

This chapter provides strategies for organising yourself during the thesis-writing process and recognising when it is time to move forward in your thesis project. By implementing these practices, you can ensure that you remain focused, motivated, and on track towards completing your thesis goals.

Stress can be both constructive and destructive for us: positive stress (eustress) can increase our concentration and performance, and negative stress (distress) has the opposite effect. The better we organise the thesis writing process, the better the benefits from stressful situations.

Our goal is to minimise distress and maximise eustress. The following sub-chapters illustrate how to achieve this goal through the straightforward organisation of your work.

4.1 KNOW YOUR FRAMEWORK CONDITIONS

First, we write down the conditions affecting the writing process. Let us begin with Table 4.1.

Table 4.1 Examples of framework conditions for thesis writing

Condition	Example(s)
Thesis Type	Bachelor Thesis, Master Thesis, Capstone Project, Doctoral degree thesis
Scope (pages/ words)	80 / 30.000
Duration (weeks)	23
(Planned) Start Date	Jan. 2nd, 2023
(Planned) Due Date	Jun. 5th, 2023

The *Thesis Type* usually defines the *Scope* and *Duration* of the expected document. If you graduate with a Bachelor of Arts/Science (B.A./ BSc), you write a *Bachelor Thesis*. If you graduate with a Master of Arts/Science (M.A./ M.Sc.) or Master of Business Administration (MBA), you will write a *Master Thesis* or a *Capstone Project*. If your goal is to receive a doctorate, you must contribute original research to your thesis.

*Consult your university
for the relevant
regulations.*

The thesis regulations of your university cover the expected *Scope* of your thesis. The scope is the first self-check item during the writing process. The scope of a bachelor thesis, master thesis, capstone project, and doctorate thesis differs. Your institution may expect, for example, 80 pages of text and approximately 30.000 words from the introduction to the conclusion of a Master Thesis. The word count may be too high for a Bachelor Thesis but insufficient for a doctorate. If you plan to submit fewer or more pages, check for the allowed tolerance to avoid your thesis being downgraded or even failing because you didn't adhere to formal requirements.¹³¹

The *Duration* is the essential factor for planning. It is the basis of all your writing activities as it influences pace and stress. If you plan to cover too many different aspects in your thesis, you may run into timing problems and feel constantly under pressure.

The last two conditions *Planned Start Date* and *Planned Due Date* are anchor points in the writing process. Together with the *Duration*, they build the basis for your project plan.

¹³¹ While universities may have guidelines for the length of a thesis, the quality of the content is ultimately more important than the number of pages or word count. Adhering to the guidelines for length can be important to ensure that the thesis is comprehensive and covers all necessary aspects of the research, it is not a guarantee of quality. Ultimately, the quality of the thesis is judged on the merits of the research and the value it adds to the academic community, rather than the number of pages or words.

4.2 HOW YOU ARE SUPERVISED

To successfully write a thesis, your supervisor plays an important role. Supervisors not only grade your thesis but are advisors and sparring partners. They help you improve your skills by challenging you throughout the writing process. They will question your strategy and urge you to consider flaws and weaknesses. If your supervisor offers reviews of drafts, make use of this opportunity.

Supervisors are not the enemy.

Supervisors do not tell what to write and how. Content is your responsibility. However, the supervisor's advice by questioning your work will help to improve the thesis.

4.3 PLANNING AND MONITORING

The basis for successful thesis submission is a robust plan. Figure 4.1. shows an example high-level plan:

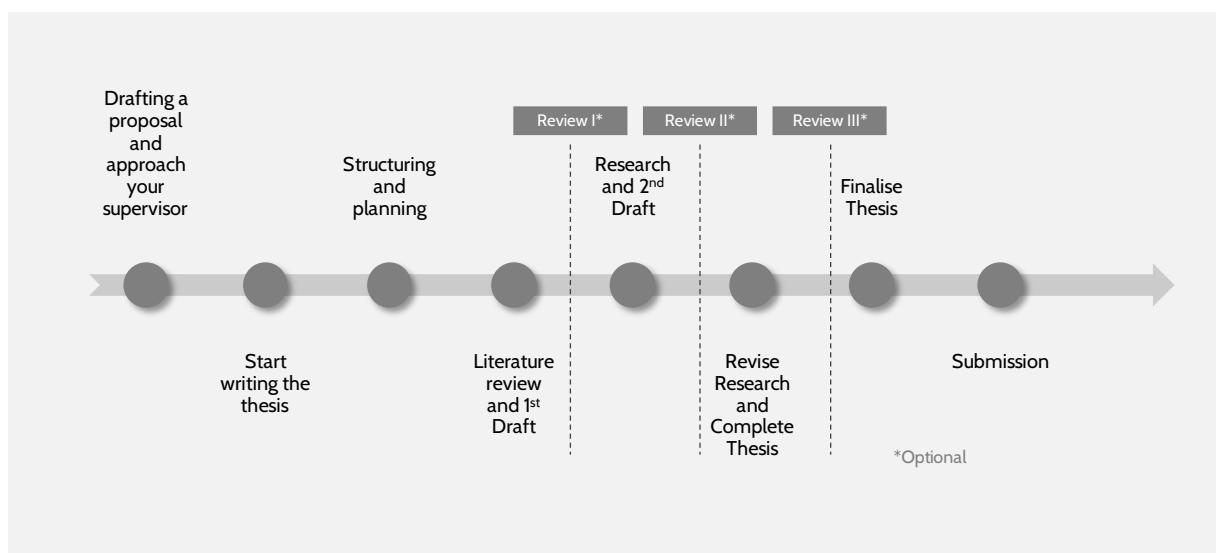


Figure 4.1 High-level project plan for thesis writing

It all starts with drafting your proposal (sometimes called an exposé¹³²). Based on your research objective, you briefly describe what you like to do in your thesis. The proposal will be the basis of your discussions with your

¹³² exposé, "display of discreditable information," 1803, initially as a French word; noun use of past participle of French exposer 'lay open' (see expose (v.)). The earliest use was in reference to Napoleon." (Online Etymology Dictionary, 2020). Seems not to be a positive annotated word for a research proposal. Or?

supervisor (see chapter 11 for writing a proposal). After drafting your research proposal, approach your supervisor to discuss it.

In parallel, you can start planning. The best practice is to elucidate at least the duration from the formal requirements specification of your institution upfront. You can use the duration to create a preliminary project plan for your writing.

Once you agree with your supervisor on your topic, you must fulfil all formal requirements to start writing. For instance, your institution may require you to register the thesis in a legal process. Such a register gives you the exact *Start Date*, *Due Date*, and the derived *Duration* for your project plan. We use these to formulate a project plan by entering dates and durations (Table 4.2).

Start with planning based on weeks.

Table 4.2 Project plan with *Start Date*, *Due Date* and *Duration*

Phase	Due Date	Duration (weeks)	Weeks left
Start Date	Jan. 2nd, 2023		23
Literature Review and 1st Draft		6	17
Review I		2	15
Research and 2nd Draft		6	9
Review II		2	7
Revise Research and Complete Thesis		2	5
Review III		2	3
Finalise Thesis		3	0
Due Date and Submission	Jun. 5th, 2023		

In the second step, we revise the project plan in by entering the exact dates calculated from the durations (see Table 4.3). We put these dates on our calendar for an overview of important milestones. The more you plan, the more you address possible obstacles upfront. This helps to increase your confidence right from the start.

During the writing process, it is best to monitor the progress of your work at least weekly and refine your plan. Some unforeseen obstacles may occur at any time, such as unexpected sickness or unavailability of required resources, such as interview partners, library opening times, etc.

Table 4.3 Project plan with completed example dates

Refine the plan with exact dates.

Phase	Due Date	Duration (weeks)	Weeks left
Start Date	Jan. 2nd, 2023		23
Literature Review and 1st Draft	Feb. 13th, 2023	6	17
Review I	Feb. 27th, 2023	2	15
Research and 2nd Draft	Apr. 3rd, 2023	6	9
Review II	Apr. 17th, 2023	2	7
Revise Research and Complete Thesis	May. 1st, 2023	2	5
Review III	May. 15th, 2023	2	3
Finalise Thesis	May. 5th, 2023	3	0
Due Date and Submission	Jun. 5th, 2023		

Your university regulations cover unexpected sicknesses by extending the duration based on the sickness period. Other obstacles must become part of your planning.

Expect the unforeseen but stay on your road.

Besides, time monitoring content is just as important. Reviewing helps reduce uncertainties and stress, allowing you to understand your flaws. Try to find an independent reviewer as he can provide a fresh perspective on the writing's content, structure, and organization, which can help identify areas for improvement and provide suggestions for how to address them. An independent reviewer can give feedback on the clarity and coherence of the writing, including identifying areas where the writing may be unclear or difficult to understand. He also can help identify and correct grammar, punctuation, and spelling errors, improving the overall readability and professionalism of the writing.¹³³

Reviews are valuable.

Sometimes, supervisors offer draft reviews. Although a draft review is optional, we recommend using it. The learnings of every review raise the level of quality of your work.

¹³³ Similar to the 4-eye principle widely used in a lot of processes. The Four Eyes Principle (also Two-man rule) is a widely used Internal Control mechanism that requires that any activity by an individual within the organization that involves Material Risk profile must be controlled (reviewed, double checked) by a second individual that is independent and competent. (Basel Committee on Banking Supervision, 2012)

4.4 SELF-ORGANISATION

The more you invest upfront into your self-organisation, the more you will benefit during the writing process. Self-organisation is organising yourself so effectively that you can master and complete the thesis on time.

Figure 4.2 shows six principles for achieving good self-organisation:

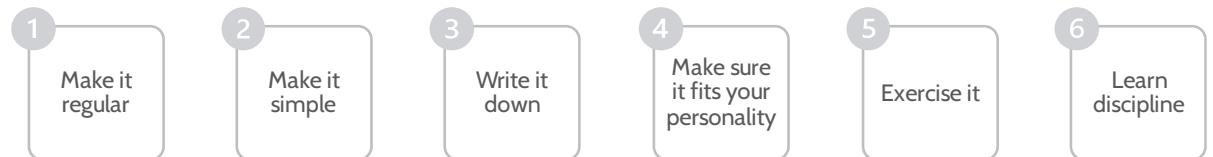


Figure 4.2 Six Principles of good self-organisation

Regularity lets you integrate the work into your daily life. For example, create a rule such as:

Every morning, Monday to Friday, from 8:00 to 12:00, you are working on your thesis.

Simplicity stops you from finding excuses for not doing things because it removes the complexity and distractions that can lead to procrastination or avoidance. A rule like *every morning* is simple enough to follow without additional effort.

Note your planning dates in your calendar. If you place the rule in your calendar, you ensure that you are not messing with this blocked time. If you know you cannot work eight hours on the same project, define rules according to your personal preferences, such as limiting the working time.

The difficulty is exercising the new self-organisation routine. The more you use it, the more you will like and benefit. Give it a try, and do not give up after failing to follow one or the other rules.

Finally, the discipline you learn will help you in life: the better your self-organisation, the lower your stress.

4.5 A LOOK IN THE MIRROR

Another preparation for successful thesis writing is to examine personal skill shortcomings to overcome them before starting. Table 4.4 offers a checklist of questions for self-reflection.

Table 4.4 Self-reflection checklist

Question	Yes	Not sure	No
Word processing skills			
Do you use the capabilities of a word processor to its necessary extent?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do you understand the style-based formatting capabilities of the word processor?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do you use indentation instead of using spaces and tabs?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do you understand how referencing works in a word processor?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do you understand how captions work in a word processor?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do you understand how pagination, headers/footers and sections work in word processors?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do you understand how to embed images into a document?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Do you understand how footnotes work?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Language and Writing Skills			
Are your grammatical skills adequate?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Is the language of your thesis your native language?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Are you familiar with writing scientific texts?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Visualisation Skills			
Are you able to create professional number-based diagrams?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Are you able to create professional process-based diagrams?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Are you able to abstract a problem or process in diagrams?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other Skills¹³⁴			
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

¹³⁴ You can extend the list on your own or together with peers. Your goal should always be to find further skill shortcomings which you may eliminate before you start writing.

If you honestly fill out the table above, you will better understand what skills are missing and where you need to invest time.

For example, if your word processing skills are unsuitable, invest a day in training, and you are ready to start.

However, you cannot achieve everything quickly or without reasonable effort. A series of tools are available to help you proceed quicker with more outstanding quality. For instance, there are built-in tools in word processors to support you with spelling, grammar, and hyphenation. We will show helpful tools in the following chapters.

The previous questions are not complete. They illustrate how you address shortcomings. Using the findings and exercising training in the respective field improves your work almost instantly. Always question yourself: what shortcomings did I recognise in the past?

5 QUILL OR WORD PROCESSOR?

A quill is for tickling.

As a student embarking on the journey of writing a thesis, one of the most important decisions you will make is choosing appropriate writing tools. With the many options available today, deciding whether to use a traditional word processor or a less convenient tool like a quill can be overwhelming.

Word processors are potent tools for writing short and long texts. This book focuses on *Microsoft Word*, the most-used tool for word processing. It is available on most platforms. Alternatively, there are commercial¹³⁵ and open-source software packages¹³⁶ available. Their capabilities are comparable to those of *Microsoft Word*, although the terminology and use differ slightly.

Word processors have powerful built-in functionality which eases the writing of a thesis. You will need additional functionality only if your research topic requires, for example, unique visualisations or advanced grammar tools (see Chapter 5.4).

Using existing tools is the best choice. Tools in generic software like *Microsoft Word* are developed based on the experience of a large community. So, you can also rely on them.

Shall we Reinvent the Wheel?

The earlier you learn how these tools work, the earlier you will achieve time savings and quality improvements in your writing. *Microsoft Word's* functionality is proven and supports you in fulfilling expected standards.

¹³⁵ For example, Google Docs

¹³⁶ For example, LibreOffice, OpenOffice

5.1 FUNCTIONS TO UNDERSTAND

Figure 5.1 summarises the tools for thesis writing and their benefits:

<i>Table of Contents</i>	<i>Figure Captions</i>	<i>Table Captions</i>	<i>References</i>	<i>Footnotes</i>
Your headings are automatically included in the table of contents	Your figures' description is included automatically in your table of figures	Your tables' description is included automatically in your table of tables	Your references are in the correct format and included automatically in your table of references	Your footnotes with automatic numbering

Figure 5.1 *Microsoft Word* built-in authoring functionality and purpose

Microsoft Word bundles this functionality in the *References Menu Tab* of the application window header. Figure 5.2 illustrates the tool locations.

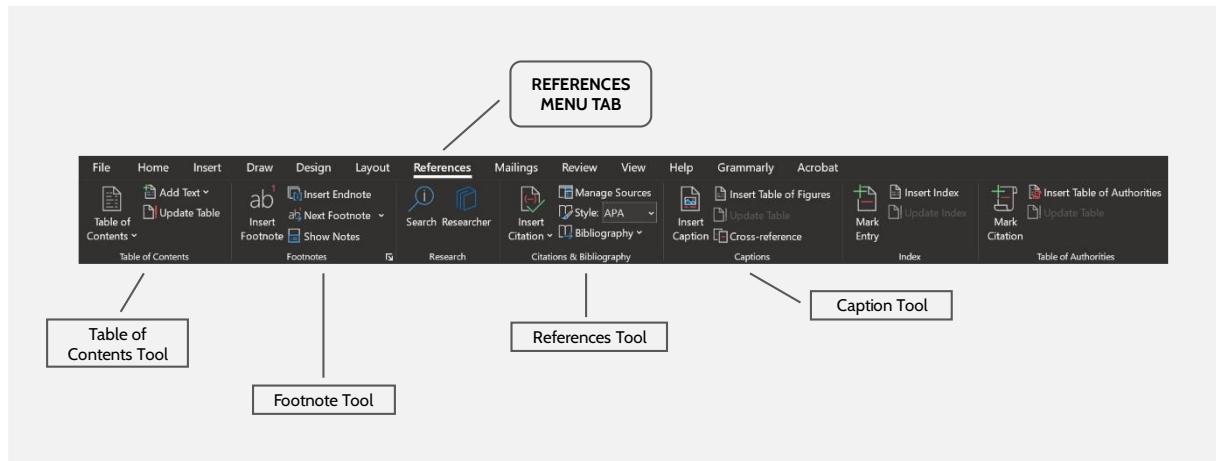


Figure 5.2 *Microsoft Word* ribbon menu authoring tool locations

You use the *Table of Contents* tool to insert the table of contents.

The *Footnote* tool contains the functionality to insert footnotes below your text automatically.

You organise references with the *Reference* tool called *Citations & Bibliography*. You can enter all required fields with built-in templates for all types of references.

The *Caption* tool contains functionality to enumerate *Figures*, *Tables* and *Equations*.

5.2 WHAT ELSE SUPPORTS WRITING

Microsoft Word supports you with built-in tools for spell checking, grammatical improvements, and hints for a better writing style.

<i>Spelling</i>	<i>Grammar</i>	<i>Writing Style</i>
Checks for spelling mistakes and suggests improvements	Checks for grammatical errors and suggest improvements	Checks your writing style and suggest improvements

Figure 5.3 Microsoft Word built-in proofing functionality and purpose

You can find the proofing tools in the following location in the *References Menu Tab*.

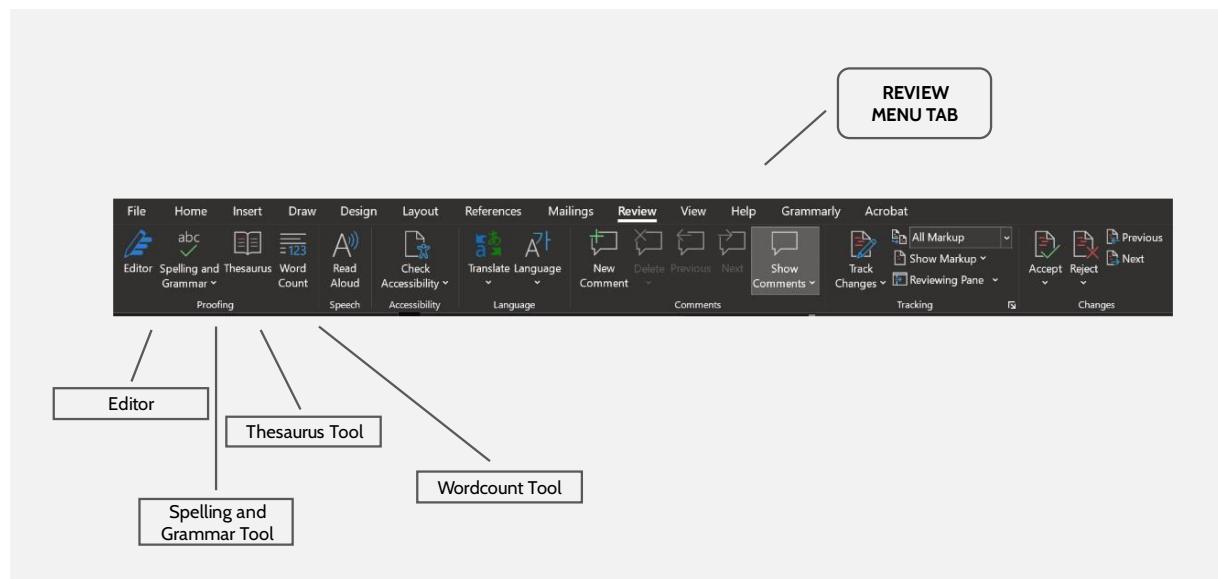


Figure 5.4 Microsoft Word ribbon menu proofing tool locations¹³⁷

All tools work independently, but the best practice is to start from the *Editor*¹³⁸. Microsoft Word's *Editor* is a tool for reviewing. You open the *Editor* by clicking on the editor button on the left of the *Review* tab. A pane on the right of your document opens and reveals an initial overview of your paper. If you open Microsoft Word's *Editor* now, you can easily follow the workflow.

Start from the Editor

¹³⁷ We assume students know what a thesaurus is good for. So, we do not explain the *Thesaurus* tool.

¹³⁸ For best checking results select the writing and proofing language by clicking on the *Spelling and Grammar* button in the ribbon menu.

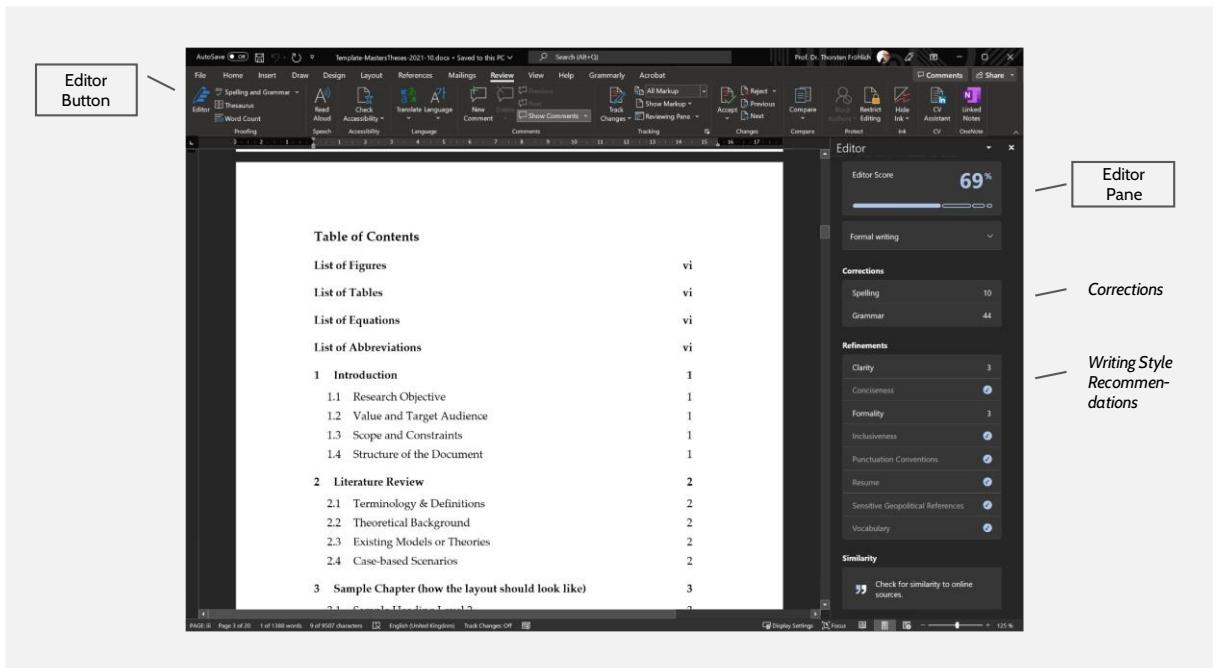


Figure 5.5 The *Editor* is the main tool for correcting and reviewing spelling, grammar and writing style.

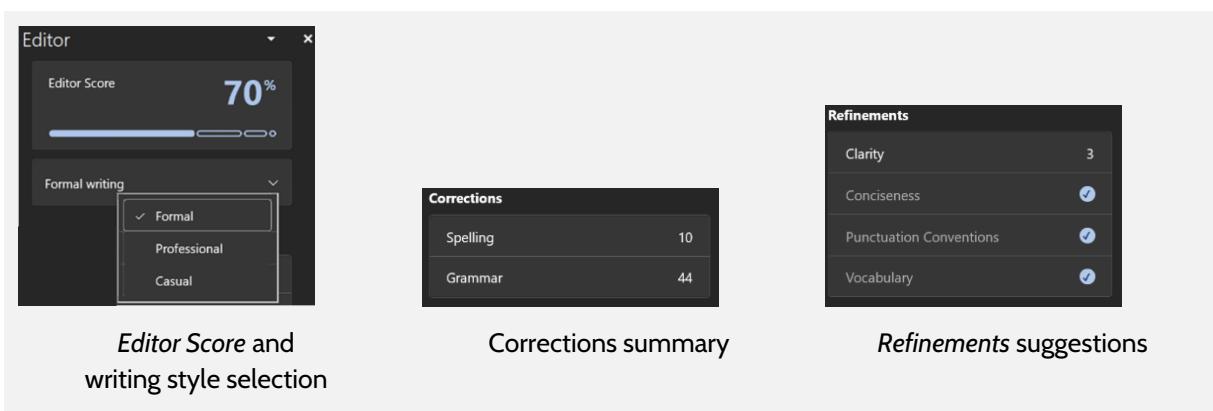


Figure 5.6 *Editor* elements *Score*, *Corrections* and *Refinements*

The pane content starts with general information on your current *Editor Score*¹³⁹ and a drop-down box for selecting your preferred writing style:

Use *Formal* as writing style since your thesis is a formal document and not of a casual nature.

¹³⁹ The tool calculates the *Score* based on the number and types of suggestions to be reviewed and the document length. The higher your score, the better.

The *Corrections* summary lists the number of spelling and grammatical errors in your paper. By clicking the *Spelling* or *Grammar* field, the *Editor* guides you automatically through your document to correct your mistakes on the fly.

The *Refinements* section works similarly but focuses on writing style suggestions (Figure 5.7).

The *Insights* section calculates document statistics (Figure 5.8).

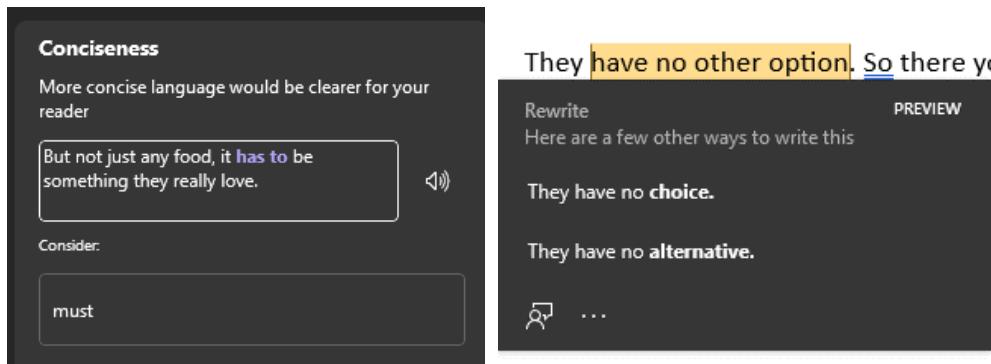


Figure 5.7 Examples of a conciseness suggestion (left) and a rewrite suggestion (right)

Readability Statistics	
Counts	
Words	312
Characters	1,401
Paragraphs	6
Sentences	24
Averages	
Sentences per Paragraph	4,0
Words per Sentence	13,0
Characters per Word	4,3
Readability	
Flesch Reading Ease	80,2
Flesch-Kincaid Grade Level	5,2
Passive Sentences	4,1%
OK	

Figure 5.8 Example document statistics from *Insights*

5.3 BUILT-IN WORD HELPERS FOR FINISHING

Once you have corrected spelling and grammar and adjusted your writing style, you must complete your thesis by adding the missing tables, such as the table of contents. Again, *Microsoft Word* helps you finalise your paper. There are three different tools you can use (see Table 5.1). Figure 5.9 shows how to select the tools from the *References Menu Tab*.

Table 5.1 Microsoft Word built-in finalising functionality and purpose

<i>Content Table</i>	<i>Figure Table</i>	<i>Reference Table</i>
Automatically creates a table of contents from the headings	Automatically creates a table of figures based on figure captions such as for tables, figures, and equations	Automatically creates a reference table based on the previously defined references

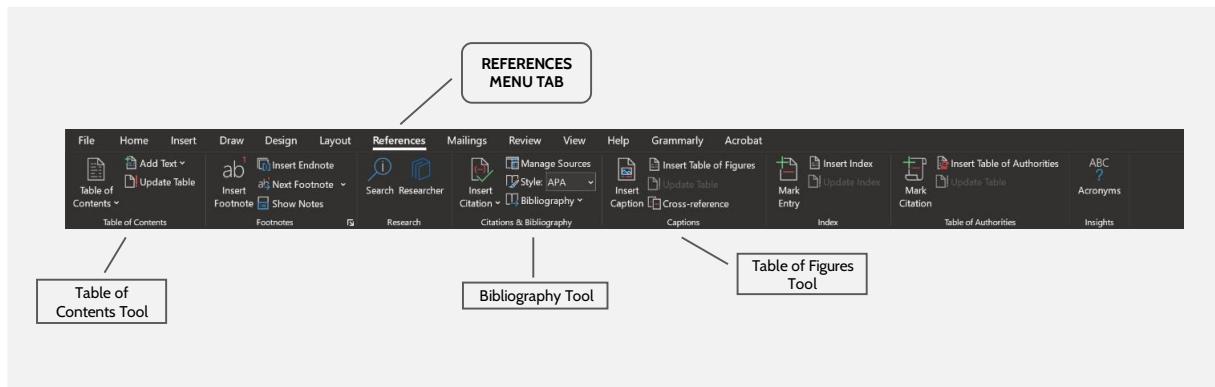


Figure 5.9 Microsoft Word ribbon menu finalising tool locations

Inserting tables at cursor positions

All tools insert a table at the current cursor position of your document.

The *Table of Contents* tool (as the name suggests) inserts the table of contents based on your document headings. The location should be at the beginning of your thesis after the other front matter.

The *Table of Figures* tool inserts tables for *Figures*, *Tables* and *Equations*. They usually follow the table of contents.

With the *Bibliography Tool*, you insert a list of references based on the references of your document in the appropriate format. Place this table after your last content chapter.

5.4 A TINY LITTLE HELPER

There is always room for improvement.

Not all authors of scholarly articles are native speakers, and not all academic theses are written in their native language. Like in all nationalities, native speakers make more or less spelling and grammatical mistakes. Also, the writing style heavily depends on the author's educational background.

Does this stop us from doing better? Of course not. Thanks to computer linguists, computer scientists and modern technology, tiny little helpers are available to improve our writing on the fly.

Chapter 5.2 already showed that built-in tools support us in the writing process. However, there is always room for improvement.

There are a couple of tools for writing support. Two examples are *Grammarly*¹⁴⁰ and *LanguageTool*¹⁴¹. Both tools provide Word add-ons for seamless text editing. Table 5.2 lists the supported languages.

Table 5.2 Supported languages of Word add-ons

Example Tools	Supported Language(s)
Grammarly	American, British, Canadian, Australian, and Indian English
LanguageTool	English, German, Spanish, French, Portuguese, Dutch

Such tools improve the removal of spelling errors, grammatical errors, and flaws in writing effortlessly. At the same time, they help learning and improving your writing skills. aids in the identification and replacement of complicated sentences with more efficient ones, refreshing repetitive language and maintaining accurate spelling, punctuation, and grammar.

Table 5.3 Examples of improvements by using writing tools

What does Grammarly improve?	
Spell Checking	Grammarly checks for spelling mistakes with high accuracy and guessing intelligence ¹⁴² .
Punctuation and Grammar	Grammarly detects basic and advanced grammar and punctuation mistakes such as alliteration, comma splices, fragments, and run-on sentences. Grammarly explains mistakes and provides exercises to improve writing.
Writing Style	Grammarly gives tips and suggestions or other advice on your writing style: sentence length, overall readability, order of sentences, or excessive use of passive voice.

Figure 5.10 shows two out of a collection of alerts from Grammarly.

¹⁴⁰ (Grammarly Inc., 2022)

¹⁴¹ (LanguageTool, 2023)

¹⁴² Grammar tools use a type of artificial intelligence called Natural Language Processing to understand and correct text. They learn from large amounts of data to identify common language patterns and mistakes. Based on this learning, they can predict and suggest corrections in your writing. However, while helpful, these tools aren't perfect and may not always catch nuances in creative or informal writing.

Try out the free version
and start to improve
your writing.

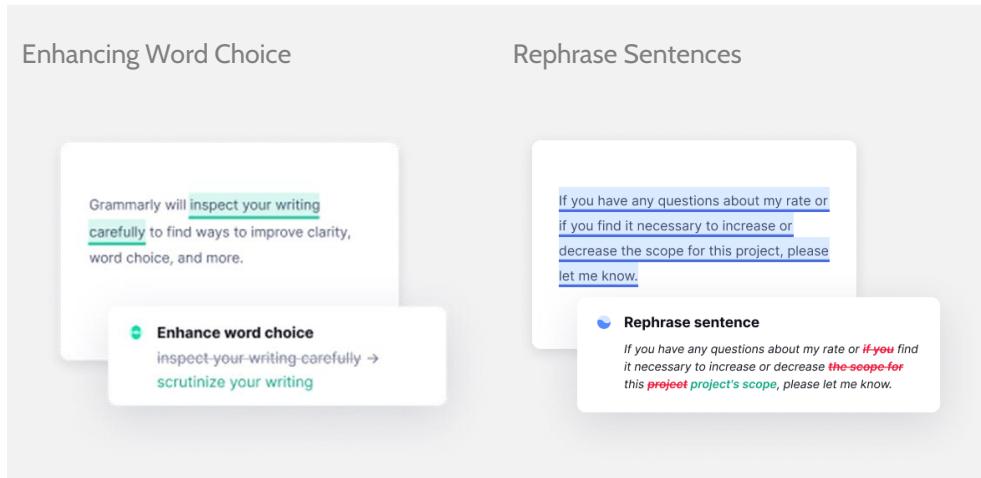


Figure 5.10 Examples from *Grammarly*¹⁴³

5.5 SAVING TIME THROUGH VOICE RECOGNITION

Modern tools provide a significant advantage for authors. They help us avoid errors and save time during the writing and the review. But can we do even more?

One summary of a professional life experience is that laziness fosters creativity. People hate to do repetitive work, providing each time with the chance to make mistakes. They think about avoiding errors and finding someone else to do the job whenever they encounter such processes.

One outcome of such a creative process in the past was the development of voice recognition capabilities for word processors. Instead of typing with lousy skills, voice recognition translates our voice into characters and places them into our document. At the same time, it improves spelling using intelligent dictionaries.

While there are commercial solutions for voice recognition, we address the Microsoft Word built-in tool *Dictate*¹⁴⁴.

Microsoft Word Dictate¹⁴⁵

Voice recognition only works if you attach a working microphone to your PC. You do not have to train the system first. You can start immediately.

¹⁴³ (adapted from Grammarly Inc., 2022)

¹⁴⁴ Google Docs contains similar functionality. To use it, go to the documents' Tools menu and activate the Voice Recognition tool.

¹⁴⁵ Dictate your documents in Word (Microsoft Corp., 2022)

You will find the *Dictate* tool on the right-hand side of the *Home* menu tab. Place your cursor in the document position where you want to enter text and click on the *Dictate* button.

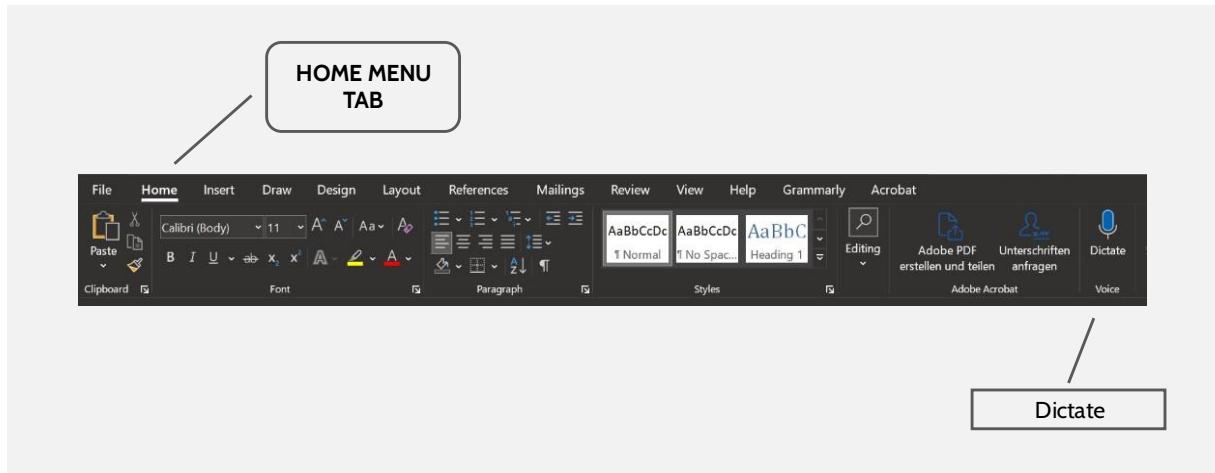


Figure 5.11 Microsoft Word Dictate tool location

After activating the *Dictate* button, a small bar with two controls appears. The *Microphone on/off* symbol lets you start and stop voice recognition anytime. The *Language Setup* button opens the *Spoken Language* selection and microphone testing dialogue.

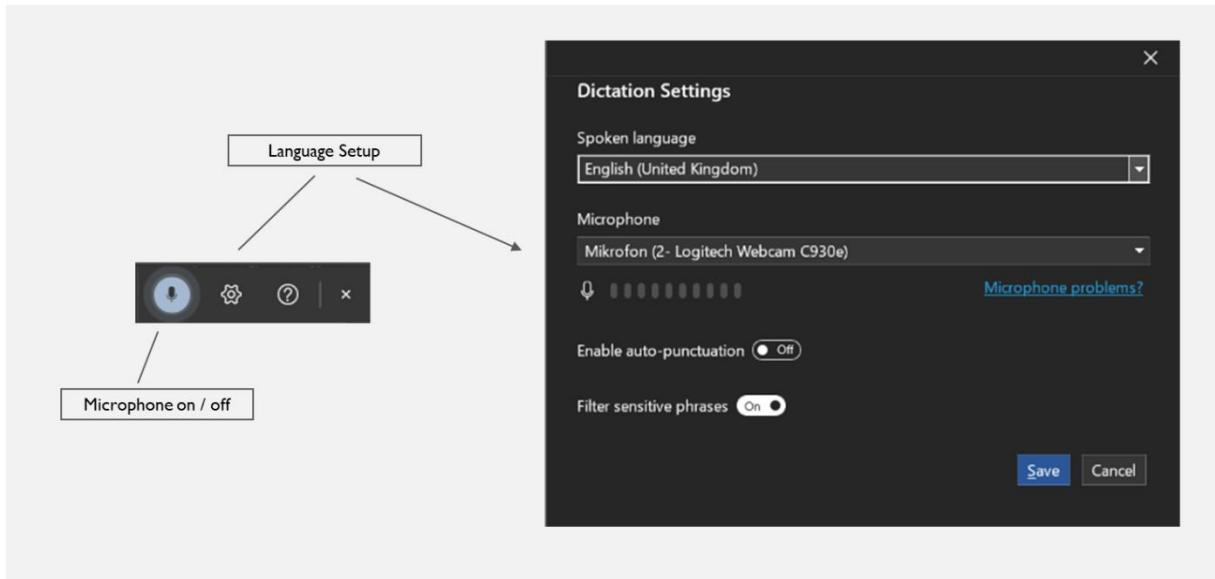


Figure 5.12 Dictate microphone and language controls and *Dictation Settings* dialogue

Select the language you like, for example, *English (United Kingdom)*, click *Save* and start dictating.

Speaking is natural for a human. You are not limited to text only. In addition to dictating your content, you can speak commands to add punctuation, navigate around the page, and enter special characters. Here are areas in *Dictate* you can control via voice commands:

- Punctuation
- Editing
- Navigation and Selection
- Formatting
- Creating lists and tables
- Dictation commands
- Symbols

6 LAYOUT AND FORM

It's amazing how often word processors are misused as typewriters.

Each text element has a particular meaning, emphasised by its visual appearance. A heading looks different than a paragraph, and a figure caption is distinguished from a table caption. If we constantly format each of them manually, we could also have used a typewriter.

Rather than wasting our precious time, we let our Word processor deal with layout and form. This ensures a consistent layout supporting our message.¹⁴⁶

Your university may define at least parts of the layout, like font style, size, and essential structuring elements. We describe in this chapter the generation of the layout and recommend a standard format you could use in case your university doesn't provide it.

6.1 BASIC WORD PROCESSOR FUNCTIONS

Word processors provide two central functions that ease the generation of text layouts. The first is a so-called *style* that defines a paragraph's format. The second is a so-called *field*, which contains commands for the automatic generation of content, such as the automatic numbering of elements. In the following, we will present examples for Microsoft Word; other word processors provide similar functions.

¹⁴⁶ You wouldn't believe how much a supervisor learns about your way of working just by looking at your layout.

6.1.1 Styles

A style is a predefined format for either a paragraph or a text passage. It includes font, size, colour, frames, numbering, and other style elements. If you format a text portion, you can store such formatting in a named style. The advantage is that you can apply it to any part of your text and ensure a consistent document layout.

Alt-Ctrl-Shift-S

The *Styles* pane shows the available styles as well as the one underlying the current cursor position. With a right-mouse click on a style, you can update a style to match the current selection or modify it for all occurrences. Press *Alt-Ctrl-Shift-S* to open it. If the *Styles* view appears as a floating window, drag it to the right or left of the Word window to dock it.

How to create a new style

To define a new style, write some text, format it manually, place your cursor in the paragraph, and click the *New Style* icon in the *Styles* view (see Figure 6.1).

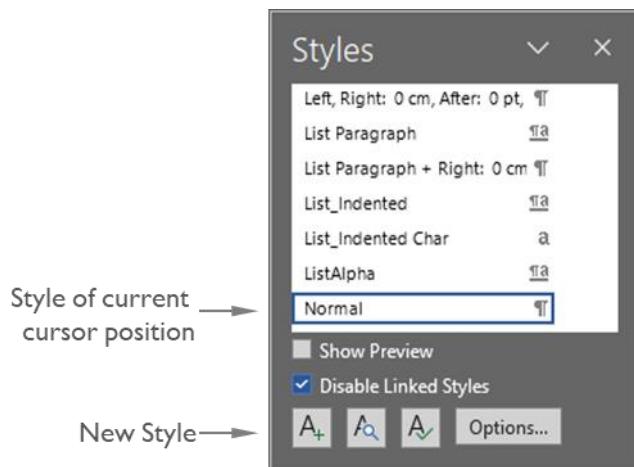


Figure 6.1 The Styles view in the undocked state

6.1.2 Fields

Microsoft Word provides *fields* that hide functions to automatically update text portions. The automatic numbering of pages, headings, or captions, the generation of the table of contents and figure or table listing relies on such fields. When you position your mouse cursor in front of a field, it is greyed out, such as the number in a caption:

Table | 10.

Shift-F9

You can display the underlying code by pressing Shift-F9 to toggle between the field code and the field result. Word shows field codes in between parentheses; for instance, the field code for the example above is:

{SEQ Table * ARABIC}

The name of the field function is **SEQ**, standing for *sequence*; **Table** is the argument, in this case, the name of the sequence; *** ARABIC** is a flag indicating the numbering symbols, in this case, Arabic numbers. Whenever Microsoft Word encounters a SEQ field, it increments the number for the corresponding sequence name (here: **Table**). To edit a field, you click it with the right mouse button and select *Edit Field*.

Since this function may not always be available in the context menu (for instance, in footnotes), creating a button for the 'Edit Field' function in one of the ribbons is useful:

1. Click on *File* and select *Options* at the bottom.
2. In the dialogue, click on *Customise Ribbon* on the left.
3. On the right, select the tab where the new button should appear.
4. In the lower right, click on *New Group*, and optionally use *Rename...*
5. Click the dropdown on the top of the left listing (reading *Choose commands from*) and choose *All Commands*.
6. Selected *Edit Field...* and click the button *Add>>* in the middle.
7. Click *OK* to close the dialogue.

Setting up the 'Edit Field' function

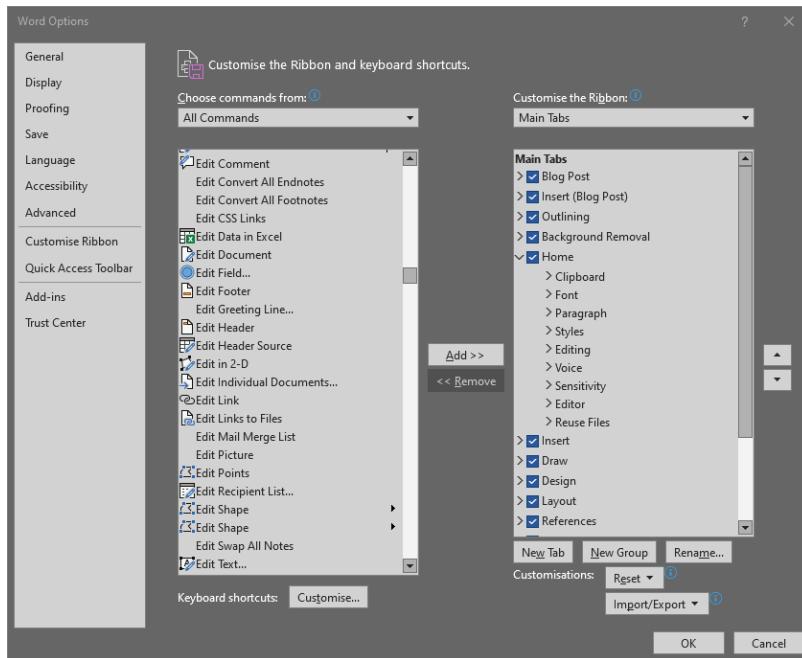


Figure 6.2 The *Customise Ribbon* dialogue.

You can use the new button to edit or create a new field under the cursor. You may also include this button on multiple tabs.

6.1.3 How to Copy & Paste

Usually, you copy and paste something using the keyboard shortcuts *Ctrl-c* (copy) and *Ctrl-v* (paste). But keep in mind that all formatting from the source is retained, thus overwriting the formatting in your document. To strip the formatting, Word provides a *Paste Special* function in the drop-down menu (select *Home – Clipboard – Paste – Paste Special...*) and the context menu (see *Paste Options*).

How to strip formatting As a rule, if you copied a text from another source, paste it as unformatted text (and don't forget to cite). You may automate this by selecting *File – Options – Advanced* in the category *Cut, copy, and paste*. We recommend using the setting *Keep Text-only* in the section *Pasting from other programs* to prevent formats from being taken over from other sources than Microsoft Word (see Figure 6.3).

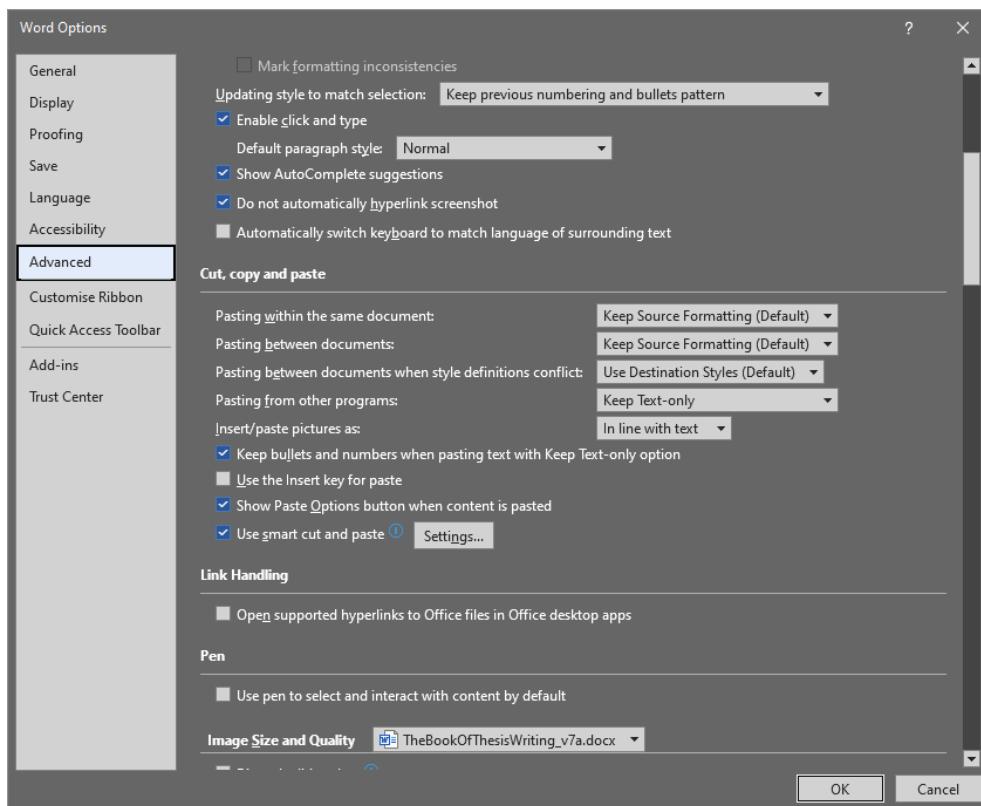


Figure 6.3 The *Options – Advanced* dialogue with copy and paste settings

6.1.4 The Navigation Pane

The *Navigation* pane helps oversee all headings that turn up in the table contents. It allows you to check the storyline, ensure consistent heading capitalisation, and identify lonely subchapters. You can also drag & drop entire

chapters; subchapters are included, and the numbering will update automatically. It additionally provides a search feature on top (Figure 6.4).

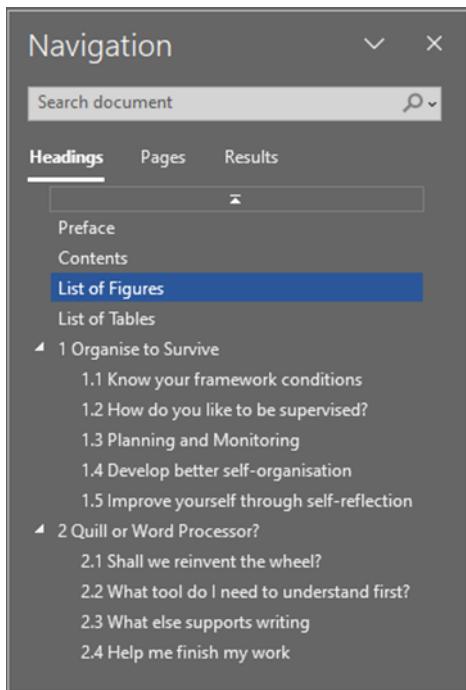


Figure 6.4 The navigation view

You open the navigation pane via the menu (*View – Show – Navigation Pane*) or by clicking the small area where pages or the number of words appear in the lower left of the Word window. If the view appears as a floating window, drag it to the right or left of the Word window to dock it.

6.2 PAGE LAYOUT

Your university usually predefines the page layout, like page margins, headers and footers, font type and size. If not, you can follow the recommendation in this subchapter. You will find the corresponding functions in the *Layout* tab.

6.2.1 Margins

Left and right margins should be about a quarter of the page width. For the DIN A4 page (21 x 29.7 cm), you could use 2.5 cm on each side. If the thesis should be printed, you need to reserve at least 1 cm on the left-hand side for the binding (so-called gutter margin) and reduce the left and right margins to 2 cm (see Figure 6.5).

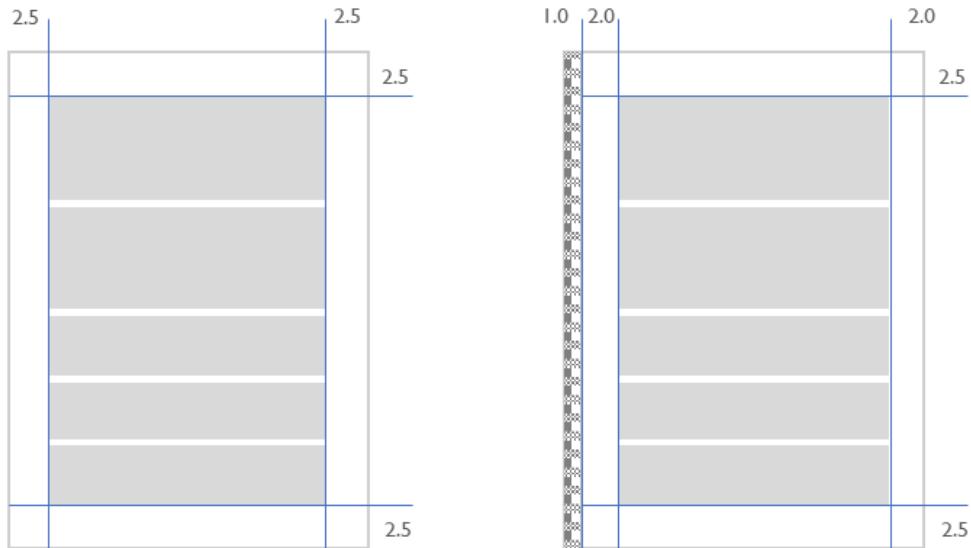


Figure 6.5 Typical margins of a document

6.2.2 Font Style and Size

Two font families are used: *serif* fonts and *sans serif* fonts. Serifs are the little extensions to a character that makes them look like handwritten text.¹⁴⁷



Figure 6.6 Serif and sans serif fonts

Since serifs help guide the eyes from character to character. A larger text is usually easier to read in a serif font. Therefore, they are the first choice for running text.

Short texts are usually easier to read in a sans-serif font. We use sans serif fonts to differentiate headings, captions, and tables visually from the running text. The preferred font for text occurring in figures is also sans serif.

¹⁴⁷ Although not confirmed, serifs may originally stem from ancient text carved in stone, where the serifs were used to neaten chisel edges. Serifs were later transferred to brush strokes (see Catich, 1968).

<p>Serif fonts are the first choice for running text. Serifs make the text easier to read since they guide the eyes from one character to another and resemble a handwritten text.</p> <p>A short text is easier to read with sans serif fonts.</p>	<i>Serif</i> <i>Sans serif</i>
---	---------------------------------------

Figure 6.7 Font styles

The recommended font size for serif fonts in DIN A4 is 11 to 12 points.¹⁴⁸ Since sans serif fonts often occur larger, they use a smaller font size of 10 to 11 points. Table 6.1 shows the recommended font sizes and paragraph spacings for three numbered heading levels, subheadings, and paragraphs.

Table 6.1 Recommended font sizes and paragraph spacings for default styles

Style	Example	Font size (pt.)	Spacing before/after (pt.)
Heading 1	Heading Text	16	24/6
Heading 2	Heading Text	14	18/6
Heading 3	Heading Text	13	12/3
Subheading	Subheading Text	12 boldface	9/3
Normal	Paragraph Text	12	0/6

6.2.3 Line Spacing

Microsoft Word measures the line spacing in multiples of the text height, which is about 130% of the font size. That is, a line of font size 10 points has a height of about 13 points. The recommended line spacing is between 1.1 and 1.2; otherwise, the text looks too tight or loose (see Figure 6.8).

¹⁴⁸ The font size is measured in points (1 pt. \cong 0.35 mm).

*Line spacing 1
(≈13 pt.)*

Font size and line spacing play crucial roles in enhancing readability and visual appeal in written communication. Font size refers to the relative size of the characters in a text, affecting how easily the content can be read. Line spacing determines the vertical gap between lines of text, influencing the overall appearance and readability of the content.

*Line spacing 1.2
(≈16 pt.)*

Font size and line spacing play crucial roles in enhancing readability and visual appeal in written communication. Font size refers to the relative size of the characters in a text, affecting how easily the content can be read. Line spacing determines the vertical gap between lines of text, influencing the overall appearance and readability of the content.

*Line spacing 1.5
(≈20 pt.)*

Font size and line spacing play crucial roles in enhancing readability and visual appeal in written communication. Font size refers to the relative size of the characters in a text, affecting how easily the content can be read. Line spacing determines the vertical gap between lines of text, influencing the overall appearance and readability of the content.

Figure 6.8 Line spacing of serif font size of 10 pt.

6.2.4 Paragraph Spacing vs. Indented Paragraphs

Paragraphs receive the default style (*Normal*), which is typically evenly distributed between the margins (justified) and automatically hyphenated. You can include spacing before or after the paragraph in the style definition to separate them. There is also an option to suppress such spacing if the preceding or following paragraph has the same style. Suppression is beneficial in lists consisting of short phrases. The paragraph spacing has consequences for the indentation on the first line.

You will often find paragraphs indented on the first line if they do not have additional spacing before or after. The reason is that we could not distinguish paragraphs from one another if the last sentence extends to the paragraph width (see Figure 6.9).

However, if you include spacing before or after paragraphs, indentation becomes redundant, and you should omit it.

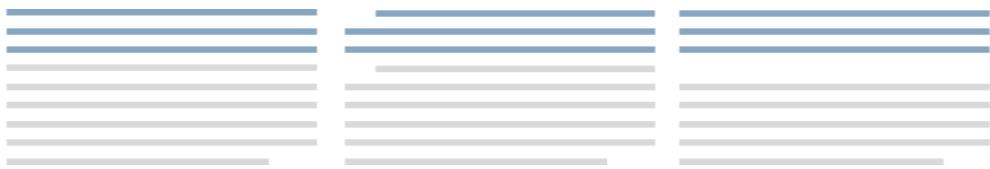


Figure 6.9 Paragraph without spacing (left), indentation (middle), and spacing (right). The dark paragraph extends to the text width and can only be distinguished from the following one by either indentation or paragraph spacing.

6.2.5 Headers and Footers

Headers on top of each page display document information, like the current chapter name. However, in documents of less than a hundred pages, headers are usually more disturbing than helping. The footer usually contains the page numbers, either centred or right-aligned. We create different page numbers for the front matter and body by using the so-called *sections*.

6.3 SECTION BREAKS

Besides pages, Microsoft Word uses *sections* that invisibly separate the document into parts. The advantage is that each section can receive its own formatting regarding orientation, headers, footers, and page numbering.

You will typically use section breaks for two purposes: (a) to create a page in landscape orientation for figures or tables that exceed the paragraph on a regular page, and (b) for different page numbering in the front matter and the body text. In both cases, you need a section break beginning on the next page (see Figure 6.10).

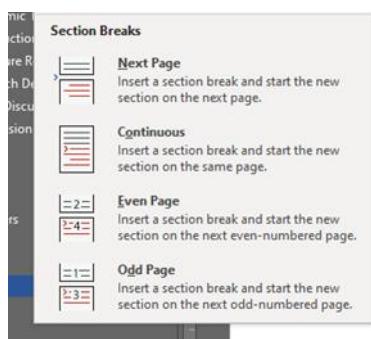


Figure 6.10 The section break dialogue in Microsoft Word (*Layout – Page Set-up – Breaks*)

Section breaks are only visible in the *Draft* view (*View – Views – Draft*). If you accidentally delete a section break, the formatting of the following section will be applied to the previous one. If you recognise it immediately, use the *undo* command (*Ctrl-z*) to revert it.

Be careful to not delete section breaks.

6.3.1 Creating Landscape Pages with Section Breaks

We use pages in landscape orientation to display figures or tables that exceed the paragraph width of the regular pages in portrait orientation. Since you are usually not allowed to exceed the paragraph width, fonts in figures or tables could be too small if they are squeezed into a page in portrait orientation. In this case, you create a section break before and after the figure or table, resulting in the layout shown in Figure 6.11.

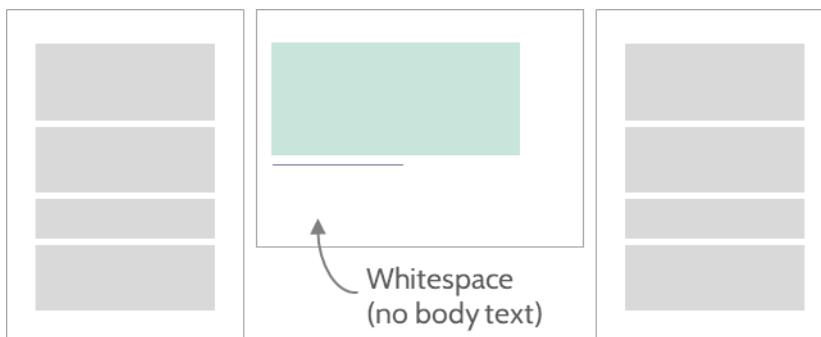


Figure 6.11 A text including a figure on a landscape page.

While a landscape page may contain multiple figures or tables, the blank space occurring behind it is not filled with running text.

6.3.2 Changing Page Numbering with Section Breaks

Imagine a printed book with mirrored pages. If we start counting pages, including the cover, an odd number always turns up on the right side, and if you open the book, all even page numbers turn up on the left-hand side. In book publishing, the book cover does not count as a page. That is, the page count starts on the first page, occurring on the right side. The left-hand page before (the inner side of the cover) is empty. In your thesis, you initially don't have a book cover; your first page is the title page. If you later print your thesis in a copy shop, they add a cover that is not numbered.

We distinguish between front matter (title page, listings), body (your text), and appendices. The front matter uses lower-case Roman numerals (i, ii, iii...) for page numbering. The body text restarts the page counting with Arabic numerals (1, 2, 3...) at 1.¹⁴⁹

¹⁴⁹ If your university defines the number of pages for a thesis, they usually refer to the body excluding the references.

Front page	Front matter	Front matter	Body	Body	Body	Appendix	Appendix
ii	iii	1	2	...	A-1	A-2	

Figure 6.12 Typical page numbering of a thesis

The back matter may either continue with the numbering of the body text or may restart on page one with another numbering format (for instance, A-1).

We achieve different page numbering with a section break beginning on a new page. If you insert a section break, the page number of the new section may continue from the previous section. To restart the numbering, double-click the footer, place the cursor in front of the page number, right-click, and select in the context menu *Format Page Number...* and *Number format*. Here, you can reset the numbering to begin with 1 (see Figure 6.13). Otherwise, select *Continue from previous section*. You may have to do this twice after each section break, but Microsoft Word will remember it and will do it automatically when you insert further section breaks.

Restart page numbering

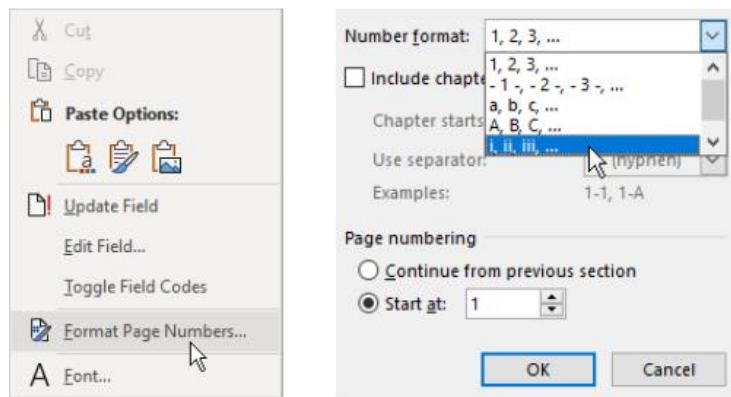


Figure 6.13 Changing the page numbering format

6.4 PAGE BREAKS AND EMPTY LINES

Page breaks may leave empty lines at the bottom of the preceding page. This is acceptable in two cases: (a) before the main chapters start on a new page and (b) after figures or tables in landscape pages. Any other page should fully use the blank space.

While working on your draft, a figure or table that does not fit the remaining space on the page will move to the next page, leaving blank space on the

previous one. The same applies when footnotes are used that do not fit the remaining space. This is not an issue with intermediate drafts.

However, the final layout should fully utilise the page without leaving empty lines. To achieve that, you move the paragraph following the figure or table to the previous page (or the other way round), as shown in Figure 6.14.

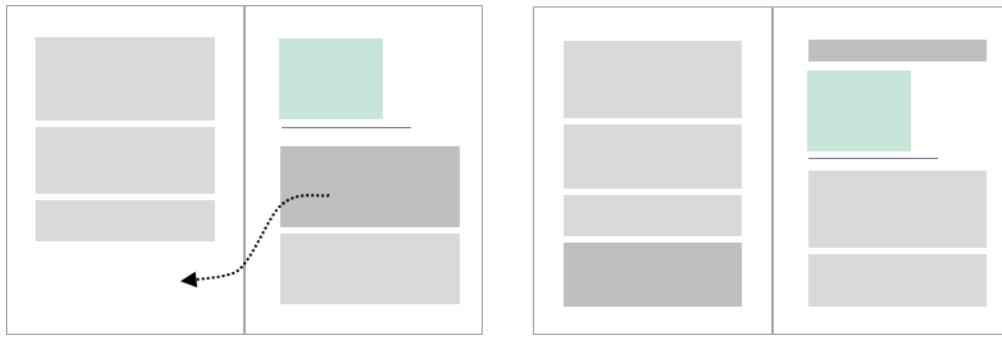


Figure 6.14 Filling the whitespace. The pages on the left show the draft with an empty whitespace left in front of the figure. The pages on the right show the dark paragraph moved in front of the figure.

Cross-reference

This requires you to refer to the figure number in the text (for example, *see Figure xx*) rather than just the position (*see figure below*). You can create cross-references that are automatically updated using the function *References – Captions – Cross-reference*. Cross-references can also refer to chapters, pages, footnotes, or any other numbered item.

6.5 HEADINGS

Headings announce the contents of chapters and are followed by text rather than another heading. The main chapters may begin on a new page; in this case, the corresponding style should include a page break.¹⁵⁰

Academic theses use numbered headings. The reason is that the author can refer to a chapter number in the text, making it easier for the reader to find that chapter.

6.5.1 Numbering and Subdivision

The default numbering uses Arabic numbers separated by full stops (for example, 1.2.1). Some universities expect to use letters for main chapters and

¹⁵⁰ In the style definition, select Paragraph – Line and page breaks – Page break before.

numbers for subchapters, like A-1.2; however, this format may be confused with appendices, which often use the same style.

Whatever format requirements exist, using more than three heading levels (for example, 1.1.2.4) is inappropriate if the thesis covers less than a hundred pages. Extensive chapter numbering complicates the table of contents and makes the references challenging to follow.

For further subdivisions, we recommend using unnumbered *subheadings* that do not appear in the table of contents. A subheading might be followed by a single paragraph.

Subheading

A paragraph ideally addresses a single aspect of a topic. If they are too small, they might not address the aspect sufficiently. If they are too large, they mix up multiple aspects. As a rule of thumb, paragraphs in theses should not exceed about 200 words or 20 lines; otherwise, they will be difficult to follow.

Paragraphs may include emphasis (like boldface or italics) on key terms that express the content of the paragraphs. Figure 6.15 shows all six levels of division.

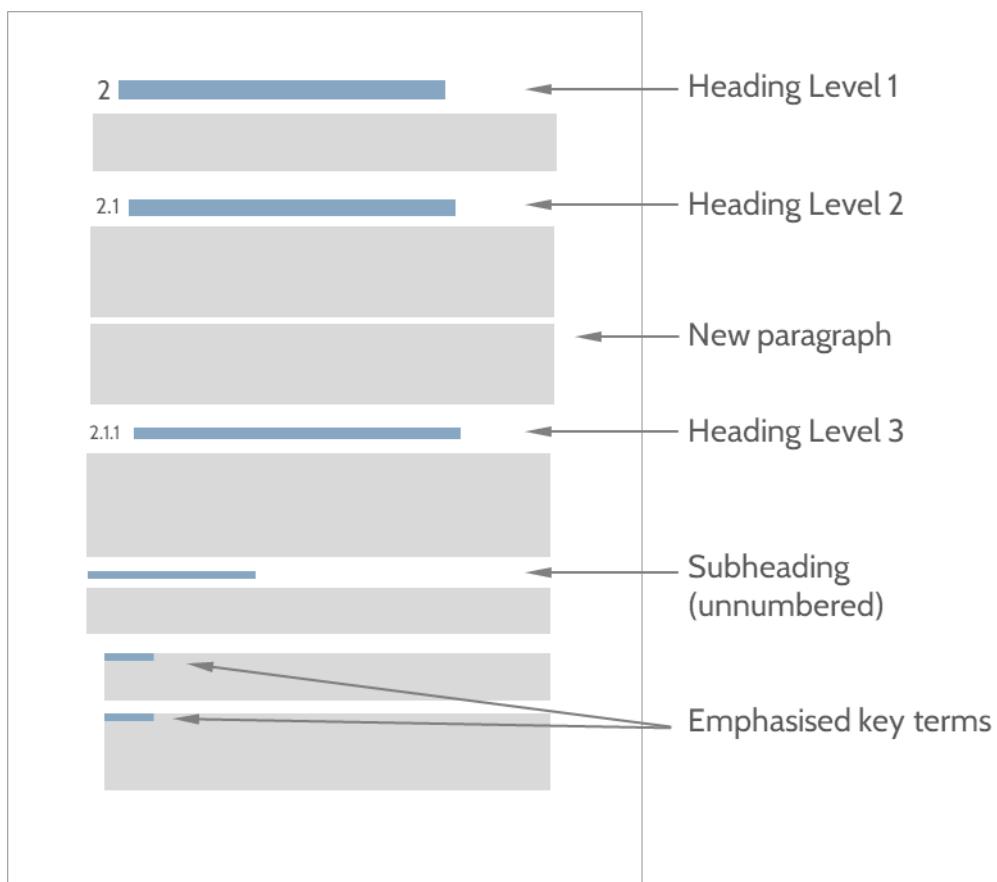


Figure 6.15 The six levels of division

Subchapters should never turn up isolated; for instance, subchapter 2.1 requires at least subchapter 2.2. You need to remove the heading if you don't have another subchapter. The same applies to unnumbered headings.

Avoid lonely headings at the end of a page in your final version. Make sure the headings contain at least two lines of text on the same page.

You can avoid lonely headings in the style definition. Choose *Paragraph*, click the tab *Line and page breaks*, and check *Keep with next*.

6.5.2 Capitalisation

Headings usually follow the same rules for capitalisation as the title: they may either begin with a capital letter (like a sentence):

2.2 Reasons for conflicts and their relationship to hierarchies

Title case capitalisation or are fully capitalised (the so-called title case capitalisation), where every word starts with a capital character except for articles, prepositions, and co-ordinating conjunctions:

2.2 Reasons for Conflicts and Their Relationship to Hierarchies

If your university does not specify the capitalisation of headings, decide on your own, but stay consistent.

6.5.3 Punctuation

The typical heading is an incomplete sentence appearing on an extra line and, therefore, does not contain a punctuation mark at the end. This is different if the heading is a complete sentence, for instance, a question.

Punctuation marks that occur within a heading can be a colon (or a dash) to separate a subheading and a comma to separate fragments:

- 2.2 Organizational Structure: Flat Hierarchies
- 2.3 Flat Hierarchies – A Case Study
- 2.4 Functional, Divisional, and Flat Hierarchies
- 2.5 Are Flat Hierarchies Better?

6.6 BULLETED OR NUMBERED LISTS

We use lists to itemise terms or short statements. We announce any list with an introductory sentence. The sequence or priority of statements defines the list type (bulleted, numerical, alphanumerical, or inline). Since international style guides are inconsistent, we show all options (Figure 6.16).

The easiest way to find out what punctuation is appropriate for an itemised list is to derive it from a common sentence structure. The following examples are self-explanatory since they use the described form.

If we have multiple related independent clauses (full sentences) and want to transform them into an itemised list, we can announce them with an independent clause followed by a colon:

- The introductory sentence is an independent clause.
- Each item ends with a full stop since it is an independent clause.

This list is an example.

If we begin with a dependent clause, we have multiple options in a sentence. We can have a run-on list that separates the first, second, and other items, like in this sentence.

<i>Inline form</i>	<i>Itemised form</i>
Independent clause ——. ——. ——. ——.	Independent clause : • ——. • ——. • ——.
Dependent clause —— item ——, item ——, and item ——.	Dependent clause —— • ——, • ——, and • ——.
Dependent clause ——: item ——, item ——, and item ——.	Dependent clause ——: • ——, • ——, and • ——.
Dependent clause ——: item ——, ——; item ——; and item ——.	Dependent clause ——: • ——, ——; • ——; and • ——.
Dependent clause ——: (a) ——, (b) ——, and (c) ——.	Dependent clause ——: a) —— b) —— c) ——
Dependent clause ——: (a) ——, ——; (b) ——; and (c) ——.	Dependent clause ——: a) ——, ——; b) ——; c) ——.

Figure 6.16 Types of inline and itemised forms of lists

The same can be done in an itemised list by

- continuing our sentence and,
- comma-separate the items (like in this list).

If we announce a series of items within a dependent clause, we can also use a colon followed by first, second, and third item.

The same applies to an itemised list, where we:

- introduce the list with a dependent clause and a colon, and
- list the comma-separated items (like in this list).

For items containing inner punctuation, we need to replace the item-separating punctuation with a semicolon and use inner punctuation in the items, as is shown in this sentence:

- the inner punctuation, such as a comma, in the items;
- semicolons to separate the items.

In case of a priority or sequence of items within a sentence, we can (a) announce the priority in the independent clause and (b) use characters in parentheses to separate the items. In the itemised form, we begin with an independent clause and just use the closing parentheses:

- a) We announce the list with an independent ending with a colon.
- b) We use characters to present the priority.

Since, in this case, the items are also independent clauses, they begin with an uppercase character and end with a full stop.

However, if the items are not complete sentences, they are typically lowercase and do not include full stops since the latter are only used in:

- a) complete sentences
- b) numbers

There is no consistent rule for whether incomplete sentences should begin with an uppercase character or not. Lowercase is usually appropriate if the items continue the introductory clause. Anyhow, the consistency within your document is more important than the list style. Consequently, we do not mix the styles described above.

If the items contain extensive text, consider presenting it as a series of paragraphs, as shown in the following.

The **introductory clause** announces the series of paragraphs and ends with a period. The indentation may be used to separate the paragraphs from the surrounding text. Bullet points are omitted since the paragraph breaks separate the items.

The **items** are emphasised in boldface or italics to distinguish the paragraphs. They can either be initial keywords followed by a colon or a period, or they can appear somewhere in the paragraph.

If a **priority** exists, it is announced in the introductory clause and can be emphasised by using prioritising terms, such as first, second, and third.

Figure 6.17. shows examples of the different forms. Again, document consistency is important; that is, you should select a style and stick to it.

Indented list with initial keywords	Paragraphs with initial keywords	Paragraphs with inline keywords
— .	— .	— .
— : — .	— : — .	— : — .
— . — .	— : — .	— : — .

Figure 6.17 Paragraphs using boldface keywords

6.7 FOOTNOTES AND ENDNOTES

Footnotes provide supplemental information, such as short explanations. You can use them if you feel the explanation would disturb the text flow:

In the case of hypothesis tests, the correlation coefficient¹² and the coefficient of determination were used to assess the magnitude of cause-effect relationships.

¹² We use Pearson's product-moment correlation, defined as the covariance divided by the product of standard deviations.

While footnotes turn up on the same page as the referenced text, endnotes may either occur after a main chapter or at the end of the text. Unless your university does not specify otherwise, we recommend using footnotes rather than endnotes to avoid the reader having to skim through different pages to find a footnote.

Footnote vs endnote

In disciplines like the humanities, individual footnote entries can cover an excursus and become quite long. They sometimes occupy more space on a page than the body text. In other disciplines, footnotes are typically short clarifications or refer to literature.

Word distributes large footnotes on multiple pages. If you want to force them to stay together, click the footnote text, right-click and select *Paragraph*, click the tab *Line and page breaks*, and check *Keep lines together*.

However, footnotes that do not fit the remaining space are moved together with the referencing text to the next page, leaving more empty lines on the previous page. The only way to avoid this is to reconsider their positioning.

Footnotes for Citations

Breaking a rule again

Although not consistently defined, we strongly recommend using footnotes for those citation styles that cite author's names (such as APA style) rather than publication numbers (such as IEEE style). The reason will become clear if we compare the following examples using conventional APA style:¹⁵¹

One study (Holschneider, Kronland-Martinet, Morlet, & Tchamitchian, 1990) employed the region-based neural networks introduced by Ren et al. (Ren, He, Girshick, & Sun, 2017), but reduced the processing speed by half. Another solution (Al Hajj, Lamard, Conze, Cochener, & Quellec, 2018) leveraged a convolutional neural network besides a simplified recurrent one. Zhao et al. (Zhao, Cai, Chang, & Cheng, 2019) suggested employing a *CNN Cascade* (Viola & Jones, 2001), comprising a sequential hourglass network (Newell, Yang, & Deng, 2016) and a visual geometry group architecture (Redmon, Divvala, Girshick, & Farhadi, 2016).

Apart from the unattractive word spacing due to the missing hyphenation of names, reading the text becomes painstaking. Although the available space for text is reduced when using footnotes for citations, the text is much easier to read without the citations:

One studies²⁴ employed the region-based neural networks introduced by Ren et al.,²⁵ but reduced the processing speed by half. Another solution leveraged a convolutional neural network besides a simplified recurrent one.²⁶ Zhao et al.²⁷ suggested an approach employing a *CNN Cascade*²⁸, comprising a sequential hourglass network²⁹ and a visual geometry group³⁰ architecture.

²⁴ (Holschneider, Kronland-Martinet, & Morlet, & Tchamitchian, 1990)

²⁵ (Ren, He, Girshick, & Sun, 2017)

²⁶ (Al Hajj, Lamard, Conze, Cochener, & Quellec, 2018)

²⁷ (Zhao, Cai, Chang, & Cheng, 2019)

²⁸ (Viola & Jones, 2001)

²⁹ (Newell, Yang, & Deng, 2016)

³⁰ (Redmon, Divvala, Girshick, & Farhadi, 2016)

¹⁵¹ The example is adapted from a master's thesis and reproduced with friendly permission of the author (Fazeli, 2021, p. 20).

6.8 EMPHASIS

The emphasis within the text helps the reader to identify key terms or distinguish running text from unique names. Boldface is useful to indicate key terms or the central aspects of a paragraph in consecutive paragraphs. Italics differentiate unique composite names (publication titles, institutional names, sayings) from the rest of the sentence:

3.2 Methods

The methods were selected according to their response potential to the objective in question and were undertaken according to their methodological assumptions.

A **survey** utilizing a questionnaire consisting of Likert, Likert-type, and semantic differential scales was used in a nomothetic approach to discover patterns in the affective, cognitive, and conative behaviour of sheep during critical incidents.

The selective **concealed observation** was used to reveal covert affective patterns that support the assessment of explanatory hypotheses resulting from answers to selected questionnaire items. Concealed observations complied with the rules set out in *The British Psychological Society Code of Human Research Ethics*, and participants were informed accordingly.

A general rule is to not use two highlighting styles, such as bold and italics, together. A single emphasis suffices.

We also recommend not using other emphasis, such as CAPITAL LETTERS, SMALL CAPS, or underlining in running text. As with emails, capitals are considered shouting, and underlining is a relic from typewriters where boldface and italics weren't available.

6.9 ABBREVIATED FORMS

Abbreviated forms shorten expressions that regularly turn up in your text. We distinguish between abbreviation, acronym, and initialism:

- An *abbreviation* is a short form of a word ending with a period, such as *dept.* for department or *approx.* for approximately. We avoid abbreviations in the running text whenever possible.
- An *initialism* combines a phrase's initial characters that we pronounce individually, like GDPR (General Data Protection Regulation) or VPN (Virtual Private Network).

- An *acronym* resembles an initialism but is pronounced as a word, like RADAR (Radio Detection and Ranging) or PIN (Personal Identification Number).¹⁵²

The plural forms extend with ‘s’ without an apostrophe. We use an apostrophe only if an abbreviation contains full stops (Ph.D.’s). However, using full-stops in initialisms is no longer prevailing; today, we commonly write PhD or PhDs. Unit abbreviations do not have a plural form (for example, 15 m, 12 kg).

Use of Abbreviated Forms

We introduce an abbreviated form on its first occurrence by writing out the phrase and presenting the abbreviated form in parentheses. In the succeeding text, we can use the abbreviation; however, we use them sparingly since they can hamper readability:

A convolutional neural network (CNN) is a deep learning algorithm. CNNs perform feature reduction and feature learning for surgical tool detection.

Academic theses usually present a list of abbreviations in the front matter. However, this does not evade writing out the full form on the first occurrence in your text. The list of abbreviations does not contain commonly known items, such as the common Latin abbreviations (see Table 6.2). Greek and Latin languages strongly influenced academic terminology. One of the reasons lies in the use of Latin and Greek in philosophy, which preceded the humanities, medicine, natural sciences, or engineering disciplines.

Another reason is that Latin and Greek languages offer comparably precise expressions. As a result, abbreviations of Latin expressions made their way into the academic literature, typical examples being *e.g.*, *i.e.*, *etc.*, *ca.*, and *vs.* Although accepted, the written-out form is usually preferred in running text as it eases the reading.

Some abbreviations (*et al.*, *cf.*, *sic*) have a special meaning for citations and are still in use. In older sources, we also find *ibid.*, *loc. cit.*, and *op. cit.*, which were used to refer to the same source previously cited. Most citation styles, meanwhile, discourage their use and recommend repeating citations. When using footnotes, a cross-reference of the previous footnote number suffices.

¹⁵² Periods in acronyms or initialisms (such as U.S.A.) are no longer encouraged by contemporary style guides.

Table 6.2 Latin abbreviations

	Latin	English	Remarks	Example
e.g.	<i>exempli gratia</i>	for example, for instance	preceded by opening parentheses, commas, or semicolons, and followed by a comma. ¹⁵³	Different statistics were calculated, e.g., mean, mode, and median.
i.e.	<i>id est</i>	that is	preceded by opening parentheses, commas, or semicolons, and followed by a comma.	This applies to the EU member states that exhibit a share in GDP of at least 10%; i.e., Germany, France, and Italy.
etc.	<i>et cetera</i>	and the other things	Extends an intuitively completable list. It is not used when beginning with 'such as' or 'for example' or 'like.'	All noble gases heavier than helium (neon, argon, etc.) solidify at atmospheric pressure.
ca.	<i>circa</i>	approximately	Expresses uncertainties in numbers.	The lunar distance from the Earth is ca. 385,000 km.
vs.	<i>versus</i>	against, as opposed to	Contrasts or compares items. Legal texts often use 'v.' or simply 'v':	The diagram shows pressure vs. temperature. The decision in the case Schrems v. Facebook Ireland Ltd.
et al.	<i>et alii</i>	and others	Represents two or more co-authors of a publication.	Born et al. described systems with single degrees of freedom.
cf.	<i>conferatur</i>	compare to	Suggests a comparison with another literature source. ¹⁵⁴	(cf. Miller, 2012; Jones & Felton, 2015)
sic	<i>sic erat scriptum</i>	thus it had been written	Indicates a literal adoption of the original text, including mistakes; embedded in square brackets.	Miller found that "Latin abbreviations [sic] are often misused."

¹⁵³ There is a debate about whether a comma should follow the abbreviation. British style guides often discourage using the comma; however, even in British English the succeeding comma is required in the written-out form (*for example* or *for instance*). Consequently, we recommend using the succeeding comma in both cases.

¹⁵⁴ In biology, cf. precedes a provisional a species, such as in *Formica cf. rufa*.

6.10 FRONT AND BACK MATTER

The front matter and back matter are the parts that occur before and after your body text, respectively. Your university typically predefines these sections. In the following, we address common elements, explain their meaning, and provide hints on how to avoid typical flaws.

6.10.1 Title Page

The title page of a thesis typically includes the thesis type, the degree achieved, the title, the author's full name, and the publication date. We do not number this page, although it counts as the first page of the front matter. Your university provides the title page layout, which may include a logo, the faculty name, the student number, the supervisors, or other details.

Titles are usually set in *title case*: every word begins with an uppercase letter, except for articles (*a, an, the*), prepositions (*as, in, of, to*), and coordinating conjunctions (*and, but, for, or*).

6.10.2 Abstract

The abstract is a summary of the thesis. Although the typical abstract consists of a single paragraph, we recommend using the more informative *structured abstract*, using labelled sections, such as:¹⁵⁵

- *Purpose*: the original intent of the study (one or two sentences)
- *Value*: the value of the study for the specified audience
- *Methodology*: the research approach used to investigate the subject
- *Key findings*: most essential outcomes
- *Conclusion*: high-level inference (what we have learnt)
- *Keywords*: a list of keywords for library catalogue entries in lower-case (except for abbreviations) and separated by a comma

Each label introduces a single paragraph and assists the reader in quickly finding the information of interest (see Figure 6.18).

An abstract does not include citations and may be redundant to parts of your text. You write it after you finalise your thesis.

¹⁵⁵ Medical journals introduced this concept (National Library of Medicine, 2018) and other disciplines increasingly adopt this useful idea.

Abstract

Purpose. The thesis investigates conflicts occurring in exceptional situations in distributed teams. It identifies the perceptions of team members and explores how behavioural patterns contribute to the occurrence and evolution of conflicts.

Value. The results support the decision-making for conflict resolution strategies in distributed teams. This allows project management offices to establish operational conditions and practices to detect, mitigate, resolve, or prevent upcoming conflicts at an early stage.

Research Design. The research utilises a survey to discover patterns in affective, cognitive, and conative behaviour. The concealed observation was used to reveal covert affective patterns. Unstructured idiographic interviews were conducted to confirm covert behavioural patterns revealed by concealed observation. Two semi-structured expert interviews were used for validation.

Key findings. Rigid team hierarchy and the diversity of the perceived severity of an exception delimit the degree of freedom in conflict management. Recurring affective patterns, such as collusiveness, seclusion, and accusation, as well as subsequent conative patterns of plan dogmatism and competence-grabbing, were found to be determinants of conflict escalation.

Conclusion. Recurring behavioural patterns that function as determinants of the emergence, evolution, and escalation of conflicts can be included in conflict management strategies to improve their effectiveness.

Keywords: distributed teams, team hierarchy, behavioural patterns, conflict resolution strategy

Figure 6.18 Example of a structured abstract

6.10.3 Declaration of Authenticity

The declaration of authenticity is a statement you need to sign with a hand-written (for printed version), scanned, or digital signature (for electronic versions). By signing this declaration, you confirm that you authored the thesis on your own and identified foreign sources clearly. It might also include a statement on previously published parts, an agreement for plagiarism check, or other legal terms. Your university defines the text, and it might either turn up in the front matter or on the last page. It is good advice to create this section in the first draft and insert your signature since forgetting it may invalidate your thesis.

6.10.4 Publication Disclaimer

If you published parts of your thesis before submission, you need to announce this to avoid a plagiarism allegation. You need to ask for permission if co-authors are involved. Anyhow, you still need a citation if you refer to your own publication in your text. The citation style should be the same as in your references.

6.10.5 Confidentiality Clause

A confidentiality clause (or lock flag) is a statement that aims to protect sensitive or proprietary information disclosed within the thesis document. It delimits access to certain persons (such as the supervisors and the examination office) and is typically part of a separate confidentiality agreement between the author and the contributing third parties. The university's library database will only make the title and keywords available to the public rather than the entire thesis. Your university regulates the details and provides a standard text for the confidentiality clause.

6.10.6 Copyright Permission

Using copyrighted material or any unpublished works created by a third party is covered by the copyright law of the country where the use takes place, usually where your university resides. In this case, you need to know who owns the intellectual property, what rights the owner declares to use the material for academic purposes, and perhaps ask for permission. In such a case, you would state the ownership in this section.

Most national regulations allow the use of a limited amount of published foreign intellectual property for educational or research purposes; usually, short excerpts or quotations from prior works presuppose they are cited. In case of doubts, contact the legal department of your university.

Special open-source licenses, like the *GNU General Public License* (GPL) and the *Creative Commons* (CC) licences, define attribution, non-commercial use, allowed derivatives or adaptations, and the terms under which adaptations must be shared.¹⁵⁶

*You still need to cite
public-domain content.*

You don't need copyright permission for material in the public domain or published under public-domain-equivalent licenses (such as CC0 or

¹⁵⁶ More information can be found the license web sites, such as <https://www.gnu.org/licenses> and <https://creativecommons.org>

Unlicensed). Although the license terms might not require attribution, you still need to cite any contribution that is not your own in academic works.

However, remember that material being available online is not necessarily in the public domain; it may have been simply posted without the consent of the copyright holder. You need to find evidence.

Public availability is not public domain.

Avoid using brand names if not required. For instance, instead of writing *Google*, write *search engine*. If brand names are required, state their full name in the same capitalisation (*ChatGPT*) and distinguish between the brand name (*Mercedes-Benz*) and the company name (*Daimler AG*). Trademark symbols are usually not required unless the thesis serves a commercial purpose or explicitly deals with trademarks.

6.10.7 Dedication

The dedication is an optional page with a single phrase (for example, ‘To my parents’) or a short statement to dedicate the work to someone to whom you are close. It is typically without a heading and uses a larger font size.

6.10.8 Acknowledgements

The acknowledgements section is a short paragraph used to express your gratitude to supporters or contributors of your thesis. It usually includes your supervisor¹⁵⁷ and persons or institutions supporting your thesis financially, with an internship, by mentoring, or by providing raw data, equipment, survey participants, or interview partners. You would also thank persons for contributing to discussion, evaluation, review, or writing. Finally, you may acknowledge people from your personal surroundings who supported you mentally or financially, like your family or friends.

6.10.9 Preface

The preface is an optional introductory text written by the author, typically addressing the motivation for authoring the thesis. The preface is signed by the author’s name, place, and date.¹⁵⁸

¹⁵⁷ Assuming the supervisor contributed something beyond just grading your thesis, for which he or she is paid anyway. On the other hand, if they supported you particularly well, it is a good idea to mention this explicitly.

¹⁵⁸ Don’t confuse *preface* and *foreword*. A foreword is an introductory essay written by another person about a book.

6.10.10 Table of Contents

The table of contents (TOC) lists the chapter headings and page numbers. Your word processor will create it automatically by referring to the corresponding heading styles (like *Heading 1* and *Heading 2*) and their occurrence on a particular page. That is, if a heading does not turn up in the table of contents, you probably applied the wrong style and can correct it by reapplying the style and updating the TOC. Make sure the heading ‘Table of Contents’ or ‘Contents’ itself does not appear in the TOC; that is, do not assign a heading style to it.

6.10.11 Listings

Listings cover figures, tables, equations, and abbreviations. Most word processors create such lists automatically from predefined text styles for figure captions, table captions, and equation numbers.

The list of abbreviations shows the abbreviations and acronyms occurring in the text. For a few abbreviations, it is easier to create them manually, using a tab between the abbreviation and its written-out capitalised form. Sort this list alphabetically and exclude common Latin abbreviations, such as *e.g.*, *ca.*, *i.e.*, and *etc.*.

If you use many abbreviations, consider using the marker function (*References – Index – Mark Entry*) to mark the abbreviation in the text and create the list using the corresponding index function (*References – Index – Insert Index*).

6.10.12 Back Matter

The back matter is anything that follows your body text. It includes at least the literature references and may be extended with appendices or a glossary.

References

The references list the literature cited in the text and turn up on a new page after your concluding chapter. We distinguish between *References* and *Bibliography*, the latter of which includes sources which are not cited in the text but provide additional information to the reader. Bibliographies are usually used in books. In theses, references are sufficient.

Use a bibliographic add-on or Microsoft Word’s built-in bibliographic tool to generate literature references. The tools automatically format the references based on a chosen citation style. Keep in mind that the references might not contribute to your page count.

Appendices

The optional appendix contains information that you refer to in the body text without showing it. Examples are statistical details, extensive tables, source codes, questionnaires, or interview transcripts. The appendix may use different numbering in headings (such as *Appendix 1*) and pages (such as *A-1*). If no specific requirements exist, we recommend keeping the standard page numbering and using prefixes (like *A-1*, *A-2*, *B-1*) for the appendix chapters.

Glossary

An optional glossary presents specific terms and their linguistic or conceptual definition. Although not a typical part of a thesis, your university or supervisor might request it if you use extensively special terminology. Otherwise, leave it out and provide the necessary definitions in your text.

7 A MATTER OF STYLE

To say that science and language are like cat and mouse would be doing the mouse wrong.

Academic writing is a matter of writing comprehensibly. On the one hand, clear terminology and precise expression are necessary to prevent misunderstandings. On the other hand, cultivating a sophisticated and (seemingly) scientific style is counterproductive.

A challenge for every author is grabbing and maintaining the reader's attention. But here is an advantage of academic style: we don't need to author a novel. All these rhetorical nuances a novelist needs to consider – like setting a mood or creating an intriguing character – are not required. Rather than creating emotions or using elaborate expressions, we have a single goal: providing valuable and comprehensible information *with each sentence*.

This chapter addresses options to find a way in the middle between precise expression and intriguing style.

7.1 THE TROUBLE WITH THE BEGINNING

We phrase an introductory sentence to acquaint our reader with the upcoming topic – whether at the beginning of the thesis or the beginning of a chapter. Sometimes, there is the misconception that we must take our readers at hand and carefully guide them from the most general perspective to the details. However, readers tend to become impatient if they deem things unim-

portant or not understandable. Suppose we open a thesis about communication technologies and read the following:

1. Introduction

A bad introduction

The age of communication has arrived, which is both a curse and a blessing. Communication is becoming increasingly important in our society, transitioning from the industrial society of the 20th century to the information and knowledge society of the 21st century. Oxford Reference Online defines communication as "The result of any action (physical, written, or verbal) that conveys meanings between two individuals."

Let us go through this introduction sentence by sentence:

The age of communication has arrived, which is both a curse and a blessing.

If you think about what information we obtained, its value is zero. The second sentence is equally informative:

Communication is becoming increasingly important in our society, transitioning from the industrial society of the 20th century to the information and knowledge society of the 21st century.

At that point, we already might lose interest in reading. If we give it a further try and read:

Oxford Reference Online defines communication as "The result of any action (physical, written, or verbal) that conveys meanings between two individuals."

we might increasingly struggle with an upcoming coma. Our remaining consciousness might just be enough to put the thesis aside and turn to more pleasant activities, like watering the plants or chatting with the neighbour's cat. Now, you can imagine how supervisors might spend their day.

Admittedly, this is a naughty beginning. But we like to emphasise a fundamental effect here: if your text contains multiple sentences without information gain, you lose the reader's attention. And you can imagine how this impacts the grade of your thesis.

And yet, it is so simple (and with less effort) to create a meaningful statement: take a step back and think about what you want your actual message to be. Let's say we want to focus on deficiencies in digital communication. It makes sense to think first about a characteristic of personal communication; for example, that language is always insufficient for conveying our thoughts.

We could use this as a starting point and write:

1. Introduction

A deficiency of human communication is that we cannot participate in the reality of our communication partner. We are imprisoned in our own minds, and our language does not even come close to conveying our thoughts. That does not change when we use digital technologies; in fact, digital communication may contribute to personal alienation.

A factual yet engaging introduction

Proficient academic writing means that each sentence contains meaningful information, in particular, the first sentence in a paragraph. Although we begin an introduction with a general statement, it must provide something of value. In that sense, the opening paragraph of a scientific topic is more of a short story than a novel. Table 7.1 shows examples of poor introductory phrases.

Table 7.1 Introductory statements and what your reader might think.

The introductory statement...	...and how your reader might perceive it.
Since the beginning of time ...	Since the big bang?
In today's world, ...	Was it another world yesterday?
Nowadays, we find ourselves...	...sitting in front of a boring thesis?
The age of ... arrived, ...	Once upon a time, in a lab far, far away...
This thesis covers ...	Ah, that's a thesis?
This study is aboutwhat we read in the title? Really?
It is important to mentionthat other things mentioned are unimportant.
In many situationsI become bored.
It is well known ...	That's why I know it, too.
It is necessary...	...to prepare for a tedious reading?
Obviously, ...	Why state the obvious?
Undoubtedly ...	Is anything ever beyond doubt?
Needless to say ...	Then it should not be said.
"[deep thought citation]"	Nothing you have to say yourself?

7.2 HOW TO WRITE A TRANSITION

A question that regularly turns up is how to write a transition from one chapter to another. The answer is simple: don't be redundant. While it might

make sense to remind the reader of something written several chapters before, it is useless to regularly announce at the end of a chapter what will come up in the next or reference at the beginning of the next chapter what was said before:

Meaningless transitions

2.2 Nonverbal Communication

In the previous chapter, the psychological theories underlying communication were described. This chapter focuses on nonverbal communication in specific social settings. ...

This chapter provided insights into nonverbal communication. The next chapter describes types of nonverbal communication.

2.3 Types of Nonverbal Communication

As mentioned in the previous chapter, nonverbal cues play an important role in communication. This chapter subsequently describes ...

...how to bore the reader to death? If you mentioned it in the previous chapter, why would you deem a reminder necessary?

For sure, you need to link chapters, and ideally, the reader can anticipate the following chapter because of the end of the previous one. But you don't always need a transition. Let's say you use the following structure:

2.3 Types of Nonverbal Communication

2.3.1 Facial Expression

2.3.2 Eye Contact and Gaze

2.3.3 Body Language and Gesture

A transition makes sense from chapter 2.4 to subchapter 2.4.1, where a general part narrows down to a specific part. And that could look like this:

2.3 Types of Nonverbal Communication

... of different nonverbal cues, which are described in the following subchapters.

2.3.1 Facial Expressions

Human faces are capable of a remarkable variety of expressions ...

This is a forward transition; there is no need to refer from the subordinate chapter 2.4.1 back to the superior chapter 2.4. A transition between the 3rd level chapters is useless if they address independent aspects. In this case, your reader would not expect any connection beyond the fact that they all belong to the superior chapter.

If a connection exists, a transition might be useful. In our example, we can connect chapters 2.4.1 and 2.4.2 because eye contact plays a role in facial expression. But again, the transition is forward and simple:

2.3.1 Facial Expressions

... and the expression of a face is supported by eye contact.

2.3.2 Eye Contact and Gaze

From the moment we engage in social interactions, our eyes become part of the unspoken connections ...

Transitions are reasonable only if their argumentative flow is a) forward, b) from a superior to a subordinate chapter, and c) between chapters of the same level if the following chapter depends on its predecessor.

7.3 LONESOME HEADINGS

While headings help you to structure your text, for the reader, they are supporting elements rather than part of your sentences. That is, if you leave out the heading, the introductory sentence must still be complete, which is not the case in this example:

2.3.3 Body Language and Gestures

Both become part of the unspoken messages that ...

Headings are not part of a paragraph.

If you remove the heading, the sentence does not make sense anymore. Simply repeating the heading in the succeeding text would be redundant, but you could write:

2.3.3 Body Language and Gestures

Movement and posture of the body become part of the unspoken ...

Another consequence is that consecutive headings without intervening text may become meaningless:

*Meaningless
consecutive headings*

2.4 Reasons for Misunderstanding

2.4.1 Hierarchy

Several studies discovered adverse effects of a flat hierarchy on...

Consecutive headings force the reader to interpret the heading as part of your message. The upper example misses the message: the reader might ask why you begin with hierarchy when discussing misunderstandings. We always create a heading followed by text that extends the heading with its meaning for the succeeding paragraphs:

2.4 Reasons for Misunderstanding

The cause of a misunderstanding may have its roots in diverse business-specific settings. The following subchapters address three central phenomena affecting business conflicts: hierarchy, communication, and qualification.

2.4.1 Hierarchy

Several studies discovered adverse effects of a flat hierarchy on...

7.4 HEADINGS AND EXPECTATIONS

Headings do not just inform the reader about the upcoming text; they also raise expectations. If you do not meet these expectations, you disappoint your reader. Imagine we write a subchapter that addresses the value of our study and the audience, and it begins like the following:

Missing the expectation

1.2 Value and Audience

This study investigates conflict resolution strategies in distributed teams and establishes a model to determine the impact of an exceptional situation on conflict evolution. A situation is termed ‘exceptional’ if the team members interpret it as decisive, uncertain, risky, or critical...

The issue here is that the heading announces two subjects, and none of the first sentences address them. Your reader may be reading this chapter just to find out if the study is of value to her or if she is part of the target audience. And she will be disappointed. And she will be disappointed.

If you decide on a heading, ensure you address the expectation immediately in the first sentence and stick to the sequence announced in the heading:

1.2 Value and Audience

The results of this study support the decision-making for conflict resolution strategies. By establishing a model that accounts for the impact of an exception on conflict evolution, the selection of proactive measures in conflict management is simplified.

Such a model allows team leaders, project and program managers, and project management offices to establish operational conditions and practices to detect, mitigate, resolve, or prevent upcoming conflicts at an early stage.

value statement

audience statement

7.5 USING PARAGRAPHS

You divide your body text into paragraphs, each separating ideas, aspects, or perspectives from one another. The line break at the end of a paragraph denotes a significant pause in the flow of argumentation.

You begin with a new paragraph if you change the perspective or address a different aspect. However, a paragraph should contain at least two sentences to avoid fragmented text. An example of a paragraph break is:

The reliability of the results was assessed via comparison with results from studies from European populations. Reference data were partially taken from Gulf Coast Native populations of the United States in cases where adequate data from EU countries were not available.

The validity of the results from idiographic interviews was examined with pilot studies and by comparison with variables that are assumed to be known as related to the construct.

A change in perspective

7.6 STYLISTIC EPISODES

Using an inappropriate writing style may detract from your message. It is crucial to identify and avoid these pitfalls to maintain readability and convey your ideas. This chapter will address typical cases of stylistic pitfalls.

7.6.1 About Trivialities

You can assume that your reader has a decent educational background, is proficient in scientific research, and has at least some knowledge of your topic.¹⁵⁹ So you don't have to explain terminology that is common in the field of research, such as the *key performance indicator* in economics, the *Pauli principle* in chemistry, *method acting* in performing arts, or the *Gettier problem* in philosophy. Ask your supervisor if you are unsure about what to explain and in what level of detail.

You should also refrain from stating trivialities that every fellow on the street would be able to conclude. It becomes particularly critical if trivial statements are phrased in a patronizing style:

We need to remember that poor product quality reduces customer satisfaction.

Before we address the research design, we must understand the concept of paradigms.

A good structure provides authenticity to the research methodology.

I begin with simple examples for those who are new to the field.

With such statements, you may inadvertently step onto the reader's academic toes.¹⁶⁰ Good scientific writing means communicating straightforwardly. A proficient author would not write:

We must consider that political unawareness poses a significant risk for contemporary leadership.

if the plain message is:

Political unawareness poses a risk for leadership.

Plain scientific writing avoids exaggeration and overuse of sophisticated terminology. Finally, you want to convince the reader about the value and relevance of your statements. Being concise improves clarity and creates space for more sophisticated arguments and evidence.

However, some authors attempt to impress their readers with pompous and seemingly scientific phrases, thereby merely unmasking their inability to grasp the essence of a statement. Let us demonstrate in an excursus how this works.

¹⁵⁹ You also wouldn't read a thesis on quantum theory if you don't have a clue what it is about.

¹⁶⁰ For risks and side effects, read this package insert and consult your professor.

Excusus: From a Simple Idea to an Impressive Statement

Suppose we wrote:

Project managers plan, organise, and control projects.

If we feel it sounds a little unpretentious, we replace the verbs with nouns:

Project managers are responsible for creating plans, establishing a project organization, and controlling the project's results.

Then, we replace some nouns with more extensive paraphrases:

Leaders of business projects are responsible for the design of process chains, for establishing a structured organization, and for ensuring the project's results are controlled in terms of expected outcomes.

Next, we arbitrarily distribute meaningless adjectives and prepositions:

Competent leaders of business projects are particularly responsible for the conceptual design of reliable process chains, for establishing a well-defined structure and combined organizational effort, and for ensuring the specific project's results are carefully controlled in terms of expected deliverables or results.

Now we anonymise the contents:

The area of responsibility of competent leaders in the field of business project management is their particular responsibility for the conceptual design of reliable process chains and extends to the establishment of a well-defined structure and combined organizational effort in order to incorporate measures of insurance concerning specific project results, whose control is carefully considered in terms of expected deliverables.

We are getting close. We just need to add some buzzwords:

The area of responsibility of competent leadership personnel in the field of strategic as well as operative management of projects, programs, and project portfolios – besides an inherent liability for the deliberate conceptual design of reliable and reproducible process chains – extends to the establishment of a well-defined structure and combined organizational efforts in order to incorporate consistent and coherent assessment of the status quo for their validity concerning strategic project's objectives, whose control is carefully considered in terms of regulative de-jure and de facto standards as expected by the corresponding project stakeholders and the company's financial shareholders.

There you go!¹⁶¹

¹⁶¹ The next time you come across a similarly sophisticated statement, keep calm, put the source aside, and add the author of such a literary elegy to your personal blacklist of linguistic villains whose contributions don't deserve wasting your time.

7.6.2 Appropriate Terminology

Sometimes, we mix up a *thesis* with a *hypothesis*, a *complex* with a *complicated* system, *stochastics* with *statistics*, and *methodology* with *method*. This can happen if words sound similar, and it is usually not a big issue if it occurs occasionally.

However, similar-sounding words can also change the meaning drastically. Try to replace the 16 inappropriate words in the following text:

A wording exercise

This study aimed at systemically investigating the role of the Scrum Master. We lied out that the role incorporates specific principals of leadership that insure a successful determination of a project. Further threads were disclosed that effect the Scrum Master imminent role, not only as mediator amongst Scrum teams during critical incidence, but also as advocate of cooperate agile transformation. By complimenting these findings with passed experiences of project personal, factors were found that bare the risk of impeding the coarse of a project.

More alarming is the regular incorrect use of terminology; for instance, if *microeconomics* becomes a *theory* rather than a discipline or if *HTML* becomes a *programming language* rather than a markup language. Readers interpret such misconceptions as evidence of the author's lack of proficiency.

The use of special terminology depends on the target audience. If we write for a general scientific audience, we generally avoid excessive technical jargon. If writing for experts, we can use specialized terminology that is appropriately defined, but we should find a balance between technical detail and simplicity.

7.6.3 Redundancies

A famous ending of German fairy tales is: "...and if they didn't die, they are still alive today".¹⁶² That sentence is an example of what linguists call a *tautology*, an inner redundancy, occurring because *didn't die* and *still alive* mean the same.¹⁶³ Such redundancy also occurs if we qualify a term or expression with a word that represents the inner meaning of the term, such as a *round circle*.

¹⁶² In German: 'Und wenn sie nicht gestorben sind, so leben sie noch heute', resembling the English phrase 'And they all lived happily ever after'.

¹⁶³ In logic, the term *tautology* refers to a statement that is necessarily true due to its logical form, such as 'To be, or not to be'.

Tautologies serve a purpose in novels, poems, or lyrics, where they create an emotional response. In academic texts, we avoid them. Can you find the 27 tautologies hidden in the following fictional sentence?

While during the global pandemic, there once was the false misconception that an individual person would be at risk only in close proximity to the original source of the localised epidemic, early premature test trials showed rapidly fast that the growing increase was first and foremost due to the worldwide globalisation, which was the causal reason for the disseminating proliferation, leading to the evident insight that artificial vaccines and natural immunisation having both the same effect and are not just inevitable necessities, but eventually end to be the ultimate solution to delimit the boundaries of the disease to finally terminate such ubiquitous pandemic.

A tautology exercise

Sounds impressive, doesn't it?¹⁶⁴ Unfortunately, it is overloaded, distorts the message, and could be reduced by 30% without losing information.

Another type of redundancy is called the 'RAS syndrome', which occurs with acronyms.¹⁶⁵ What is interesting about this term is that it already explains its meaning: RAS stands for *redundant acronym syndrome*, making the term 'RAS syndrome' the *redundant acronym syndrome syndrome*.

The RAS syndrome

The RAS syndrome occurs if the acronym (or initialism) is followed by the written-out form of its final letter. Examples are:

AC current	HTML language	NFC communication
ATM machine	ISO organization	PDF format
B2B business	ISBN number	PIN number
BMI index	JSON notation	QM management
COVID disease	KPI indicator	RAM memory
CSI Investigation	LCD display	RFID identification
DC current	LED diode	SARS syndrome
GIF format	LLC company	SONAR ranging
HIV virus	NASA administration	UNICEF fund

7.6.4 Metaphoric Excesses

A metaphor is an expression that implies a resemblance to something beyond the context of the literal meaning of a word or phrase. Examples are *cloud computing*, something *in a nutshell*, or the *coming out*.

¹⁶⁴ If you feel you heard something similar before, it's probably because you listened to a politician's speech.

¹⁶⁵ The term was coined in an article of the British journal *New Scientist* (New Scientist, 2001)

Metaphors are not uncommon. They are fundamental rhetorical figures that found entrance into our everyday language, sometimes unnoticed (did you recognise the three metaphors in this sentence?).¹⁶⁶ They create associations to facilitate understanding. But they can also obscure a message if overused and turn it into a pointless marketing text (find 22 metaphors):

A metaphor exercise

In the digital landscape, cloud computing emerges as a radiant service, expanding the technological horizon to a boundless universe. It orchestrates a symphony of virtual resources, harmonizing storage, processing power, and software. Cloud services leap from server to server, seamlessly delivering their offspring to a thankful community. It bestows upon businesses and individuals the power to soar to new heights of sharing, unleashing their joint creative spirit. However, while cloud services are a flourishing business embracing all digital assets, they pave the road to the World Wide Web's very heart of user privacy and turn it into a discounter full of bargains for cybercriminals.

We use metaphors sparingly and phrase them carefully. While they are rarely adequate in argumentation, they can emphasise conclusive statements. The following example shows a final statement from the conclusion of an academic essay,¹⁶⁷ where the metaphors are well-placed and appropriate:

Metaphors are used appropriately.

Stakeholders must realise that the Galápagos Islands are more than just the place where Darwin developed his theory of evolution. It is more than a brand of a diverse country. It is a World Heritage site that is home to a variety of rare animals. It is a living laboratory struggling to survive the impact of climate change and tourism. And if residents, government, and industry fail to reconcile their interests with preserving this environment, it would mean the end of precious natural habitat.

This example is what we call a *demand statement*, used to raise awareness and provoke further debate.

7.6.5 A Very, Very Important Rule

An adverb often qualifies another adjective, making it more specific. However, if the adverb is an intensifier, it may exaggerate the adjective's meaning beyond its purpose.

¹⁶⁶ fundamental (construction basis), figures (illustration), entrance (doorway)

¹⁶⁷ adapted from (Velasco, 2015, p. 8) with friendly permission of the author.

A typical example is the adverb *very*,¹⁶⁸ and an issue occurs if the corresponding adjective does not fit the intuitive comparison. While a *very big* elephant makes sense since we intuitively compare it to different animal sizes, a *very big* challenge does not since the intuitive comparative of size is missing.

The same applies if the adjective following the adverb is a conceptual one which is not intuitively measurable. Compare *very large* with *very important*. While *very large* is a comparative statement, *very important* is not. You can still use *more important* to distinguish multiple important things or *most important* to indicate the highest, but *very important* does not provide any meaningful hint about the level of importance.

Linguists call such combinations that lack information gain a *pleonasm*,¹⁶⁹ which is something you want to avoid. Try yourself whether you can find the 20 pleonasms in the following (fictional) sentence:

It is very important to note that quantum theory – despite of being really complicated – is tremendously successful in describing quite complex systems, each and every one of which is generally considered completely unpredictable. Physicists fully agree upon that quantum theory is not just limited to highly sophisticated problems but has absolutely proven to be extremely useful for perfectly describing the observable macroscopic world. However, if its assumed premises would turn out to be essentially wrong, it would ultimately render the theoretical concept entirely useless and vastly overrated.

A pleonasm exercise

7.6.6 Getting it Right

The verb *get* has many meanings in informal speech, such as *obtain, buy, earn, acquire, receive, fetch, and become*. Therefore, we recommend replacing the word with a more appropriate one. Try to find the 24 occurrences of *get* and its analogues in the following text:

Getting a university degree is essential for success. A university education not only opens opportunities to get a better job, but you also get more proficient by getting the skills and knowledge that you need in everyday life.

A get exercise

¹⁶⁸ Pulitzer Prize winner William Allen White already stated in 1935: „Never use the word, ‘very.’ It is the weakest word in the English language; doesn’t mean anything.” (White, 1935)

¹⁶⁹ *wordiness* can also be considered a synonym for *pleonasm*, as it refers to the use of more words than necessary to express an idea, making a sentence or phrase overly complicated.

You may get into believing that topics like mathematics or science are complicated to get. In fact, it takes a while to get into the topic, but the more you get down to the learning, the more you get to like it. If you need to get help on a topic, you could get a more proficient student who can help you with getting better insights. However, you should not get this for the ultimate solution to get a deeper understanding. To memorise things in the long term, it is good advice that you get ahead to regularly explain things you already got to those fellow students who are still in need to get support.

After you get your university degree and get out of the university, you will get practical experience. You can still decide later to get your studies extended. With a higher degree, you get on the way to get promoted to higher positions that get the driver for your further professional career.

7.6.7 Absolutism

One of the ethical principles of science is honesty. An honest scientist must admit that searching for absolute truth is not his duty. Absolute truth – if it exists – might be a topic in a metaphysical debate, but scientists try to explain sensory impressions or mental constructs to create a coherent system. A scientist is also aware that any result can be reduced to absurdity simply by questioning its assumptions.

Consequently, scientists would not claim that they *always* use a method, call it *extremely* useful, or the *best* because they are self-reflective enough to refrain from such absolutism. Using such words or similar exaggerations regularly can turn an informative text into a biased passage. The following paragraph about artificial intelligence demonstrates this (find 14 exaggerations):

An absolutism exercise

Recent advances in the field of artificial intelligence (AI) have been nothing short of revolutionary. AI has made unmatched progress in an awesome range of applications, from natural language processing to robotics and autonomous driving. AI systems have become extraordinarily sophisticated and perform the most complex tasks with unsurpassed accuracy and speed. Consequently, AI has become an inextricable part of our life. The unprecedented potential of AI is truly astounding, making our lives exceptionally easier and considerably more efficient and paving the best way for us to make unprecedented decisions for the brightest future.

While these statements may appropriately describe the potential of AI, they unveil the author's close emotional connection to the topic. They leave the impression that this technology only positively affects our lives and, therefore, misses the objectivity and critical notion required for scientifically valuable statements. Even non-experts know that any technology that makes

our lives easier comes at a cost. Try to rephrase the above statement into a reasonable scientific one.

7.6.8 Relativistic Considerations

Instead of discussing Einstein's theory of relativity, we want to talk about rhetorical and contextual factors that govern the arrangement of statements within a text, enhancing its persuasive power and clarity. The relative position of statements in texts may impact the overall meaning. Compare:

Management decided a month later to revise the policy.
Management decided to revise the policy a month later.

Although similar, the sentences differ in their meanings. In the first sentence, management made the decision a month later. In the second sentence, management decided to do the revision a month later.

The importance of relative position becomes clear with conjunctions:

A balloon is a harmless toy for a child unless it explodes.

Poor child. The intended meaning was probably:

Unless it explodes, a balloon is a harmless toy for a child.

Another example:

Particularly at risk are the personal data of superiors since their state is critical.

While this might be true for some superiors, it is the data in a critical state rather than the superior. Misunderstandings can also happen with dependent clauses joined by pronouns:

A problem arose with colonisation that has not yet been overcome.

What is not overcome? The problem or the colonisation? We would intuitively assume that the *that* relates to the latter noun, but the unambiguous version would be:

Colonization has raised a problem that has not yet been overcome.

7.6.9 Use of Conjunctive Adverbs

Scientific reasoning often uses conjunctive adverbs to combine two clauses into a logical chain of arguments. Table 48 shows how we use conjunctive adverbs for different types of reasoning.

Table 7.2 Reasoning and corresponding conjunctive adverbs

Reasoning	Adverb	Meaning	Example
Conclusive	thus	in this/that way	The GDPR enhances data privacy regulations, thus giving individuals more control over their personal data.
	therefore	for this reason	Processing personal data of EU citizens must comply with the GDPR, therefore ensuring greater data protection.
	hence	from this/that	The GDPR has led to increased awareness of data privacy issues, hence encouraging NGOs to demand higher data security measures.
	consequently	as a result	Non-compliance with the GDPR can result in significant fines; consequently , businesses are more vigilant in adhering to it.
	inevitably	resulting in any case, unavoidable	Infringements of the provisions of the GDPR are inevitably subject to administrative fines.
Contrasting	however	contrasting from positive to negative	Most companies adhere to the GDPR; however , the number of violations still increases.
	nevertheless	contrasting from negative to positive	Companies still violate regulations; nevertheless , with decreasing frequency.
	although, even though	granted that	Although the GDPR did improve data security, consumer associations still deem it insufficient.
	despite, notwithstanding	in defiance of something	Despite being obligatory, the GDPR is often not fully implemented.
Comparative	similarly, likewise	in the same manner	Other countries have implemented similar data protection laws, likewise drawing inspiration from the GDPR's principles.
	accordingly	in accordance with	The heavy use of personal data repeatedly posed a risk to data privacy in the EU. Accordingly , the European Commission enacted the GDPR.

Reasoning	Adverb	Meaning	Example
Adjunctive	furthermore, additionally	in addition to	The GDPR addresses the consequences of violation. Furthermore , it regulates fines and penalties.
	moreover	in a larger sense	Regulations are required for consumer safety. Moreover , they stabilise societies and their markets.
	besides	in line with, as a side effect	Besides its stabilizing effects, regulations shape cultural habits.
	anyhow, anyway	apart from what was said before	The GDPR puts a burden on management. Anyhow , regulations are required for consumer safety.

7.6.10 Verbs for Reasoning

Conclusive conjunctive adverbs, such as *thus*, *hence*, or *consequently*, have limited use with inductive generalisation and are inappropriate for abductive inference. Abductive or inductive inference may *indicate*, *illustrate*, *imply*, *suggest*, *convey*, or even *reveal* something with a certain probability but cannot *infer*, *demonstrate*, *determine*, *attest*, *testify*, or *prove* something. Table 7.3 shows appropriate verbs for the types of reasoning.

Table 7.3 Verbs for different types of reasoning

<i>Reasoning</i>	<i>Verb</i>	<i>Explanation</i>
Abductive	indicate	To hint at something based on observed evidence.
	imply	To indirectly convey an idea without explicitly stating it.
	infer	To draw a conclusion based on evidence or reasoning.
	propose	To put forward an idea, hypothesis, or explanation.
	assume	To accept a proposition.
Inductive	estimate	To determine an approximate value.
	reveal	To disclose previously unknown known to others.
	predict	To forecast an outcome based on probability.
	expect	To anticipate an outcome based on probability.
Deductive	verify, affirm	To provide evidence.
	confirm, prove	To establish a state of truth beyond doubt.
	validate	To confirm the correctness of a conclusion.
	deduce	To reach a conclusion based on logical reasoning.
	entail	To necessitate a consequence based on premises.
	imply (logic)	To indicate an indirect logical consequence.

7.6.11 Vague Qualifiers

Would you discuss a *bit of evidence* or a *fairly significant result*? The fact that a distinct result is not achievable is still valuable scientific information, and there is no need to obscure it in vague wording. Vague qualifiers often turn a clear message into a fuzzy, imponderable statement.

That does not mean vague qualifiers are useless in academic texts. They can help add nuance to an argument if a conclusive statement is impossible or express ideas without overly broad statements. But here is one thing to

remember: if you refrain from a distinctive conclusion, you leave the interpretation to the reader. If intended, using indeterminate statements is appropriate. Otherwise, avoid vague qualifiers. Can you find 18 vague statements in the following paragraph?

A vagueness exercise

Nature commonly encompasses a lot of captivating elements that leave us a bit speechless. It's fairly intriguing how it seems to embody a myriad of complexities, still maintaining a somehow striking balance. In some instances, we can barely comprehend the pretty intricate ecosystems. Sometimes, it might feel as if nature possesses a sort of wisdom that may quite surpass our own understanding. Probably, nature's enigmatic forces hold a somewhat hidden magic that tends to evoke a sense of reverence within us when we witness its rather efficient design compared to the poor performance of human achievements.

7.6.12 Expressing an Author's Stance

Rather than writing something that was *found*, you can express your (or another author's) stance more precisely. The more carefully you select the verbs, the more you clarify the intention and how it influenced your further argumentation. Table 7.4 shows examples of alternative verbs you can use instead of *found*.

7.6.13 Active vs. Passive Voice

Whether you write that 'scientists discovered a new phenomenon' or 'a new phenomenon was discovered by a scientist' does not seem to be much of a difference in terms of its meaning. However, it differs in perception: the first case (the active voice) focuses on the scientist as an actor, whereas in the second case (the passive voice), the focus is on the phenomenon.

The passive voice was dominant in traditional scientific writing since it insinuates a neutral stance and supports the objectivity of statements. Meanwhile, style guides recommend using active voice in scientific writing since it is more direct and resembles natural conversation. It emphasises the person or entity responsible for the action described in the sentence, thus engaging the reader more.

There are certain cases where the passive voice may be more appropriate, such as when the focus is on the action rather than the actor or when the actor is unknown or unimportant. This typically applies when discussing past actions, such as in the research design section. Choose between active and passive voice based on what best serves the needs of your argument and the clarity of your writing.

Table 7.4. Different verbs to express an author's stance

Verb	Meaning
agreed	having the same opinion
argued	fighting for an opinion
asserted	being confident in a finding
assumed	referring to a premise
believed	being confident without an argument
claimed	being confident in an assertion
concluded	inferring from premises
considered	taking something into account
contended	disputing something
demonstrated	finding evidence for something
discovered	being the first to find something
emphasised	drawing attention to something
exposed	unmasking something
indicated	pointing at something
noted	remind on something
objected	fighting for another opinion
observed	monitoring something
proposed	suggesting something
revealed	discovering something hidden
supposed	presuming an axiom or postulate

7.6.14 Personal Pronouns

Although personal pronouns were formerly discouraged in scientific writing, there seems to be the same paradigm shift as with passive to active voice. In traditional scientific writing style, we avoid personal pronouns since they could create a perception of subjectivity. An academic text should remain neutral and impartial, achieved with a third-person point of view.

If you write: *I doubt the conclusion is valid*, you leave the impression of a personal opinion rather than one based on evidence. Writing *the conclusion's validity can be doubted* transfers the responsibility from you as a person to the proof.

However, writing: *the researcher was interested in this topic due to her professional experience* not just sounding unnatural but reduced the author to an anonymous entity. Talking about your motivation for research from a third-

person point of view would be inappropriate. The same applies to those topics that require a personal opinion, such as moral or aesthetic judgements.

You may use the personal pronoun 'I' if you refer to subjective personal reasons or opinions and refrain from using them if you rely on evidence outside your opinion. Using the personal pronoun 'we' is only appropriate for multiple authors.

7.7 REMARKS ON PUNCTUATION

Although we assume you being familiar with punctuation marks (see also Table 7.7), we would like to clarify some flaws we regularly encountered.

7.7.1 The Neglected Semicolon

A semicolon is a versatile – but often neglected – tool. When you pronounce a sentence, the semicolon indicates a pause longer than a comma but shorter than a full stop. In fact, the symbol does represent a period over a comma and can replace both.

Replacing a full stop A semicolon can replace a full stop to indicate a close relationship between two sentences. For instance, when you write:

The study relies on surveys. Interviews were used for validation only.

you could emphasise the close relationship by joining the sentences with a semicolon:

The study relies on surveys; interviews were used for validation only.

Similarly, the semicolon can replace connecting words (such as *and*, *because*, *since*, *as*, *for*), emphasising the relation between the clauses even more.

Note that if we use a conjunctive adverb (*however*, *therefore*, *hence*, *thus*, *consequently*, *nevertheless*, *meanwhile*) in the second sentence:

The study relies on surveys. Nevertheless, interviews were used for validation.

joining them requires a semicolon in any case:

The study relies on surveys; nevertheless, interviews were used for validation.

Replacing a comma Another use of the semicolon is to replace a comma in a list of items containing inner punctuation:

We distinguish scenarios that are (a) assessable, but not predictable; (b) predictable and critical to success; or (c) determined, but uncritical to success.

You must note that a full stop, a semicolon, and a colon generate different meanings. Compare:

*Full stop vs colon vs
semicolon*

Smith argued conversely. Other studies were not conclusive.

Smith argued conversely; other studies were not conclusive.

Smith argued conversely: other studies were not conclusive.

The first example states two independent facts. The second example indicates the relationship between the studies of Smith and the others. The colon in the third example indicates the outcome of Smith's argumentation.

The colon usually announces literal speech, explanations, definitions, or listings. We also use a colon when we introduce an equation with an independent clause:

Colons and equations

We define the harmonic sinusoidal wave as follows:

$$\psi(x, t) = A \cdot \sin(\omega t - kx) \quad (3)$$

However, if the equation – although in a new line – becomes part of the sentence, we omit the colon:

The harmonic sinusoidal wave

$$\psi(x, t) = A \cdot \sin(\omega t - kx) \quad (3)$$

is a function of the location x and the time t .

7.7.2 Hyphens and Dashes

Although *hyphen* (-), *en dash* (-), and *em dash* (—) look similar, they serve different purposes. The names of the latter two refer to the length of the uppercase N and M, respectively.

Your text processor uses hyphens for automatic hyphenation. Besides that, they appear in certain *compound adjectives*: two or more words linked generating a new adjective, such as *long-term* or *three-dimensional*.

The *en dash* (-) can replace the word 'to' in a numbered range:

Chapters 2.1–2.5 address the existing theories.

However, if you replace the dash with 'to', your sentence must still be correct. For instance, the following is wrong:

The literature covers studies between 2020–2022.

and should read '...studies between 2020 and 2022'. A good rule is to avoid the dash between numbers and replace it with *to*.

A pair of dashes may replace parenthetical expressions. The strength of a dash is that it emphasises the insertion more strongly:

The strength of the correlation depends on the discriminative potential of the algorithm and – to a minor extent – on time and duration of the phase.

US English often uses an *unspaced em dash* (—) rather than the spaced *en dash*; however, even US style guides are inconsistent in this case.

7.7.3 Single or Double Quotation Marks

Unfortunately, single and double quotation marks are still used differently in British and US English. Traditional British English often uses single quotation marks for quotes and double quotation marks for nested quotations, whereas US English does the opposite. In addition, the rules for whether the punctuation of a sentence appears within a quote or outside is handled differently.¹⁷⁰ A British style example is:

Smith draws attention to hierarchy, where a ‘single organizing principle is both “too much and too little”, for it could account for everything’, and thus bars the way to other hypotheses.

The US English style would be:

Smith draws attention to hierarchy, where a “single organizing principle is both ‘too much and too little,’ for it could account for everything,” and thus bars the way to other hypotheses.

You see the comma following the outer and the nested quotation in British English become part of the quote in the US English style.

Breaking a rule again Although we don’t want to add to the inconsistency, we have good reasons to recommend a different approach and follow it throughout this book: we will use double quotation marks for outer quotations, but we will not include punctuation of our sentence in a quote. We do this for two reasons:

- we use: “...’...’...” because it seems more reasonable to us to interpret single quotation marks as subordinate to double quotation marks. This is increasingly adopted in British English style guides.
- we will not extend a quote with punctuation marks since it changes the original phrase.¹⁷¹

¹⁷⁰ For the related debate between linguists and copy editors, see (Pullum, 1984).

¹⁷¹ For a more extensive argumentation, see also (Trask, 1997)

7.8 ABOUT CITATIONS

The reader of your text assumes that facts, ideas, or conclusions that are not cited are your own intellectual property. However, if you cite every triviality, you render your text unreadable. The following excursus shows a (not so seriously meant) example.

Excursus: Why we don't cite trivialities

Suppose we write an introduction and cite each piece of information that is not our own intellectual property. In conventional inline style, it would look like:

Since the World Wide Web (Berners-Lee, 1991, p. 15) has been made available to the public (Oxford Dictionary, 2015), no other evolution (Darwin, 1889) in humankind (Genesis 1:27) was so successful as digital (Peirce, 1886, p. 514) social (Comte, 1851, p. 123) networks (Hiltz & Turoff, 1978, p. 23). In the year (Gregor XIII, 1582, as cited in Borromea, 2002, p. 63) 2014, the Federal Statistical Office (destatis, 1953, par. 3) of Germany (Frankfurt Parliament, 1848, as cited in Obermann, 1985, p.123) found that 29 million (Statistisches Bundesamt, 2014, p. 134) people in Germany were connected over Internet (ARPA, 1969, p. 244) using social media (Kaplan & Haenlein, 2010, p. 12).

Looks a little complicated. Let us use footnotes rather than inline citations:

Since the World Wide Web¹ has been made available to the public², no other evolution³ in humankind⁴ was so successful as digital⁵ social⁶ networks⁷. In the year⁸ 2014, the Federal Statistical Office⁹ of Germany¹⁰ found that 29 million¹¹ people in Germany were connected over Internet¹² using social media¹³.

Now, we omit the citations for common knowledge and trivialities:

Since the World Wide Web has been made available to the public, no other evolution in humankind has been so successful as digital social networks. In the year 2014, the *Federal Statistical Office of Germany* found that 29 million people in Germany were connected over the Internet using social media.¹

We finally remove invaluable information to arrive at a good introductory statement:

The *Federal Statistical Office of Germany* found that 29 million people in Germany were connected via social media in 2014.¹

Remember that a scientific paper needs everything but trivial introductory statements, which only inflate your text. If you are faced with the (seemingly) tricky question of what to cite, take a step back.

7.8.1 What to Cite

We can easily find out what to cite if we reconsider what a citation is about. We cite to (a) *acknowledge* the fellow researcher who was the originator of a

The meaning of a citation

valuable idea or information,¹⁷² (b) *direct the reader* to further information, and (c) demonstrate how *authoritative sources influenced* our argument. In other words, citations express appreciation, inform the reader, and determine your argument.

We can cite from any accessible source, such as peer-reviewed literature, internal reports, meeting minutes, images, accessible audio or video recordings, verifiable personal communications, or something we published previously.¹⁷³ Publications may be printed or only available online, such as patent applications, peer-reviewed online journals, or authoritative online encyclopaedias.

When we cite

But we only cite what *we have read* and – whenever possible – in the original language. Otherwise, we run the risk of overlooking important aspects of the context. In the worst case, we run into the trap of false translation.

We always look for the *primary source* to credit the originator of a valuable idea rather than an imitator.¹⁷⁴ We use a *secondary source only* if its meaning differs from the primary source and if this difference is relevant to our context. That is, we avoid indirect citation (*as cited in*) unless the original source is not accessible anymore.¹⁷⁵

Nevertheless, we *refrain from repeatedly citing the same source*. It creates the impression that we have been too lazy to find other sources. A literature review is always a comparative approach.

Citation with a remark

We are careful when citing sources that are not peer-reviewed, such as *magazines, newspapers, or weblogs*. Statements in such sources often merely represent the author's opinion, which might lack scientific foundation. Even if we find an author being an authority in the field, the lack of peer reviewers renders the content unverifiable.

We can still cite an unreliable source to discuss it, refer to a newspaper article as representing public opinion, or cite a biased statement, such as about the success of Apple Inc. from the Apple corporate website, if we intend to address this bias. In such cases, we indicate the lack of reliability in our text.

¹⁷² A *valuable* idea may be novel, inventive, or creative. Such pearls of wisdom like 'companies must protect sensitive customers data' or 'managers are not necessarily leaders' do not deserve further attention (as other works from the corresponding author do not, too).

¹⁷³ It may sound weird to cite yourself, but this avoids people publishing the same things repeatedly just to enhance their publication list.

¹⁷⁴ If we want to refer to Kant's original idea of the categorical imperative, we need to cite the *Grounding for the Metaphysics of Morals* from 1785. Any secondary source will interpret it differently.

¹⁷⁵ An acceptable reason to cite a secondary source would be if you have problems accessing the *Qumran Caves Scrolls* in the original; not that you just can't find shoes to go to the library.

However, if we cannot assess the reliability of a source, we cannot use it as the basis for our argumentation.

7.8.2 What Not to Cite

We will not cite anything that is *well-known* or *trivial*, such as "Economy is understood as the system by which goods and services are produced, sold, and bought in a country or region".

Online portals, such as *Wikipedia*¹⁷⁶ or *Statista*, are usually not the source of information. If credible, they refer to the original source that we can cite. The same applies to *lecture materials*; even lecturers rely on other sources (or their own publications).

We also do not cite any unpublished intellectual property of our own.¹⁷⁷ If you are in doubt, whether a citation is required or not, ask your supervisor.

Table 7.5 Checklist for citable statements or concepts

Criterion	Description	
primary	Is it the primary source?	<input type="checkbox"/>
secondary	If not, does the source represent the original idea?	<input type="checkbox"/>
original	If not, is the difference relevant to your context?	<input type="checkbox"/>
uncommon	Is it unknown or unusual enough to be cited?	<input type="checkbox"/>
valuable	Does it contribute to your research objective?	<input type="checkbox"/>
required	Is it required for your argumentation?	<input type="checkbox"/>
credible	Is it unbiased, and is the source reliable?	<input type="checkbox"/>

7.8.3 How to Cite

A citation acts as a link to the list of references at the end of your document. As mentioned in Chapter 6.7, we recommend using footnotes for those citation styles that cite the author's names to avoid disturbing the text with lengthy name entries. An advantage of using footnotes is that if you repeatedly refer to the same source and page number, you can use a cross-reference

¹⁷⁶ Although *Wikipedia* has a worldwide review community and contains some excellent articles (the other are written far too complicated), you cannot ensure they were reviewed at the time of retrieval. However, you may use the peer-reviewed literature cited at the end of the article.

¹⁷⁷ This also applies to the remark '(own illustration)' in figure or table captions. We are aware that some guidelines expect such note in captions for figures drawn by the author. Unfortunately, we never heard a reasonable explanation. If you, dear reader, can provide one, please let us know.

to the footnote number rather than creating redundant citations. The following examples use footnotes and otherwise follow the style recommendations of the *American Psychological Association* (APA).

Suppose we want to cite the following statement about corporate social responsibility (CSR):

"CSR activities are more visible than ethical decision making, since often ethics decisions only become visible when there is misconduct."¹⁷⁸

This statement can be either quoted or paraphrased.

Quotation

A *quotation* states the identical wording (including any literal errors) between double quotation marks. The quotation can cover the complete sentence, or you may partially embed it in your sentence:

Ferrell et al. emphasise that those activities related to CSR "are more visible"¹⁷⁸ than decisions around ethical issues.

We place additions or remarks within square brackets:

"CSR activities are **more visible** [emphasis added] than ethical decisions".¹⁷⁸

Literal errors are indicated with *sic* in square brackets:

"CSR activities are more visible than etical [sic] decision making."¹⁷⁹

We indicate any omission in the quote with ellipses:¹⁷⁹

"CSR activities are more visible..., since often ethics decisions only become visible when there is misconduct".¹⁷⁸

Make sure that your change to the quotation does not change the meaning of the original statement.

Indented block quotation

With quotations of more than a sentence, we recommend using an indented block quotation to separate it clearly from your text:

Ferrell et al. emphasise the need for further research in this field:

"CSR activities are more visible than ethical decision making, since often ethics decisions only become visible when there is misconduct. The finding that business ethics has more influence on brand attitudes hopefully will encourage more research to determine if business ethics has more influence than CSR on reputation as well as other attitudes toward the organization."¹⁷⁸

The citation (or footnote number) appears behind the quotation mark.

¹⁷⁸ (Ferrell, Harrison, Ferrell, & Hair, 2019, p. 499)

¹⁷⁹ Some citation styles use ellipses in square brackets.

Quotations only make sense if you feel that you couldn't say it better or if it is a statement that you want to discuss extensively. Otherwise, avoid quotations and favour paraphrases.

A *paraphrase* expresses the meaning of a statement in your own words, for example:

Paraphrase

Ferrell et al. observed that ethical decisions are less perceptible by the public than immediate CSR activities.¹⁷⁸

The footnote number behind the period indicates that the content of the entire sentence is cited. If only part of your sentence contains cited information, the number appears immediately behind the punctuation mark (comma, semicolon, or colon):

Ferrell et al. observed that ethical decisions are less perceptible by the public than immediate CSR activities,¹⁷⁸ although they do not clarify how decisions are communicated.

If an entire publication is cited rather than a particular statement, the number may also appear behind the author's (or institution's) name or the publication's title:

Ferrell et al.¹⁷⁸ addressed the relationship between CSR activities and ethical decisions.

In any case, the position of the citation (the footnote number) must indicate what information stems from the source and what your contribution is.

The citation contains at least the author(s) and the year of the publication if you refer to the whole source. However, it includes additional information if you quote or refer to a particular fact in a source.¹⁸⁰ Referring to an entire source does not include a page number:

Page numbers in a citation

An outline of the life of famous cartoonist Charles M. Schultz is given in a book.⁷⁷

⁷⁷ (Schulz C. M., 2010)

For a concrete fact or information, we refer to a page number:

Charles M. Schulz describes that he was early influenced by Disney characters when drawing his first cartoons.⁷⁸

⁷⁸ (Schulz C. M., 2010, p. 6)

¹⁸⁰ Although rarely found in publications, page numbers are often required in theses.

The same applies to a quotation:

Already at school, Charles M. Schulz “quickly distinguished himself as a budding artist”.⁷⁹

⁷⁹ (Ball, 2021, p. 13)

For a web source, the page number is replaced by a paragraph number:

Yawar describes the role of Lucy van Pelt in her role as a psychiatrist as a “broken person”.⁸⁰

⁸⁰ (Yawar, 2015, para. 3)

Alternatively, we can refer to a heading if too many paragraphs make the search too difficult:

The categorical roles of a narrative are displayed in a comic in visual panels, arranged in canonical order”.⁸¹

⁸¹ (Cohn, 2014, 'The structure of visual narrative')

In audio recordings, video recordings, or movies, you refer to the time stamp in hours or minutes:

“Charlie Brown, you’re the only person I who can take a wonderful season like Christmas and turn it into a problem. Maybe Lucy’s right. Of all the Charlie Browns in the world, you’re the Charlie Browniest.”⁸²

⁸² (Mendelson L. , 1965, 1:12)

For transcripts of interviews or field notes that turn up in the appendix, we recommend using line numbers:

Respondent 3 referred to the value of Charles M. Schulz comics for education.⁸³

⁸³ (Appendix B-2, line 142)

Alternatively, we use the time stamp of the audio recording of the interview by referring to the electronic file.

7.8.4 References

The citation is a link to the list of *references* at the end of your document, which provides the complete information required to access the source.

Most referencing styles follow the general scheme:

Author (Year). Title. Source. Access details.

You can find examples in the online resources for the corresponding citation style or in university library resources.¹⁸¹

We strongly recommend using a bibliographic tool or the corresponding function of your text processor, such as *Insert Citation* in Microsoft Word or *Bibliographic Entry* in OpenOffice. To place multiple citations within single parentheses, place the cursor before the closing brackets and insert a new citation.

Don't write references yourself.

When you enter the data in the bibliographic tool, ensure you provide all information required for a complete reference. Replace full capitalisation (*all caps*) with sentence case capitalisation. Remove any unnecessary query information in hyperlinks that refer to your user behaviour; for instance, you can often omit the part behind the question mark. Check out in your browser which part is required to reach the document online.

If details of the source are missing, you can follow the advice in Table 7.6.

Table 7.6 Managing missing details in references

Case	Comment
Missing author	Replace the entry with the institution that published the document. ¹⁸²
Missing date	In ancient sources with unknown dates, use '(n.d.)'. In contemporary sources, the date is required. ¹⁸³
Missing title	Replace with a description in square brackets. for example, Cartwright, B. (2016). [Internal Memo on IT Management]. Bonn: Siemens AG.
Missing publisher's details	Replace with '(n.p.)'
Missing page numbers	Use either paragraph number (Cartwright, B., 2016, para. 2), line number (Cartwright, B., 2016, line 11), or section heading (Cartwright, B., 2016, 'Final remarks').

¹⁸¹An overview on the most important referencing styles can be found in the *University of Pittsburgh Library System* (University of Pittsburgh, 2022)

¹⁸² Although citation styles recommend using the article name instead of the author, ask yourself: how can you verify a source if neither author nor a publishing organization exist?

¹⁸³ If you neither find a date in a web document nor in its source code, how can you assume it is still valid? A missing date in a contemporary printed source renders it useless.

7.8.5 Plagiarism

Plagiarism occurs when you repeatedly either fail to cite or incorrectly cite original and valuable foreign intellectual property (such as thoughts, ideas, expressions, quotations, facts, visual, film or audio material). The same applies if you repeatedly cite sources whose content does not match the quoted or paraphrased statement in your text (fake citations). In both cases, your thesis fails, and you will face disciplinary action from your university or even legal consequences in your country.

7.9 A STYLE SUMMARY IN A NUTSHELL

Understanding the meaning of words is the basis of science. Therefore, scientific authors:

- write comprehensibly,
- use correct terminology,
- are precise in expression,
- select metaphors carefully,
- avoid meaningless phrases,
- refrain from redundancy,
- do not exaggerate, and
- refrain from patronising or arrogant statements.

Table 7.7 Typical uses of punctuation marks

Punctuation	Typical use	Example
.	Full stop (period) after complete sentences as separator in captions as separator in compound numbers	A full sentence ends with a period. Figure 4. Chapter 1.2.1
,	Comma after introductory clause after subordinate clause before coordinating conjunctions <i>and, but, for, or, nor, so, yet</i> , if they join independent clauses for insertion as serial comma	After the first measurement was performed, the parameters were refined. While the null hypothesis was accepted, the working hypothesis was rejected. The hypothesis was accepted, and the underlying model was refined. We define the parameters, pressure, and temperature in advance. The miscommunication affects the team, the project, and the program managers.
;	Semicolon between independent clauses (replacing coordinating conjunctions or subordinating conjunctions) before conjunction or transitions in nested lists (if list items contain punctuation)	The method uses qualitative data; quantitative data were not used. The method uses qualitative data; however, quantitative data were relevant. The classes include (a) constants, (b) variables that are negative but significant, and (c) positive variables.
:	Colon before literal speech before lists before equations (if not part of a sentence) before explanations	The respondent answered: "That depends on the situation." We calculate three statistics: mean, median, and mode. We define the sinusoidal wave as follows: $\psi(x, t) = A \cdot \sin(\omega t - kx)$ Black sheep effect: the phenomenon that subjects judge likeable ingroup members more positively than similar outgroup members.
-	Hyphen for hyphenation for compound words	24-hour service; long-term concept; four-dimensional space

<i>Punctuation</i>	<i>Typical use</i>	<i>Example</i>
	between prefix and word if the merged version has a different meaning or is hard to read	re-lease (lease again), re-release (release again), co-ordinate (2 nd ordinate) intra-abdominal, re-evaluate, anti-inflammatory, pre-operative, de-ice
– en dash	for number ranges for insertions	The literature covers studies of the period 2020–2022. The strength lies in the effectiveness and – to a minor extent – in efficiency.
— em dash	In US English, for insertions	It could be verified that the correlation depends on the discriminative potential of the algorithm and—to a minor extent—on time and duration of the phase.
() Parentheses	for insertions to announce acronyms or initialisms	We encounter recurring affective patterns (e.g., collusiveness and accusation). We conduct an interpretative phenomenology analysis (IPA).
[] Brackets	for insertions and remarks in quotations	Ginelli found that "fear [amongst sheep] increases with the distance to neighbours".
" " double quotation marks	for quotations (British English) for inner quotations (US English)	Smith draws attention to hierarchy, where a 'single organizing principle is both "too much and too little", for it could account for everything' and thus bars the way to other hypotheses. (British English)
' ' single quotation marks	for quotations (US English) for inner quotations (British English)	Smith draws attention to hierarchy, where a "single organizing principle is both 'too much and too little,' for it could account for everything" and thus bars the way to other hypotheses. (US English)

8 CHATGPT AND AI TOOLS

Utilizing a cutting-edge deep learning algorithm, the AI model could dynamically integrate hyper-contextualised syntactic and semantic embeddings to effectively optimise its neural network architecture, resulting in a profound augmentation of its cognitive capacity and emergent capacity for task generalization.¹⁸⁴

AI tools such as ChatGPT¹⁸⁵ are transforming how we approach academic writing. They assist writers in generating ideas, verifying facts, and improving the quality of writing. Students and researchers must use these tools responsibly and follow academic guidelines. Failure to do so may have severe consequences, including disciplinary action and loss of credibility.

The authors used various tools, including ChatGPT, to assist them during the development of this book. They used these tools ethically, ensuring that the final product reflected their original ideas and voice while benefiting from these tools' assistance. The learning is:

By utilising AI tools responsibly, writers can maintain their integrity and ensure the quality of their work.

When the industry introduced pocket calculators, they were a ground-breaking innovation that enabled people to perform complex calculations. *Pocket calculators were disruptive*

¹⁸⁴ What happens if you force an AI tool to the wrong direction, it can formulate devastating.

¹⁸⁵ (OpenAI, L.L.C, 2023)

Similarly, AI tools like ChatGPT represent a significant breakthrough in computer science, as they can understand and respond to user queries conversationally and naturally.

Just as pocket calculators made it easier for people to perform arithmetic calculations, AI tools like ChatGPT make it easier for people to access and process information and carry out tasks such as customer service, language translation, and personal assistance.

Pocket calculators and maths

Critical use is essential. AI tool users and users of pocket calculators have something in common. In both cases, users must understand the underlying technology well to justify the results.

For example, while pocket calculators can perform complicated calculations quickly and accurately, users must have a solid comprehension of mathematics to ensure that the results are correct and make sense. Similarly, while AI tools like ChatGPT can generate responses to user queries, users must have a basic understanding of how the technology works to evaluate the accuracy and relevance of the answers.

In the case of AI tools, users must also be aware of potential biases and limitations of the technology, such as the reliance on pre-existing data and the risk of overgeneralization. Therefore, having a good understanding of the limitations and shortcomings of AI tools paired with the ability to scrutinise the output is vital for users of AI tools. This ensures that they are using the technology effectively and responsibly.

8.1 ChatGPT

ChatGPT is an influential AI-based conversational agent that uses natural language processing to understand and respond to user queries. Similar tools include Siri, Alexa, and Google Assistant, designed to provide users with helpful information and assistance through voice commands or text-based chat. These tools aim to improve the user experience by providing quick and accurate responses to their inquiries, whether to answer a question, complete a task, or provide recommendations. ChatGPT, in particular, is trained on a vast text corpus and can understand the context and generate coherent responses. It makes it a valuable tool for many applications, from customer service to language translation.

The acronym GPT stands for *Generative Pre-trained Transformer*. Researchers designed this neural network architecture for natural language processing

tasks, like language translation, text summarisation, and text completion. GPT models undergo pre-training on massive amounts of text data, enabling them to generate coherent and contextually relevant responses to user queries. OpenAI developed the GPT architecture, and it has gained popularity in natural language processing due to its ability to produce high-quality language output.

The developers designed ChatGPT to engage users in natural language conversations and respond to their queries in a usual manner. *Chat* refers to the conversational nature of the tool, while *GPT* refers to the neural network architecture that powers the tool.

Humans like conversations



Figure 8.1 ChatGPT start screen¹⁸⁶

8.2 ChatGPT AND THESIS WRITING

Using ChatGPT as a tool in thesis writing can be a valuable resource. However, using it ethically and following academic honesty guidelines is vital. Here are some guidelines to follow:

Use ChatGPT to generate ideas and inspiration.

ChatGPT can be a tool for generating new ideas and inspiration for your thesis. You can use it to explore different topics and angles and to get a sense of the current state of the research on a particular subject.

¹⁸⁶ (OpenAI, L.L.C, 2023)

You can use ChatGPT to generate a list of potential research questions. For example, if you write a thesis on using social media in marketing, you can ask ChatGPT to generate a list of related research questions with the query:

I want to write a thesis on "Using Social Media in Marketing". Generate a list of related research questions and a summary of what each question will investigate.

ChatGPT answers:

1. Research Question: How does social media usage influence consumer purchasing decisions?

Summary: This research will investigate the extent to which social media activity impacts the purchasing decisions of consumers, exploring aspects such as online reviews, influencer marketing, and social media advertisements.

2. Research Question: What role does social media play in brand awareness and perception?

Summary: This question aims to examine how companies use social media to create and enhance brand awareness, as well as how this online presence impacts brand perception.

3. Research Question: How effective are social media marketing strategies compared to traditional marketing strategies?

Summary: This research will provide a comparative analysis of social media marketing strategies versus traditional ones, assessing their respective effectiveness in terms of reach, engagement, and return on investment.

However, using ChatGPT solely for thesis content is improper. While it can assist in idea generation and content refinement, you need to show your contribution through original research question formulation, data analysis, findings discussion, and unique conclusions. Your unique insights should be present in the query.

Use ChatGPT for fact-checking and verification.

ChatGPT can verify facts and information about your thesis topic. Checking can help ensure that your research is adequate and up to date. For instance, with the prompt:

I encountered there is no scholarly reference for creating hash codes before 1960. Is this correct? If not, do you know a scholarly reference?

ChatGPT answers:

The concept of hash functions or hash codes emerged in computer science around the mid-20th century, with notable implementations such as the hash-coding used in IBM's Fortran language compiler, developed in the 1950s. However, formal scholarly references for hashing before 1960 are scarce, given the relative novelty of computer science as a field. Detailed historical analyses and foundational publications often date from the 1960s or later. Therefore, you may

not find specific scholarly references about hash codes before 1960. Always consult a variety of reliable academic sources to gain the most accurate historical understanding.

This indicates that your initial assumption may be true.

Use ChatGPT as a writing tool, not a writing substitute.

ChatGPT can be a valuable tool for generating text and ideas, but you should not use it as a substitute for your writing. For instance, you may use ChatGPT to generate a **rough draft** of a section of your thesis but then revise and refine the text to reflect your voice and ideas. However, generating an **entire section** of your thesis without making any changes or adding your original ideas is inappropriate.

Be transparent about your use of ChatGPT.

When you use ChatGPT, it is necessary to be transparent about your use of the tool and to give credit where credit is due. For instance, your methodology section mentions using ChatGPT to generate a list of potential research questions and explains how you used the tool. If you use ChatGPT extensively throughout your thesis without acknowledging the tool or how you used it is close to plagiarism and will be recognised by your supervisors.

8.3 POSITIVE AND NEGATIVE EFFECTS ON YOUR SKILLS

Table 8.1 compares the long-term effects on students using ChatGPT. The subsequent chapters explain the effects more comprehensively.

8.3.1 Positive Effects

If students use ChatGPT as a tool ethically while following the guidelines, they can gain various positive long-term effects on their skills and development. Here are a few of them:

Improved critical thinking skills

Using ChatGPT to generate ideas and verify facts, users learn critical thinking about the information they receive. Dealing with a wider variety of information can help them develop their analytical skills and better evaluate different sources of information.

Positive long-term effects

Enhanced research skills

ChatGPT can help students learn how to conduct effective research and gather relevant information. Students can develop their research skills by using the tool to generate research hypotheses, verify the information, and become more proficient at finding and evaluating sources.

Enhanced writing skills

Using ChatGPT as a writing tool can help students improve their writing skills. Students can learn how to structure their arguments effectively, write clearly and concisely, and develop their writing style by generating text and ideas.

Increased creativity

ChatGPT can inspire students to think outside the box and develop new and innovative ideas. Students can become more creative and build their unique perspectives by using the tool to generate ideas and explore different angles on a topic.

Improved time management skills

Using ChatGPT as a tool can help students manage their time more effectively. By generating ideas and text quickly, students can spend more time refining their writing and conducting research, leading to higher-quality work in the long run.

Translation

ChatGPT can assist students with translation tasks by providing near-instant translations for numerous languages. This utility can aid students in comprehending foreign language materials and supporting their language learning process. However, it's important to note that AI translations may not be perfect, particularly for complicated sentences or idioms; hence, they should be used as a learning aid rather than an absolute authority.

Learning about AI capabilities and limitations

ChatGPT offers a practical way to understand the capabilities and limitations of AI tools. For instance, while it can generate coherent and contextually relevant responses, it does not understand or process information like a human does. It can't provide personal experiences or opinions and occasionally might produce incorrect or misleading information. This hands-on interaction aids in appreciating both the potential and constraints of AI technology, fostering critical thinking about its usage and ethical implications.

Table 8.1 Comparison of positive and negative effects on students' skills

<i>Skills</i>	<i>Positive effect</i>	<i>Negative effect</i>
Critical Thinking	Enhanced ability to evaluate and analyse information.	Stunted development due to overreliance on the tool.
Research Skills	Improved proficiency at finding and evaluating sources.	Limited understanding due to lack of source variety.
Writing Skills	Improved structuring of arguments and writing clarity.	Poor development of unique writing style.
Creativity	Increased ability to think outside the box and innovate.	Limited creativity due to over-dependence on the tool.
Time Management	More efficient use of time due to quick idea generation.	Overreliance can lead to poor self-management skills.
Translation Skills	Enhanced comprehension of foreign languages.	Potential for misunderstanding complicated phrases.
Understanding of AI	Improved awareness of AI's capabilities and limitations.	Potential for misinformation due to AI's limitations.
Academic Integrity	Encourages ethical use and acknowledgement of AI tools.	Potential for academic dishonesty if misused.

8.3.2 When do we Encounter Negative Effects?

But what are the long-term effects on students' skills and development if they follow the guidelines not ethically?

If students do not ethically use ChatGPT and do not follow the guidelines, their skills and development can have adverse long-term effects. Here are a few potential consequences:

Stunted critical thinking skills

Students relying solely on ChatGPT to generate ideas and information may not develop critical thinking skills. They may become overly dependent on the tool and struggle to evaluate information and think critically about different perspectives. *Possible adverse effects*

Limited research skills

Students who do not verify information or use other sources may have a limited understanding of a topic. This can lead to weaker research skills and hinder their ability to think creatively and develop new ideas.

Poor writing skills

Students who use ChatGPT to generate entire sections of their thesis without adding their original ideas or voice may not develop their writing skills. They may struggle to articulate their ideas effectively and develop their unique writing style.

Limited creativity

If students rely solely on ChatGPT to generate ideas and text, they may not develop their creativity or ability to think outside the box. This dependence can limit their potential to create innovative solutions and ideas.

Academic dishonesty

If students do not acknowledge their use of ChatGPT or use it as unethical, they may be engaging in academic dishonesty. This can have serious consequences, including failing the thesis or facing disciplinary consequences.

8.4 AI TRANSLATION TOOLS

Artificial Intelligence (AI) has evolved remarkably over the past decades, permeating various sectors, especially in language translation. Online AI-based translation tools such as DeepL¹⁸⁷ and Google Translate¹⁸⁸ have transformed the landscape of language translation, offering quick, accessible, and increasingly accurate translations. These platforms harness the power of machine learning and large-scale data analysis to provide translations across numerous languages, serving as invaluable resources for scholars, business professionals, and casual users alike.

For researchers writing a thesis, these tools can be instrumental in understanding foreign language sources or ensuring their research is accessible to an international audience. Suppose a researcher is writing a thesis on ancient Greek philosophy and discovers a critical source written in Greek. Using an AI-based translation tool, they could quickly translate the original into their native language, allowing them to access vital information promptly. However, the tool might not accurately capture the complex philosophical terms and context-specific nuances. In this case, while the AI translation provides a broad overview, the researcher should consider consulting a human expert or learning the language basics to ensure the validity of their research. Table 8.2 summarises the pros and cons of AI translation tools.

¹⁸⁷ (DeepL, 2023)

¹⁸⁸ (Google, 2023)

Table 8.2 Pros and Cons of AI translation tools

<i>Pros</i>	<i>Cons</i>
Accessibility: These tools provide immediate access to a wide range of languages. For thesis writers, they can open doors to a wealth of resources previously inaccessible due to language barriers.	Accuracy: While AI translation tools have improved dramatically, they are not infallible. They can struggle with complex grammatical structures, idioms, or context-specific language, which might lead to inaccuracies in translation.
Efficiency: AI-based translation tools offer speedy translations, saving researchers significant time compared to traditional manual translation.	Lack of Nuance: AI translations often lack the nuance and cultural context a human translator would understand. This could be problematic in a thesis, where accuracy of language is crucial.
Usability: They are user-friendly and require no advanced technical knowledge, making them a convenient tool for thesis writers.	Reliability: The reliability of AI translations can vary between languages, particularly for less commonly spoken languages. This may limit the utility of these tools for some thesis writers.
Cost-effectiveness: Most AI translation tools offer free or affordable options, making them a cost-effective solution for students or researchers on a tight budget.	

Although we cannot universally recommend all translation tools due to their varied levels of accuracy and effectiveness, DeepL stands as a commendable choice due to its advanced AI technology and reliable performance.¹⁸⁹

DeepL

A relatively new player has entered the machine-based translation market in the last decade with growing success. Established in 2009 and headquartered in Cologne, Germany, DeepL is a firm that specialises in deep learning. The company utilises artificial intelligence (AI) and machine learning (ML) to develop language translation tools, including the bilingual dictionary service Linguee and the machine translation platform DeepL.

DeepL supports, as of July 2023, 31 languages with high accuracy. Recent tests and media reports emphasise the high quality of the translations, which are better evaluated by translation professionals than Google Translator.¹⁹⁰

¹⁸⁹ Alternatives to DeepL include Cognism, ZeroEyes, and Rossum.

¹⁹⁰ Check yourself as DeepL and Google Translate are free. Here is a good start: (Colin, 2023)

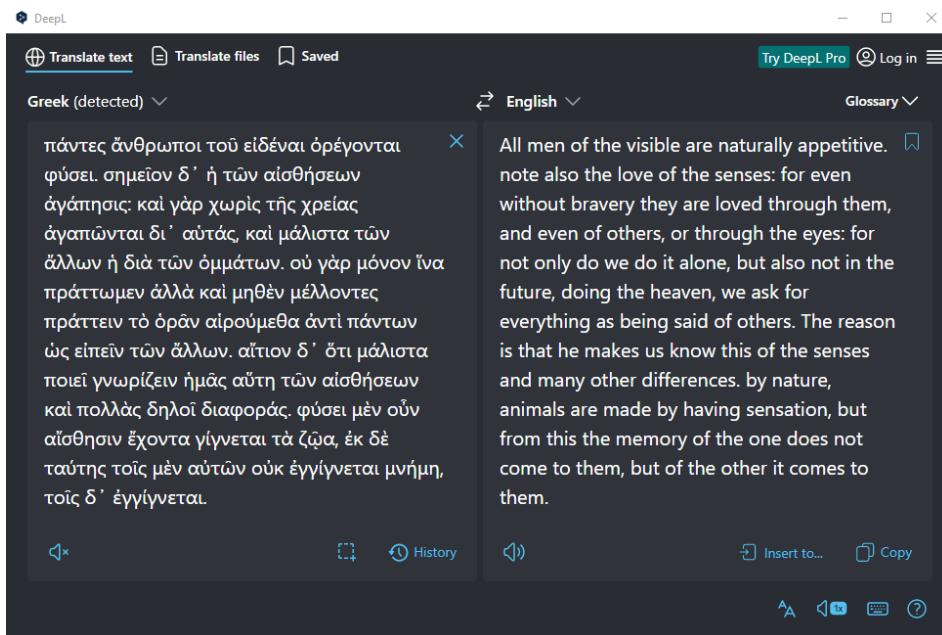


Figure 8.2 DeepL Example Screen with Aristotle's text translation from Greek to English

9 VISUALISATION

*A picture is worth a thousand words, so they say.
But how to draw this?*

The power of visual communication is to convey complicated ideas. However, creating compelling visualisations can be challenging when dealing with abstract concepts. To draw impactful pictures, it is essential to understand the message that needs to be conveyed and choose the correct visual elements to express that message. This requires not having advanced artistic skills but an understanding of design and visual communication principles.

Furthermore, considering the intended audience for selecting the adequate picture is crucial, as different visual styles and techniques may be more effective with one audience or another. Creating compelling visualisations requires creativity, technical skill, and an understanding of the subject matter.

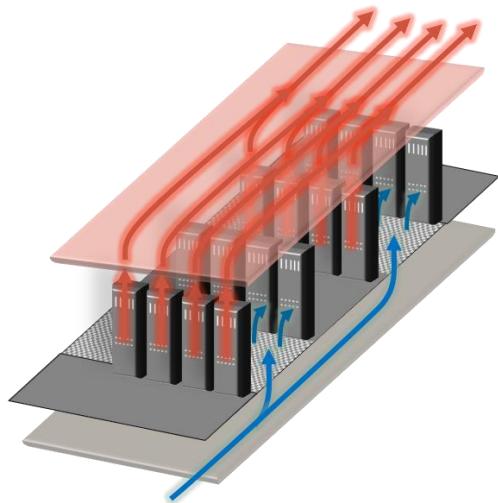
9.1 MISSING GRAPHICAL TOOLS?

Various tools are available to create diagrams, charts, and infographics. With a limited budget, we should use tools that are either free or part of our installed software package.

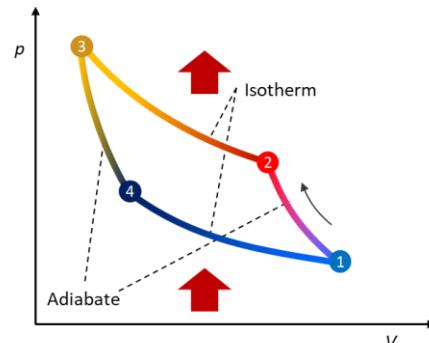
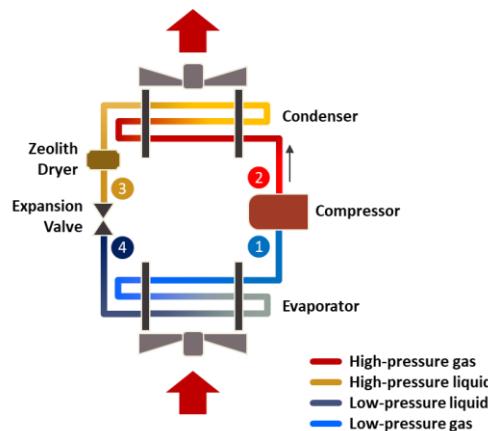
An underestimated companion that is easily accessible for creating graphics is Microsoft PowerPoint. To create diagrams and graphics of various kinds, we can use PowerPoint as it provides a series of built-in features identical to Microsoft Word. PowerPoint offers multiple shapes and icons to create visually engaging graphics. It also includes features like animation, transitions, and text formatting, allowing to customise diagrams, charts, and infographics. The following examples show a few illustrations created with PowerPoint.

*Microsoft PowerPoint
as graphics tool*

Illustrations help to understand a text.



Infographics are easy to remember.



Schemes are outstanding supporting elements.

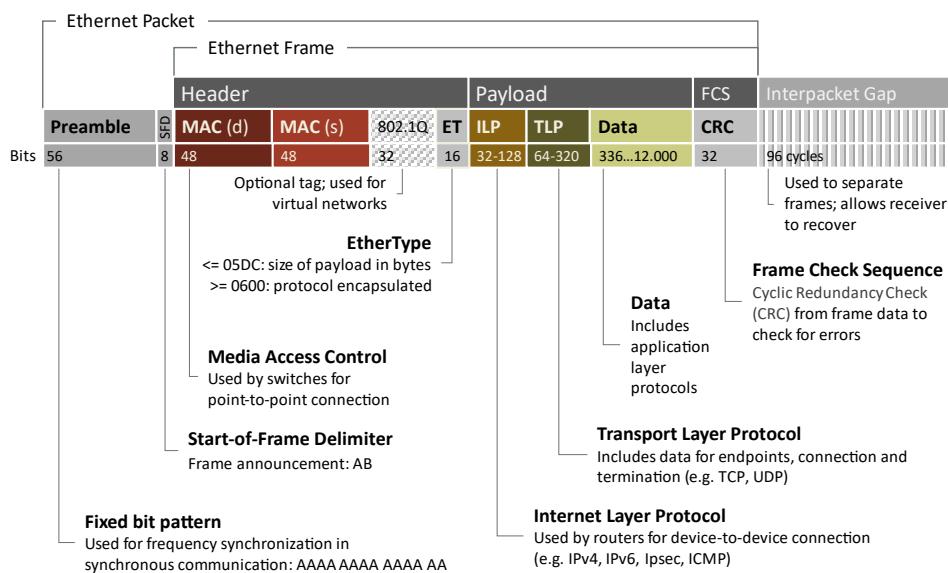


Figure 9.1 Illustrations created with Microsoft PowerPoint. Above a raised floor system in a data centre. In the middle an ideal reverse Carnot cycle. At the bottom, components of an Ethernet packet.

Copy & Paste – The enemy of quality?

Most teachers consider copy-and-paste functions “evil” because they encourage unhesitatingly taking over content from third-party sources. Copy and paste carries the risk of plagiarism, as extracting material from the Internet and forgetting about giving proper credit to the original author is easy. However, we can avoid this by using it thoughtfully.

It is good practice to separate graphics creation from text writing. It allows for focused attention on each task and enables the utilisation of specialised skills in both visual design and written expression. Use PowerPoint as your generator and container of illustrations and copy them into the text document. The best practice is to paste graphics as pictures. The image format ensures the graphics remain as designed, for example, keep the same aspect ratio.

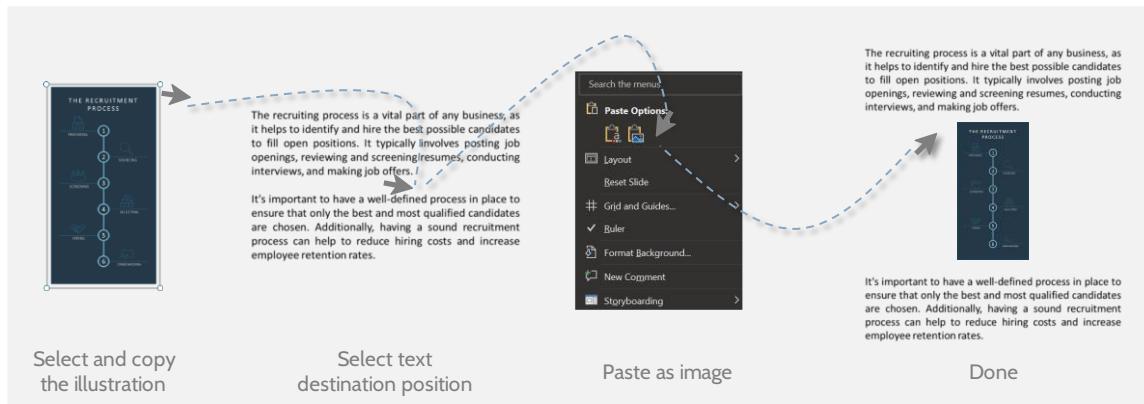


Figure 9.2 Copy and paste as image

9.2 PRESENTING PRIMARY AND DERIVED DATA

Primary data are the ones that you obtain during your research, such as answers to questionnaire items, answer frequencies, interview transcripts, observation field notes, and results from measurements. Such primary data must be available to the reader to assess your results.

Depending on your university's regulations, you can provide primary data in the text, in the appendix, or as an electronic file attached to the printed version. In the latter case, you note this in your research design section.

Provide primary data to follow up on your results.

However, if you miss providing your primary data, your thesis fails. The primary data provided by the writer of a thesis is essential for demonstrating the validity and accuracy of the research. Additionally, primary data allows readers to verify the research results for themselves and helps to increase transparency in academic research.

We present primary data best in tables and figures. You will subsequently apply the methods for data analysis described in the *Research Design* section to the results to gain derived data, such as a statistic. The following chapters guide you to the best practices of data presentation.

9.3 THE GOOD, THE BAD AND THE UGLY

The title of Sergio Leones' epic Spaghetti Western¹⁹¹ refers to regular appearances of results in theses. We want *good*, but we see *bad* and sometimes *ugly* results presentations. Can you explain why the latter two diagrams in Figure 9.3 (next page) are bad and ugly? Look at what is missing and readability.

The impact of bad and unattractive visuals, such as poorly designed charts and graphs, can be significant communication. Visuals are meant to enhance understanding and retention of information, but when they are unclear, cluttered, or aesthetically unappealing, they can have adverse effects. In the context of data presentation, confusing or inaccurate charts can lead to misinterpretation, causing misinformation and potentially poor decision-making. The failure to convey information effectively can also undermine trust in the source of the data, impacting the credibility of the presenter.

Furthermore, ugly visuals can hinder audience engagement and retention. Human beings are naturally drawn to appealing visuals, and aesthetically pleasing charts and graphs can make information more memorable. In contrast, ugly visuals can cause disinterest and cognitive dissonance, making it difficult for the audience to focus on the content being presented. This lack of engagement can result in missed opportunities to convey important messages or to persuade and inform the audience effectively.

Conversely, visually appealing graphics have the power to enhance understanding and engagement. Clear and aesthetically pleasing visuals not only attract attention but also facilitate easier comprehension of complex information.

When charts are thoughtfully designed with proper labelling, suitable colour schemes, and easy-to-follow visual hierarchies, they can efficiently communicate data. Such well-structured visuals can aid in highlighting trends, patterns, and relationships within the data, enabling viewers to make more informed interpretations. Moreover, they tend to capture the audience's interest and maintain their attention, which is crucial for effective communication and retention of information.

¹⁹¹ Original title: Il buono, il brutto, il cattivo (Sergio Leone, 1966)

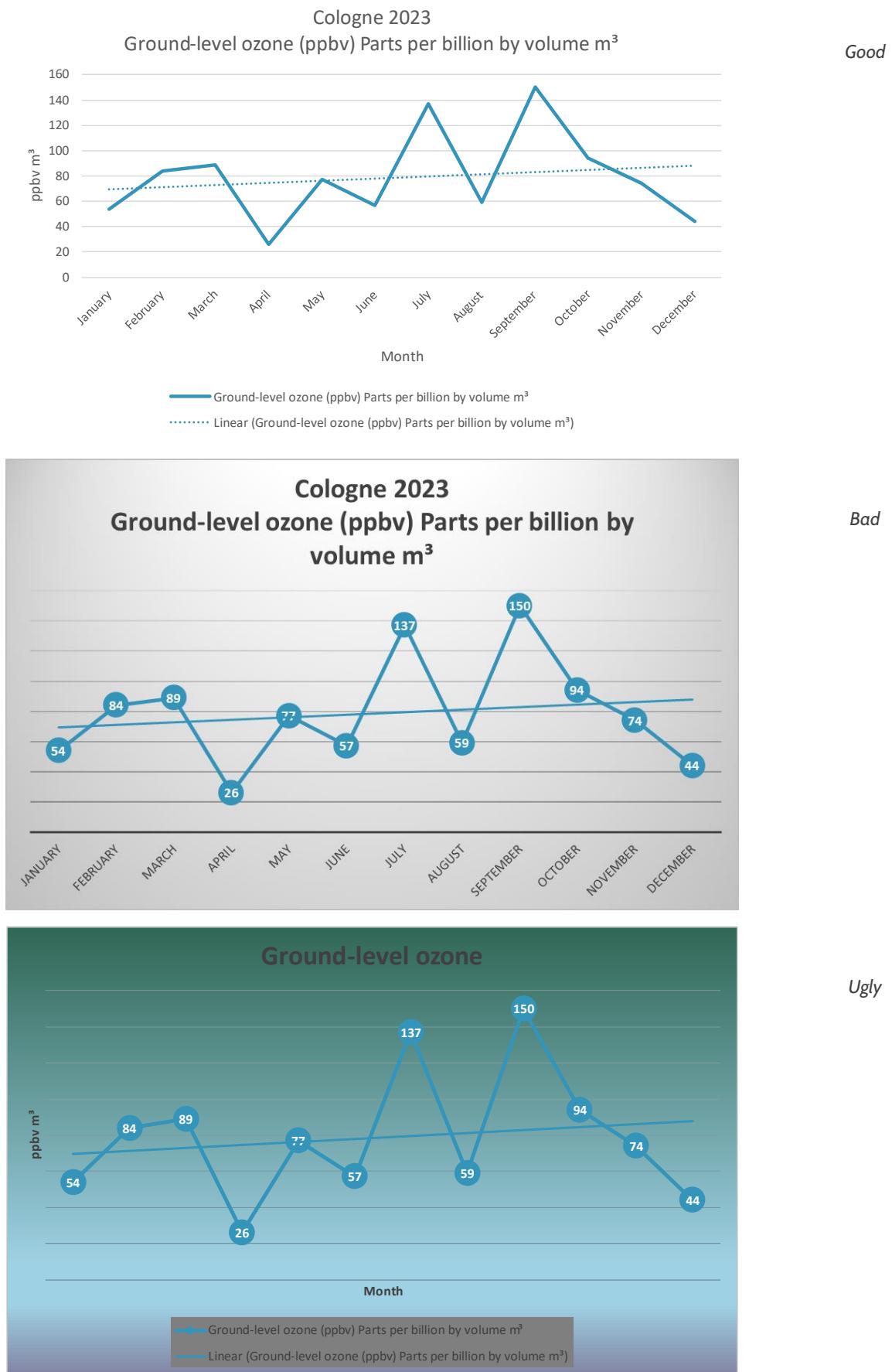


Figure 9.3 Examples of good, bad, and ugly diagrams

Text and visuals belong together.

Combining text and visuals in a thesis is vital because visuals help to illustrate and explain complicated concepts and ideas that may be difficult to understand solely through the written word. Visuals can also help to engage readers and stimulate their interest in the research topic. Visuals also provide readers with additional context for understanding the material, which can help them comprehend the information presented in the text. Finally, visuals can provide an organised structure to the thesis that can help readers keep track of the various components of the research. An excellent visual says more than a thousand words.

To select the correct visualisation, we must look at the nature of our results. Simple and complex results have different visualisation needs.

9.4 SIMPLE AND COMPLEX RESULT TYPES

There is an analogy for understanding result types to use data types, for example, in programming languages such as Python.¹⁹² Figure 9.4 explains the commonalities.

The following subchapters describe how to achieve a *good* presentation based on the type of results.

9.4.1 Simple Result Types

Understanding the nature of your results and your intention for what you would like to demonstrate will guide you to the best visualisation of your data. The following paragraphs describe simple result types and their visualisation.

Textual Results

The quality of the text is as important as the visualisation.

Textual results are the written results of a research project. They typically include summaries of data, analysis, and conclusions.

The best practice in a thesis to visualise textual results is using a combination of running text, tables, graphs, and diagrams. These can help convey information more concisely and visually appealingly, allowing readers to understand the results quickly. We use tables to summarise data and show relationships between variables, while we can create graphs and diagrams to visualise trends and correlations.

¹⁹² (python.org, 2023)

		PROGRAMMING	RESEARCH
		DATA	RESULTS
SIMPLE	SIMPLE	Simple data types include integers, floats, strings, and Booleans Simple data types are single values	Simple result types are data representing textual, numerical, graphical, and process results Simple result types describe results from a simple context with limited aspects
	COMPLEX	Complex data types are collections of multiple values such as a list of integers or a dictionary of strings and floats Complex data types include lists, tuples, dictionaries, and sets	Complex result types use a combination of simple results to create a presentation that provides an overall picture of the situation. Complex results are of descriptive, prescriptive, development and informal nature Complex result types describe multiple results from a context with a variety of aspects
COMPLEX	SIMPLE	Complex data types are collections of multiple values such as a list of integers or a dictionary of strings and floats Complex data types include lists, tuples, dictionaries, and sets	Complex result types use a combination of simple results to create a presentation that provides an overall picture of the situation. Complex results are of descriptive, prescriptive, development and informal nature Complex result types describe multiple results from a context with a variety of aspects
	COMPLEX	Complex data types are collections of multiple values such as a list of integers or a dictionary of strings and floats Complex data types include lists, tuples, dictionaries, and sets	Complex result types use a combination of simple results to create a presentation that provides an overall picture of the situation. Complex results are of descriptive, prescriptive, development and informal nature Complex result types describe multiple results from a context with a variety of aspects

Figure 9.4 Analogy of Simple and Complex Data Types in Programming and Simple and Complex Result Types in Research

Visual structuring of text is not only a domain of graphs and diagrams. Besides tables, we can use optical structuring techniques for text.

Optical structuring techniques for text include

- the use of headings and subheadings to denote different sections or levels of information,
- indentation or bullet points to highlight key points or create a hierarchical structure,
- paragraph breaks to separate distinct ideas or topics and
- using formatting options such as bold or italics to emphasise important terms or phrases.

Additionally, carefully arranging sentences and paragraphs to create logical flow and coherence within the text can contribute to effective visual structuring of the content.

1.1 Interview Results

The results of the interviews conducted with the study participants suggest a strong correlation between the degree of physical activity and mental health.

...

The interviews conducted with the study participants revealed a **positive correlation between physical activity and mental health**. Those who engaged in more physical activity reported higher positive mental health outcomes, such as improved mood, increased focus and concentration, and reduced stress. Physical activity can help release endorphins, natural chemicals in the brain that can improve one's overall mood. The research shows that regular physical activity is linked to reduced levels of depression. Moreover, physical activity can help to improve one's self-esteem and sense of well-being.

...

5.8 Survey Results

The survey results showed that most respondents were in favour of implementing more sustainable energy technologies in their communities.

...

Sustainable energy technologies such as solar, wind, and geothermal energy can provide clean and renewable sources of energy that reduce carbon emissions and help protect the environment. This survey revealed that most respondents are in favour of implementing more sustainable energy technologies in their communities. This supports the idea that people are increasingly aware of the need to transition away from non-renewable energy sources and towards more renewable and sustainable options.

Figure 9.5 Example of textual results

Numerical Results

Numerical data only seem to be easy to visualise.

In research, numerical results are the numerical output. They could be quantitative data or statistical results. We visualise numerical results differently, such as graphs, charts, or tables.

For example, a thesis on the effects of air pollution on public health could include numerical results showing the average air quality of an area over time. This could be visualised using a line graph, showing the changes in air quality over time.

Table 3. Ground-level ozone concentrations in 2023

Month	Ozone (ppb/ m ³)
January	24
February	81
March	19
April	99
May	126
June	130
July	117
August	52
September	5
October	103
November	147
December	0

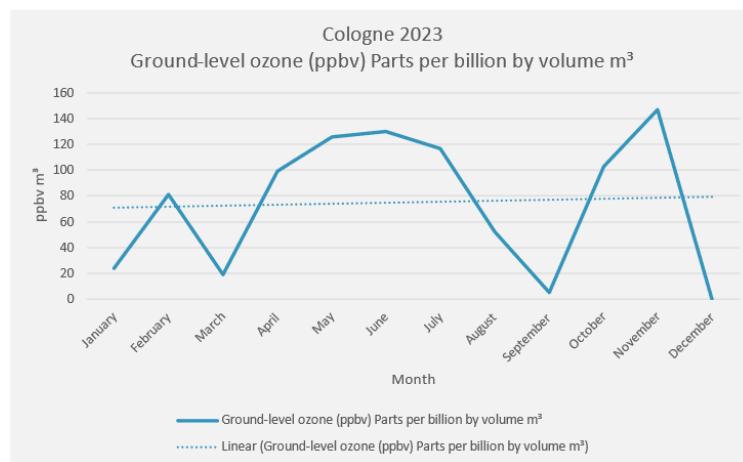


Figure 15 Example data table visualisation by a line graph

Figure 9.6 Numerical results example

Graphical Results

Visuals stay, and the text disappears.¹⁹³

Graphical results are visual representations of data or information. To illustrate findings and explain concepts in an engaging and accessible way, we use visualizations. Cases of graphical results include charts, diagrams, and maps. Let us have a look at two examples.

Bar graph

A bar graph illustrates the percentage of survey respondents responding positively to a question.

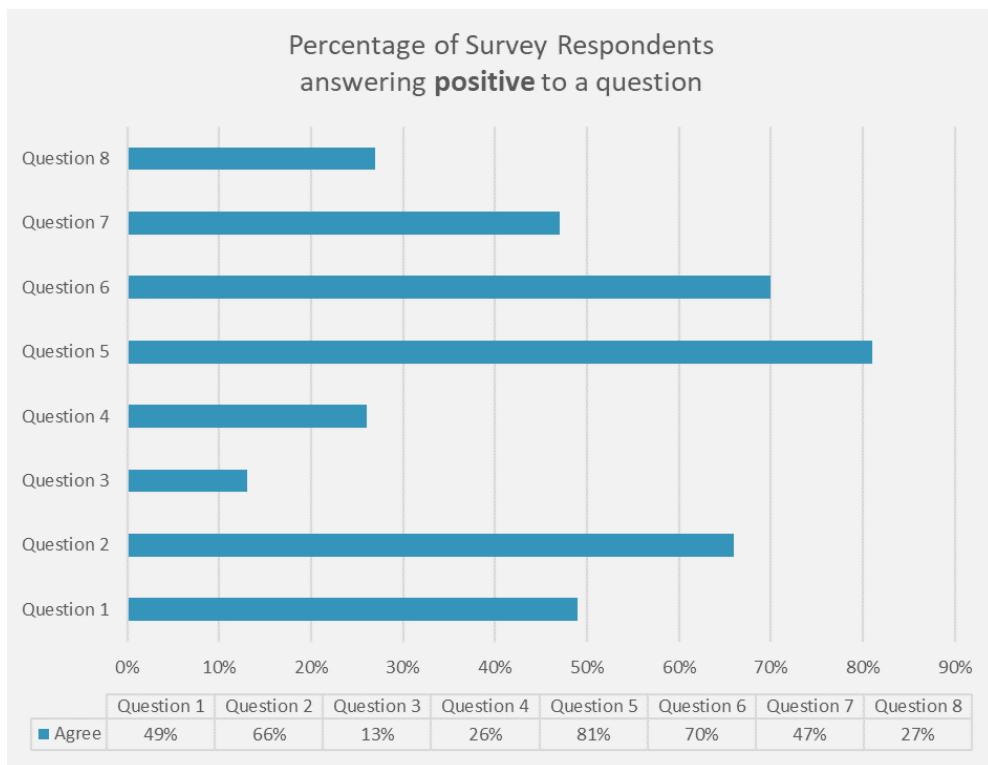


Figure 9.7 Bar graph showing respondent fractions

Pie chart

A pie chart illustrates the breakdown of different categories of expenditures for a particular budget.

Process Results

Processes have significant impacts. So does their illustration.

Process results in a thesis are the findings of a research process, such as data analysis or literature synthesis. We can visualise process results in a variety of ways. Let us have a look at two examples.

¹⁹³ Analogy to the Latin phrase "verba volant, scripta manent" translates to "spoken words fly away, written words remain."

Graphs

We use graphs to demonstrate trends and patterns in the data. For example, a chart can show the correlation between two variables or display the average response to a survey question.

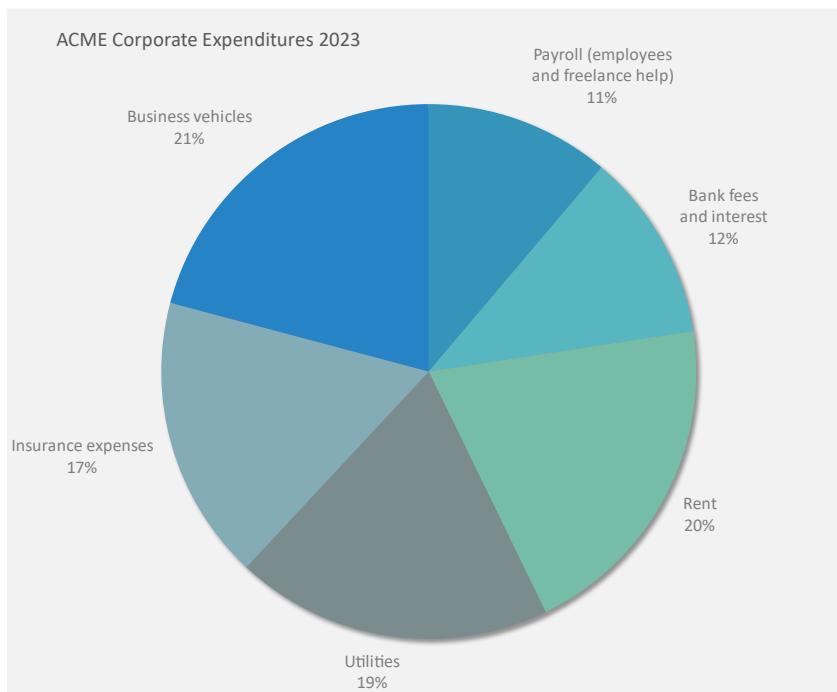


Figure 9.8 Pie chart breakdown

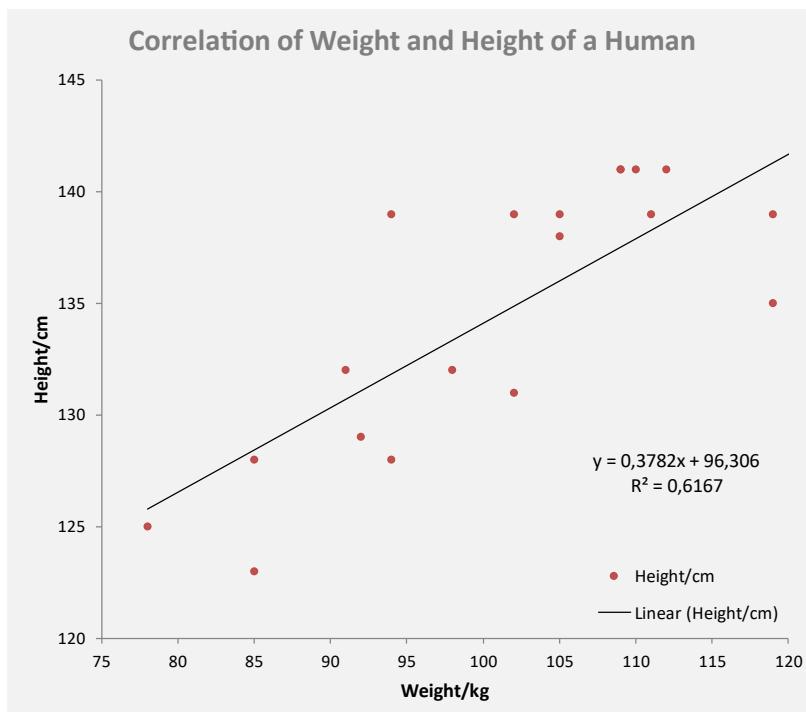


Figure 9.9 Correlation of two variables

Infographics

Infographics are visual representations of data that use symbols, images, and text to convey information. They can be used to illustrate complex data understandably or to present the results of a survey or focus group in an eye-catching way.

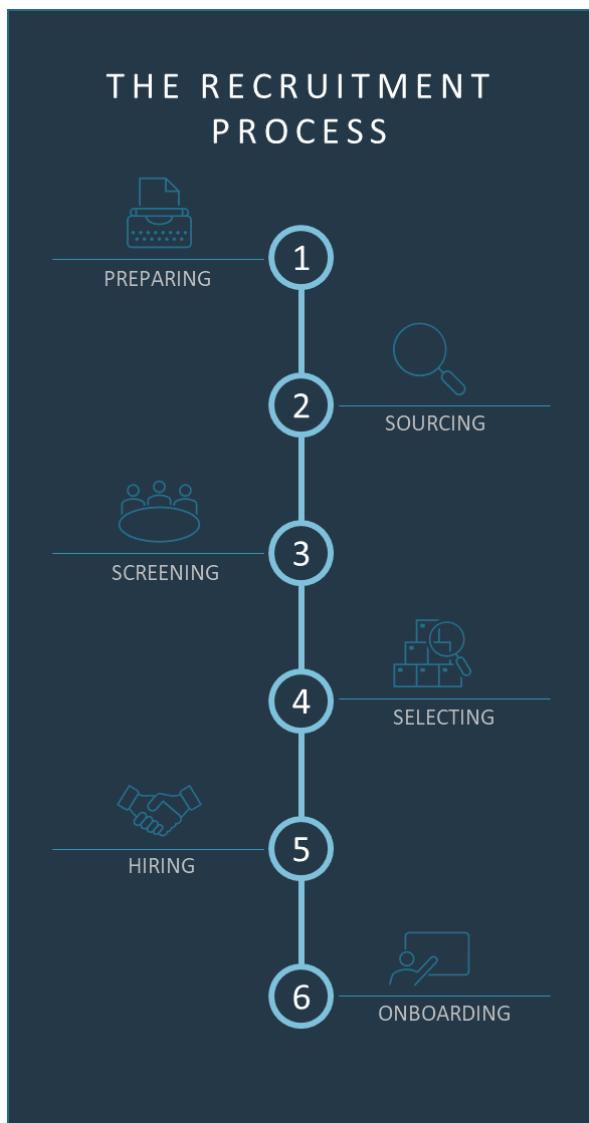


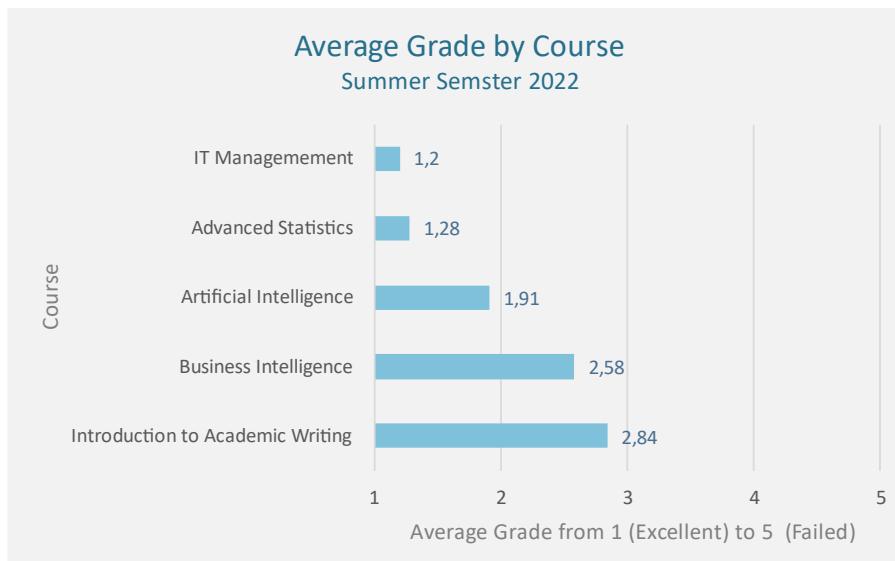
Figure 9.10 Infographic for a recruitment process

9.4.2 Complex Result Types

Complex result types combine simple results to create a presentation that provides an overall picture of the situation. The following paragraphs explain the nature of complex results using descriptive, prescriptive, development, and informal categories.

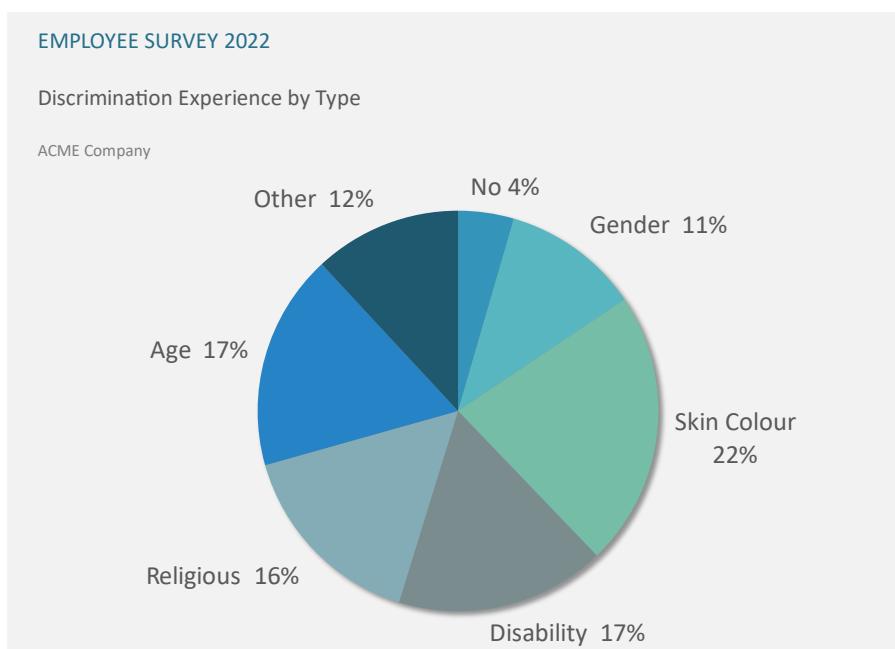
Descriptive Results

A thesis's descriptive results are results used to describe the data collected from a research study. Descriptive results are usually presented in tables, charts, and graphs to provide an uncomplicated way to visualise and understand the data. Descriptive results may include the mean, median, mode, and standard deviation. Let us have a look at two examples.



Bar graph

Figure 9.11 A bar graph showing the average grades of students in a particular course.¹⁹⁴



Pie Chart

Figure 9.12 A pie chart showing the percentage of people in a particular age group who have experienced different types of discrimination.

¹⁹⁴ The different bars are sorted to support the message to convey. In this case, the author wants to show the performance courses from best to worst.

Prescriptive Results

Illustrating the right choice

Prescriptive results in a thesis are solutions and recommendations to address a problem or a challenge. We present these results based on the research and analysis conducted for the thesis. Visualising prescriptive results can help to illustrate the solutions and make them easier to understand. Examples of visualising prescriptive results include flowcharts, diagrams, tables, and graphs. Let us have a look at two examples.

Flowchart



Figure 9.13 A flowchart illustrating the steps required to implement a new process

Table

Table 9.1 A table comparing the options for a garage customer for solving a severe motor problem

<i>Solution</i>	<i>Cost</i>	<i>Repair Time</i>	<i>Pro</i>	<i>Con</i>
Repair Engine	€2000	2 days	Fast and inexpensive	The repair warranty is limited to the repaired parts and not to the engine as a whole.
Replace with Refurbished Engine	€4000	5 days	The replacement engine is newer, and the warranty is not limited to parts	Acceptable repair time but higher costs.
Replace with New Engine	€6000	15 days	New engine with the best warranty	Long repair time and highest costs.

Development Results

In general, a thesis is a document that presents the author's research, findings, conclusions, and developments on a particular subject. Developing something new in a thesis can involve collecting, analysing, and interpreting data from multiple sources to draw conclusions and support the author's argument. It can also include introducing a new concept, system, methodology, or theoretical framework. There are many ways to illustrate the outcomes. Here are two examples.

Graphs are a way to visualise the results of a new technique. For example, you can use a graph to compare the results of a new approach against existing methods or to show the improvement in accuracy or speed of the new design.

Graphs

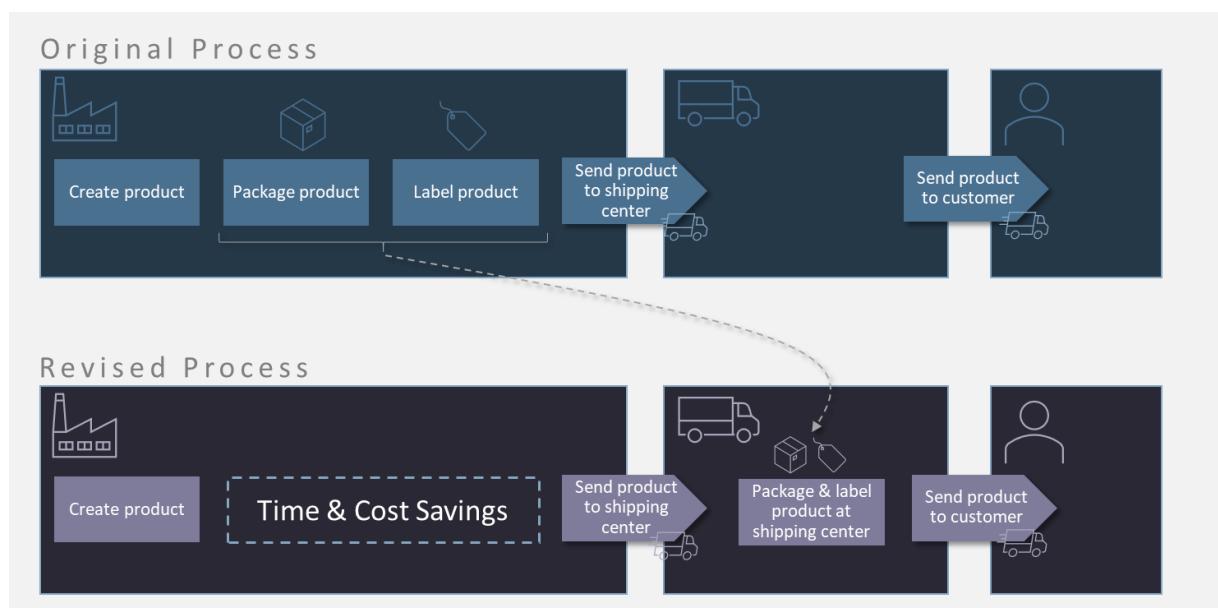


Figure 9.14 Comparison of the original and revised process with time and cost savings. The revised process is a speed improvement because it eliminates the need to package and label the product at the factory, which saves time by allowing the shipping centre to do this instead.¹⁹⁵

Heat maps are a way to visualise the results of a new technique. Heat maps show the areas of improvement or highlight the areas of weakness in the new approach compared to existing methods. Heat maps also show the relative performance of the different regions of the technique.

Heat Maps

¹⁹⁵ Did you recognise the icons in the graph? The icons are from PowerPoint's built-in *Insert→Icons* menu. Simple icons help to illustrate graphs without dominating them.



Figure 9.15 Heatmap created with Excel's *Conditional Formatting* feature.¹⁹⁶

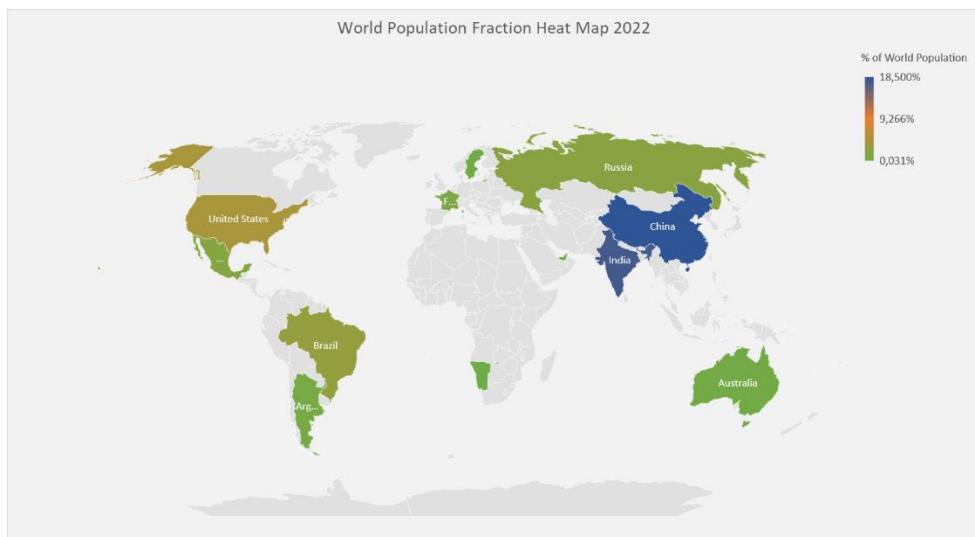


Figure 9.16 World Population Fraction Heat Map¹⁹⁷

¹⁹⁶ Miss something? Yes, in this example, the legend for the colours is missing. You are getting better. It is a 3-colour scale with the midpoint at percentile 30.

¹⁹⁷ Created with Excel. Example provided by (Microsoft Corp., 2023).

Informal (Infographic) Results

Infographics are visual representations of data or information. They are often used to convey complex information in an easily understandable way. Infographics help present results in a thesis because they can quickly and concisely communicate large amounts of data and help the reader understand the results better. They can also break up text and add visual interest to the thesis.

Timeline

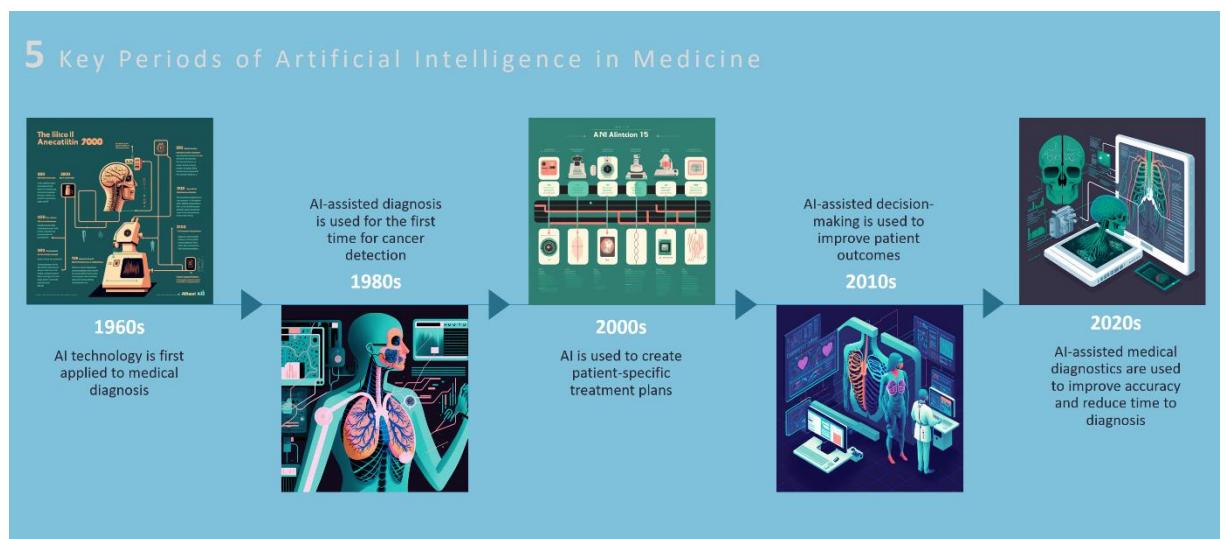


Figure 9.17 Timeline Infographic

Venn Diagram

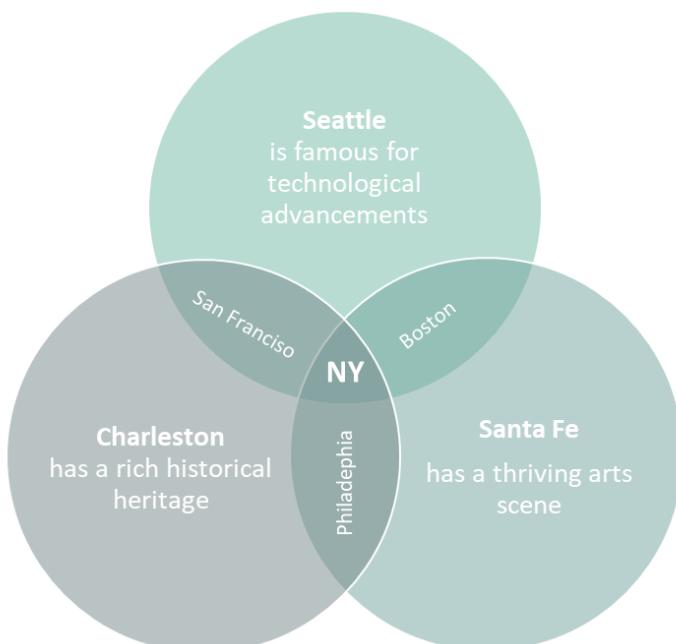


Figure 9.18 Venn diagram comparing research results about "Best places to live in the US" and their intersections.

9.5 TABLES

Tabular results support understanding. Tables are an essential component of a thesis and serve several purposes. There may be a misconception that tables are inherently dry and uninteresting and that design elements are unnecessary or distracting. However, effective table design can help to make complex data more accessible and engaging to readers and can help to reinforce key messages and arguments in the thesis.

The quality of table design in a thesis is sometimes underestimated and neglected for several reasons. One reason is a lack of formal visual communication or information design training. Authors often do not fully appreciate the importance of good table design in effectively conveying information. Additionally, they focus too much on the textual content rather than the presentation of their data and do not prioritise the design of their tables. Here are some aspects of tables.

To present data

We use tables to present numerical or quantitative data clearly and in order. Tables can help readers quickly understand the data, compare data sets, and identify patterns or trends.

To summarise the information

You also use tables for summarising information, such as the results of experiments, survey responses, or other research findings. Tables help to condense large amounts of information into a more manageable format.

To provide context

Tables provide context for other parts of the thesis, such as graphs or figures. For example, a table may provide the raw data used to create a chart, allowing readers to better understand the underlying data and the presented trends.

To support arguments

Tables support the arguments or conclusions of the thesis. For example, we use a table to show statistical significance or correlations between variables and provide evidence to support a particular hypothesis or claim.

To enhance readability

Finally, tables can help enhance the thesis's overall readability and organization. By breaking up large amounts of text with clear and concise tables, readers can more easily navigate and understand the presented information.

9.5.1 Tips for Better Readability of Tables

Here are some tips for improving the readability of tables in your thesis:

Tips for creating tables

- Keep the table simple and uncluttered. Avoid including unnecessary information and focus on presenting the important data that support your argument.
- Use a clear and readable font, and ensure the text is large enough to read easily. Use a consistent font and size throughout the table.
- Use a consistent format for the table, including consistent spacing, alignment, and borders.
- Use headings and subheadings to label and organise the data in the table. Consider using colour or boldface to highlight important information.
- Avoid using vertical lines in the table if they do not improve readability.
- If necessary, use shading or colour to highlight important information or groups.
- Ensure that the table number is referenced in the text and provide a clear and concise caption that summarises the content of the table.
- Use tables sparingly and strategically, and only include them when they add value to your thesis.

9.5.2 What is Easier to Read?

Simplicity is essential for reading a table because our brains cannot process information at any given time. When presented with complicated or cluttered information, our brain must work harder to process the data, which can lead to mental fatigue and decreased comprehension. On the other hand, when presented with simple and easy-to-read information, our brain can quickly process the data, allowing us to understand better and retain the information given. Let us check this by example.

Try to find the negative numbers in the two example tables and tell what table revealed its secret more easily.

Table 9.2 Example of a hard-to-read table (without units for instructional purposes)

Sample	Fixed acidity	Volatile acidity	Citric acid	Residual sugar	Chlorides	Free SO ₂	Total SO ₂
1	74	7	0	19	76	110	340
2	78	88	0	26	98	250	670
3	78	76	4	23	92	150	540
4	112	28	56	19	75	170	600
5	74	7	0	19	76	110	340
6	74	66	0	18	-75	130	400
7	79	6	6	16	69	150	590
8	73	65	0	12	65	150	210
9	78	58	2	20	73	90	180
10	75	5	36	61	71	170	1020

Table 9.3 Example of a well-designed table (without units for instructional purposes)

Sample	Fixed acidity	Volatile acidity	Citric acid	Residual sugar	Chlorides	Free SO ₂	Total SO ₂
1	74	7	0	19	76	110	340
2	78	88	0	26	98	250	670
3	78	76	4	23	92	150	540
4	112	28	56	19	75	170	600
5	74	7	0	19	76	110	340
6	74	66	0	18	-75	130	400
7	79	6	6	16	69	150	590
8	73	65	0	12	65	150	210
9	78	58	2	20	73	90	180
10	75	5	36	61	71	170	1020

Easy to read and understand

Additional recommendations

For the optimal presentation of tables in a thesis, authors should adhere to the following recommendations:

- **Avoid unnecessary lines:** Extraneous lines can detract from readability. Therefore, use only those lines necessary to separate and delineate columns and rows.

- **Consistent alignment:** Text within cells should have uniform alignment. Usually, numeric data are right-aligned, while textual data are left-aligned.
- **Appropriate capitalisation and formatting:** Table headers should follow a consistent capitalisation style, either sentence case or title case. The chosen format should be maintained throughout the thesis.
- **Font size:** The text within tables should be of readable font size, ensuring the content is clear and easily discernible without straining the reader's eyes.

9.6 CHART TYPES

The quality of charts and diagrams in theses is crucial since they should ease the understanding of the message behind data or information. Authors use charts and graphs to illustrate and demonstrate a point, helping readers to comprehend the material more clearly. Although this sounds easy, inexperienced authors often struggle with selecting the right chart type.

Andrew Abela¹⁹⁸ created a classification of charts to help authors select the correct diagram for their results presentation. We use this classification for your orientation. Every chart has a function related to what you want to demonstrate. Figure 9.19 illustrates types and functions.

The following figures present a selection schema based on logical classifications, helping you select the adequate chart to show your results.

To learn more about visualising quantitative information, refer to "The Visual Display of Quantitative Information" by Edward R. Tufte¹⁹⁹. It is an excellent resource for anyone learning to visualise quantitative data effectively. Here are a few key recommendations based on the book:

Show the data

Tufte emphasises the importance of showing the data clearly and concisely. Avoid using unnecessary chart elements distracting from the data and focus on presenting the information straightforwardly.

¹⁹⁸ (Abela, 2013, pp. 186-194)

¹⁹⁹ (Tufte, 2001).

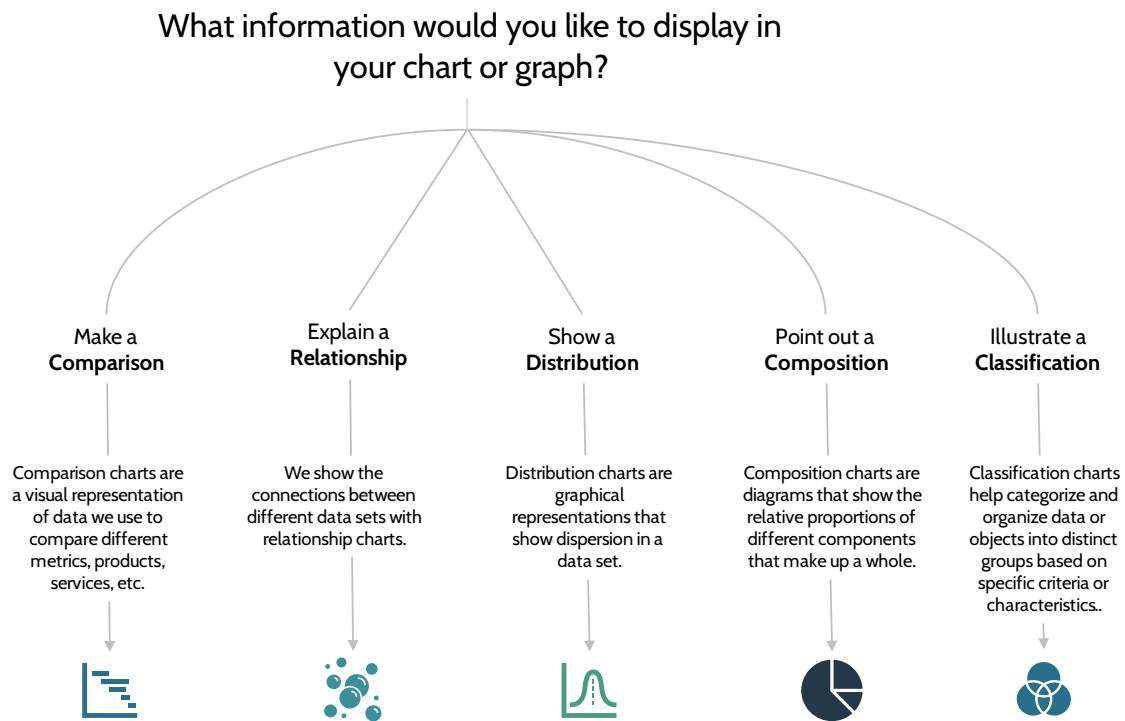


Figure 9.19 Basic types and functions of chart types

Use a variety of chart types

Tufte encourages the use of a variety of chart types to represent different types of data. For example, a line chart may be more appropriate for showing trends over time, while a bar chart is better for comparing values between different categories.

Maximise data-ink ratio

Tufte suggests that the amount of ink used to display data should be maximised while minimizing the ink used for non-data elements. This approach can help to simplify the chart and make the data more prominent.

Label clearly

Clear labelling of the chart elements helps viewers understand the data. Use concise and descriptive labels that are easy to read and understand.

Aim for simplicity

Tufte advocates for simplicity in the design of charts and recommends removing unnecessary elements that do not add value to the presented data.

Primary goal — Dynamics — Variables / Periods — Items / Cyclicity — Chart

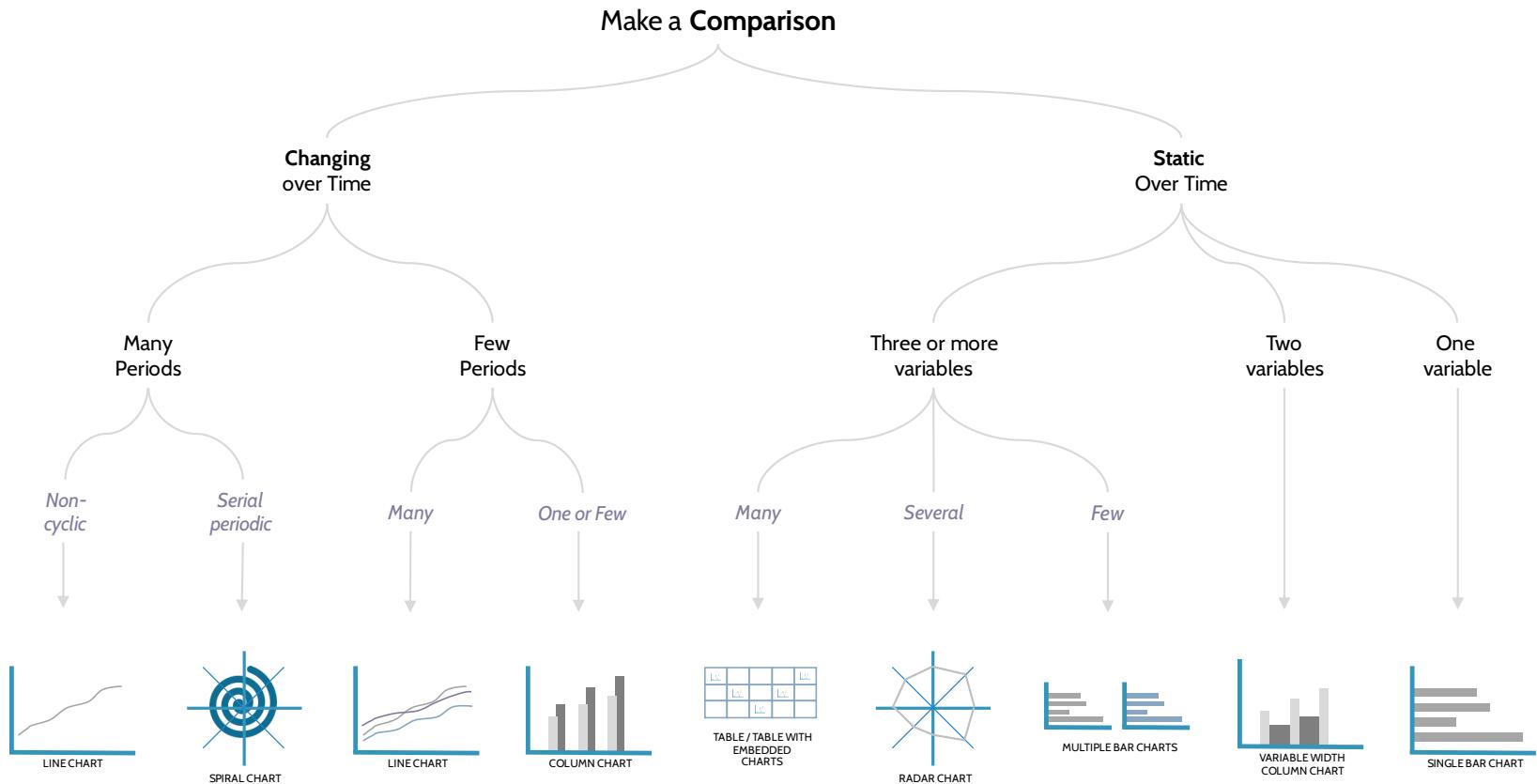


Figure 9.20 Comparison chart selection (adapted from Abela, 2013, pp. 186-194)²⁰⁰

²⁰⁰ For visualisation of serial periodic data see (Carlis & Konstan, 1998)

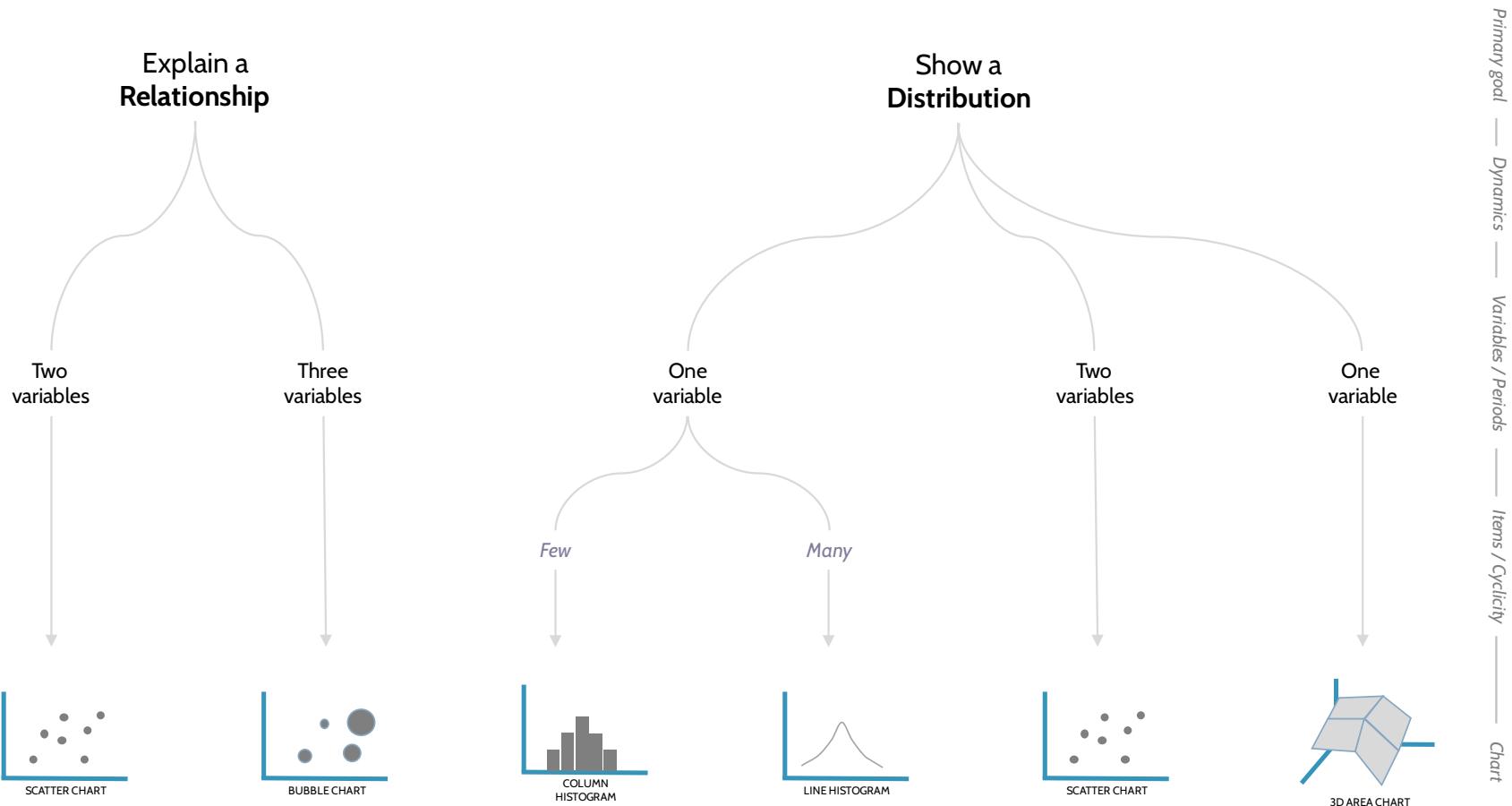


Figure 9.21 Relationship and Distribution chart selection (adapted from Abela, 2013, pp. 186-194)

Primary goal — *Dynamics* — *Variables / Periods* — *Items / Cyclicity* — *Chart*

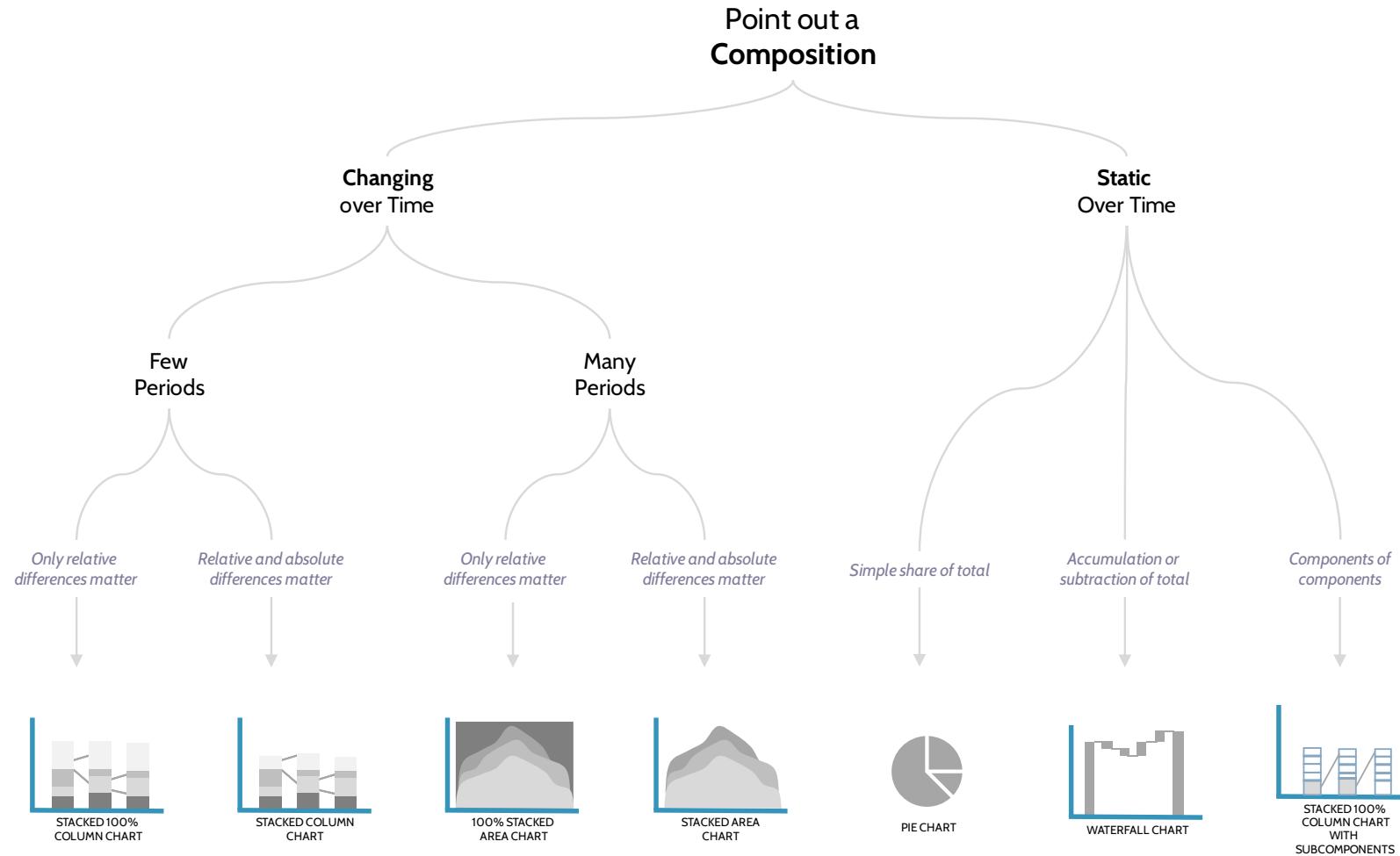


Figure 9.22 Composition chart selection (adapted from Abela, 2013, pp. 186-194)

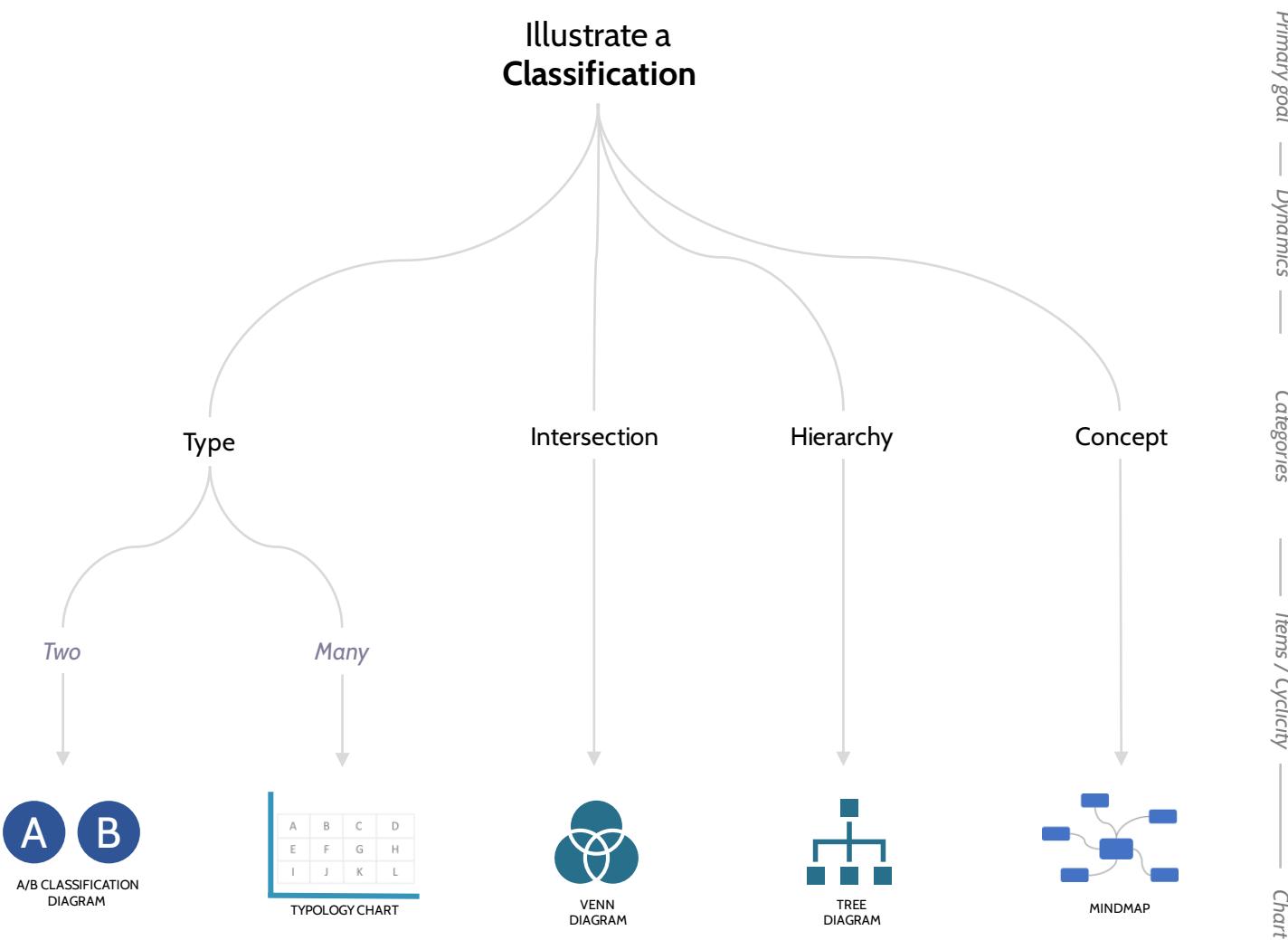


Figure 9.23 Classification chart selection

9.6.1 Comparison Charts

Comparison charts are a visual representation of data we use to compare, for example, different metrics, products, services, features, pricing, or performance of two or more items. Comparison charts make it easier to see the differences between objects. Ideally, they help to derive knowledge through interpretation and can help make decisions. Following are a few examples of comparison charts.

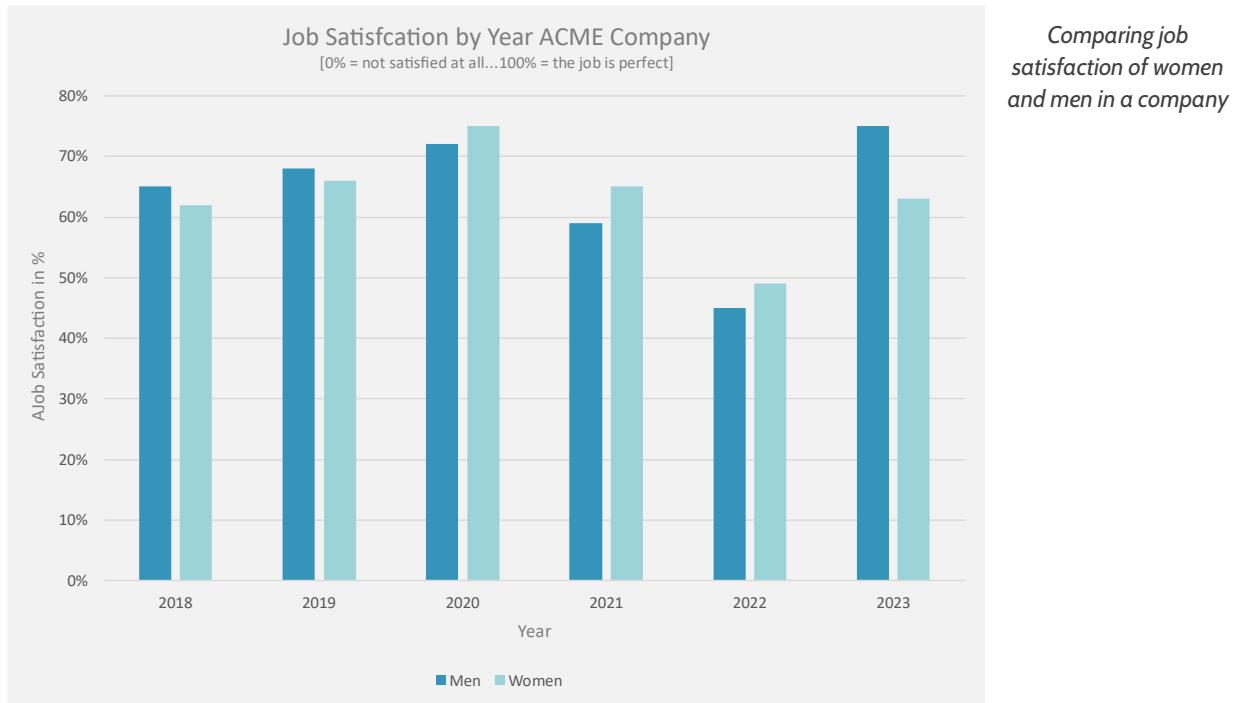


Figure 9.24 Comparing job satisfaction in a company

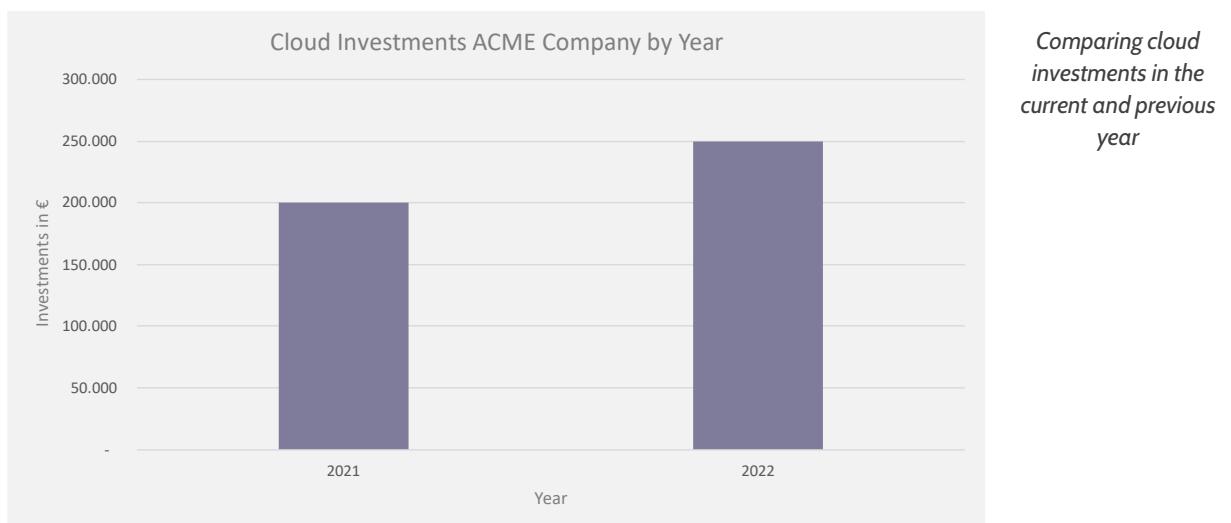


Figure 9.25 Comparing cloud investments in the current and previous year

Comparing multiple risks for quality, cost and time of a project

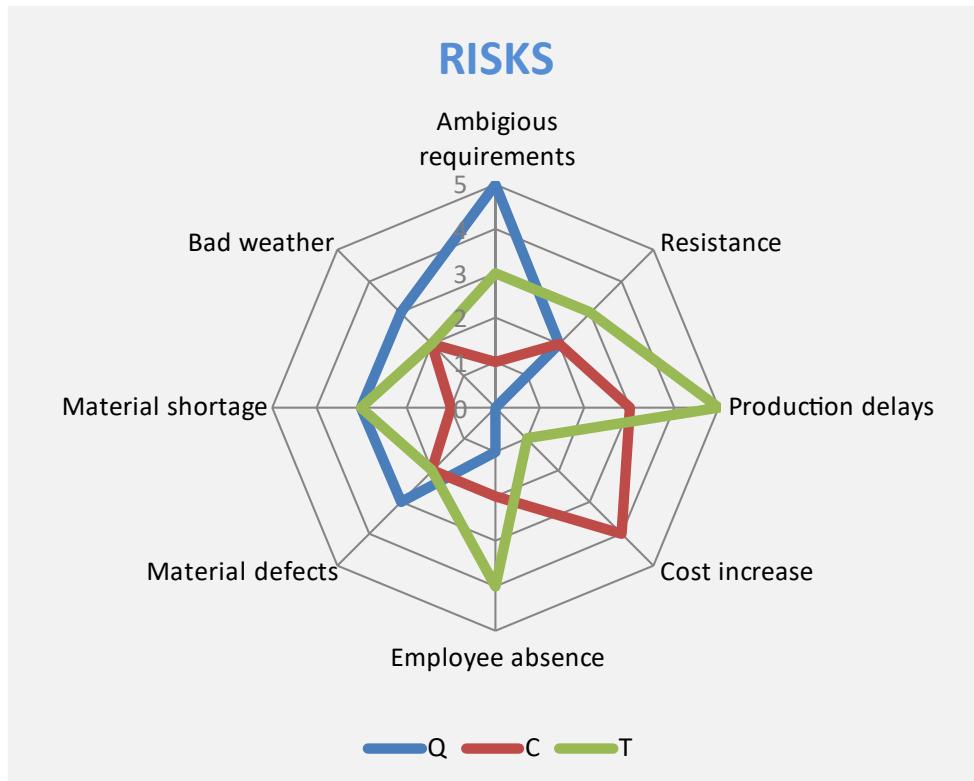


Figure 9.26 Comparing risks for quality (Q), cost (C) and time (T)

9.6.2 Relationship Charts

We show the connections between different data sets with relationship charts. These charts are diagrams that show how two or more entities are related to each other.²⁰¹ In business, we use them to display the connections between, for instance, departments and employees or to map out the relationships between customers and companies. The chart type selection depends on the number of variables in the data. Scatter plots are suitable for bivariate (two-variable) data sets. Bubble charts are adequate for trivariate (three-variable) data sets. For multivariate data, relationships can be illustrated using techniques such as parallel coordinate plots, heatmaps, or 3D scatter plots, which allow for the visualization of multiple variables simultaneously, enabling the analysis of complex relationships and patterns within the data. The two following examples illustrate relationship charts.

²⁰¹ Comparison charts highlight the similarities and differences between different entities or variables, while relationship charts emphasize the connections, associations, or dependencies between entities or variables.

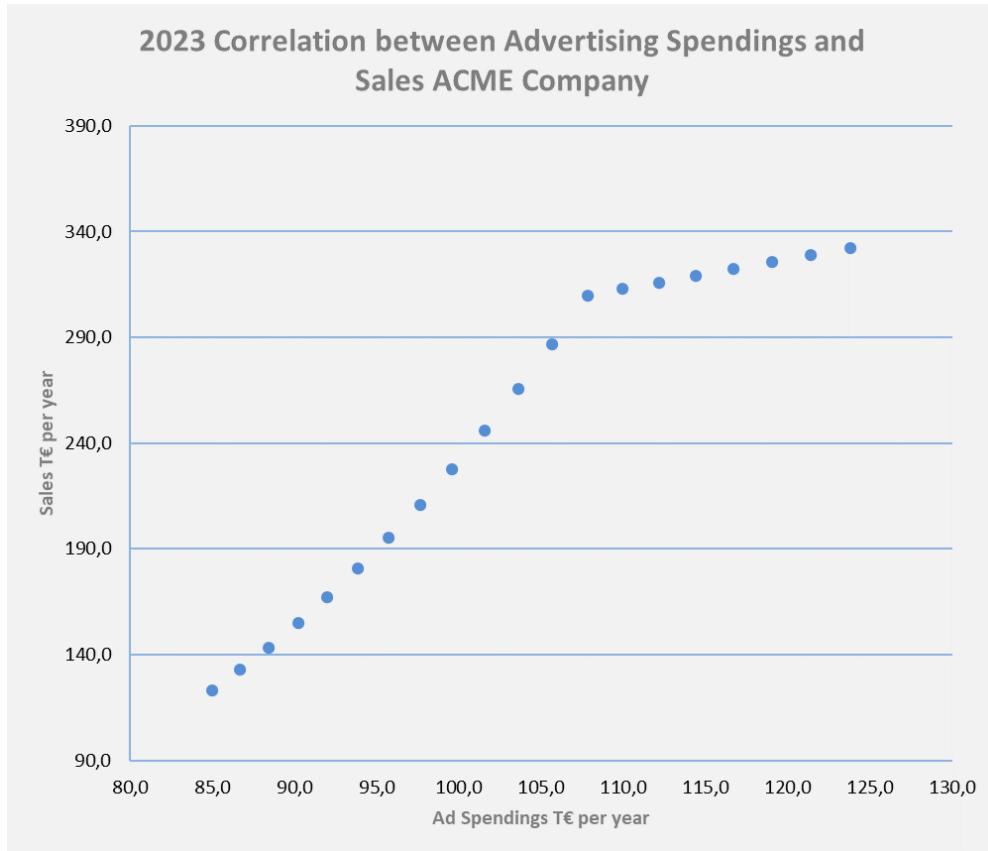


Figure 9.27 A scatter plot illustrates the relationship between two variables (bivariate data)

Scatter plots help to understand the relationship between two variables where each tuple (x and y) may be an independent measurement. Three variables are better displayed using bubble charts.

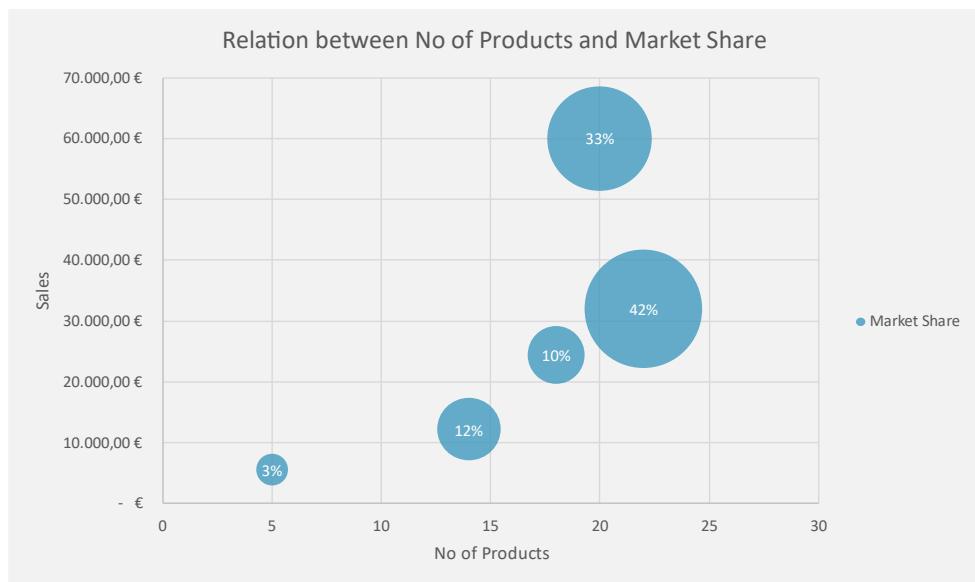


Figure 9.28 A bubble chart illustrates the relationship between three variables (trivariate data)

Where to use scatter plots

9.6.3 Distribution Charts

We use distribution charts to compare data sets, analyse trends, and identify outliers. Distribution charts are graphical representations that show data spread in each set. They use bars, histograms, pies, and lines to illustrate the variability and distribution shapes within the data. The following are two examples of distribution charts.

Price ranges customers are willing to pay for a specific smartphone

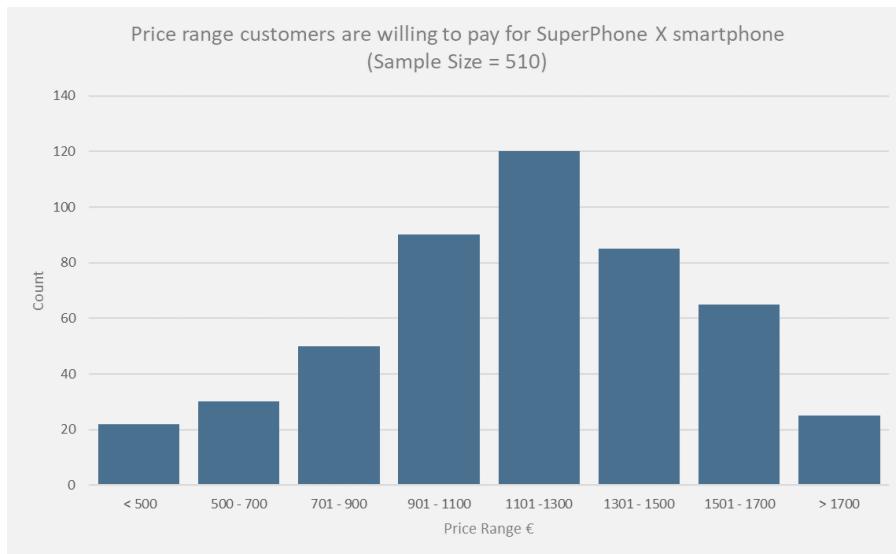


Figure 9.29 A price range customers are willing to pay for a specific smartphone

An error range for the prediction of specific cluster memberships

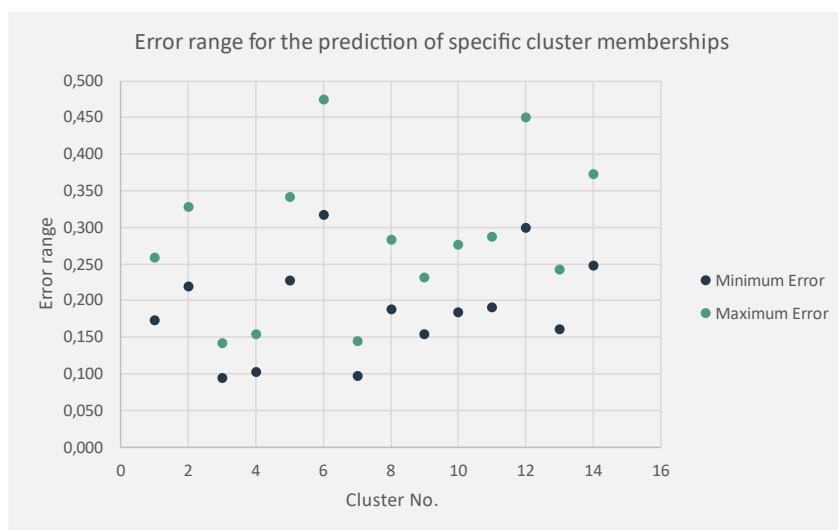


Figure 9.30 An error range for the prediction of specific cluster memberships²⁰²

²⁰² Often asked: A scatter plot depicts individual data points to represent the relationship between two variables, whereas a line chart connects data points in sequence, often used to illustrate trends over a period.

9.6.4 Composition Charts

Composition charts are diagrams showing the relative proportions of components that comprise a whole. All parts must sum up to 100%. Composition charts visually represent the various elements of a mixture or compound. They also compare the relative proportions of different ingredients in a recipe or recipe mix. The following examples show different types of composition charts.

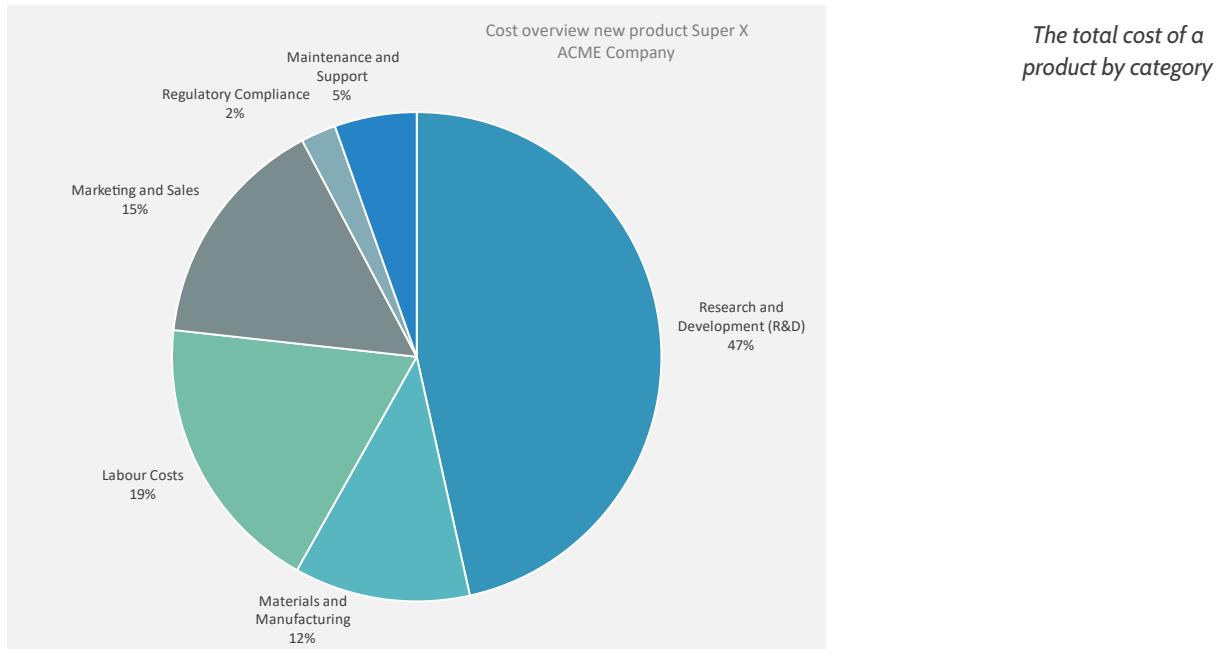


Figure 9.31 The total cost of a product by category using a pie chart

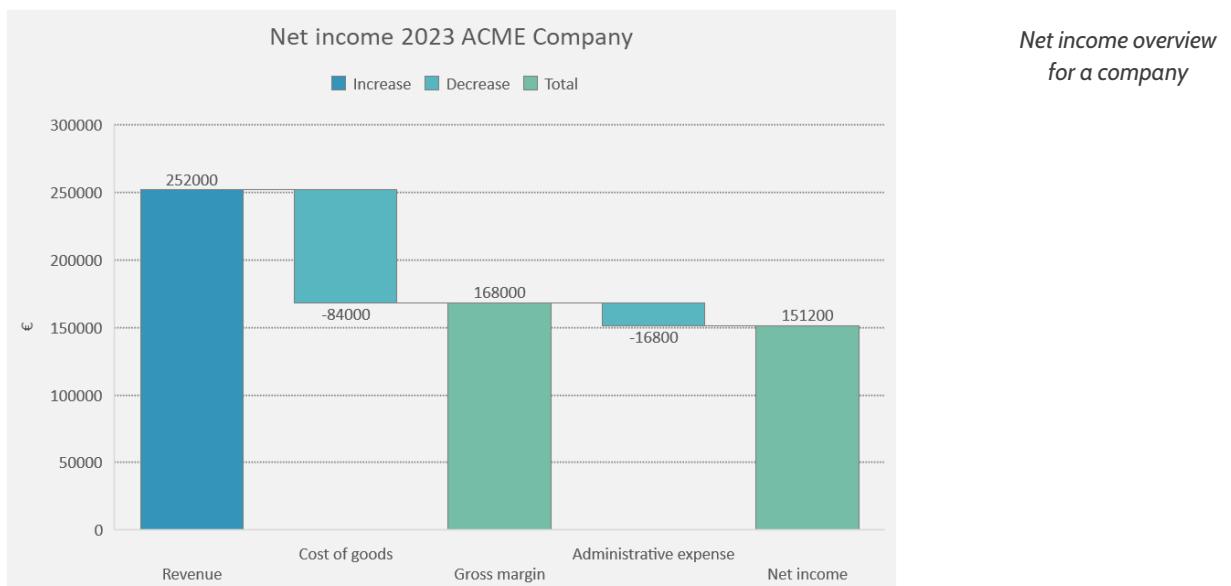


Figure 9.32 Net income overview for a company using a waterfall diagram

9.6.5 Classification Charts

Classification organises data into meaningful groups

Classification charts may help to visualise a systematic and intuitive approach to understanding complex relationships and hierarchies among data.

A/B Diagrams bifurcate data or concepts into two types, elucidating dichotomous classification. They are often employed where a binary data division is pertinent to the investigation.

Typology Charts facilitate the organization of multiple categories or types. They are instrumental in showcasing diverse data classes and providing a clear picture of the variations within a dataset.

Venn Diagrams represent intersectionality among different sets, thereby identifying commonalities and divergences. They are handy in situations where we need to visualise overlapping classifications.

Tree Diagrams depict hierarchical relationships, presenting a tiered data classification from general to specific or parent-to-child categories. They are most effective when illustrating nested categories or hierarchical data structures.

Mind maps allow for a comprehensive illustration of concepts and their interconnectedness, enabling the visualisation of complex relationships in an easy-to-understand manner. You can use them for brainstorming, planning, or summarising concept information.

The following examples show different types of classification charts.

A mind map for an online marketing strategy

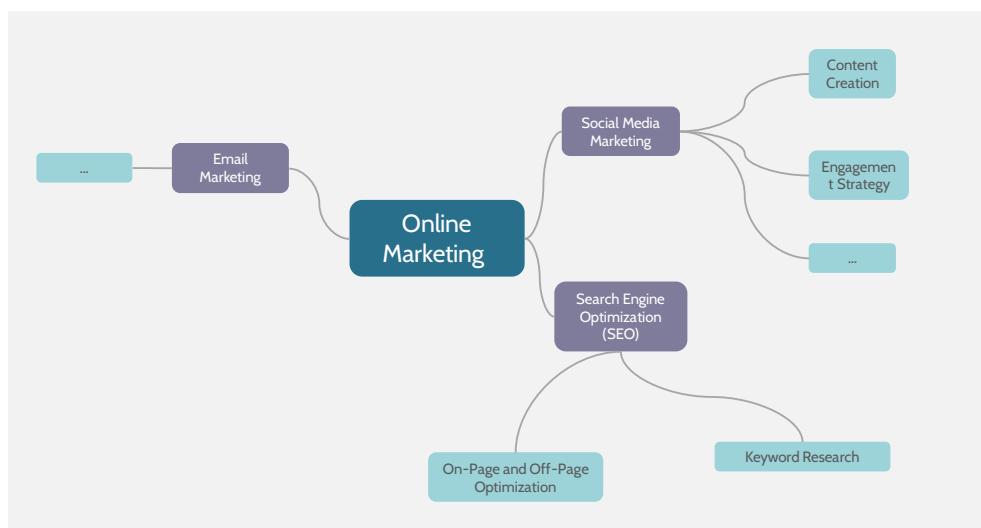


Figure 9.33 Extract of a mind map for an online marketing strategy

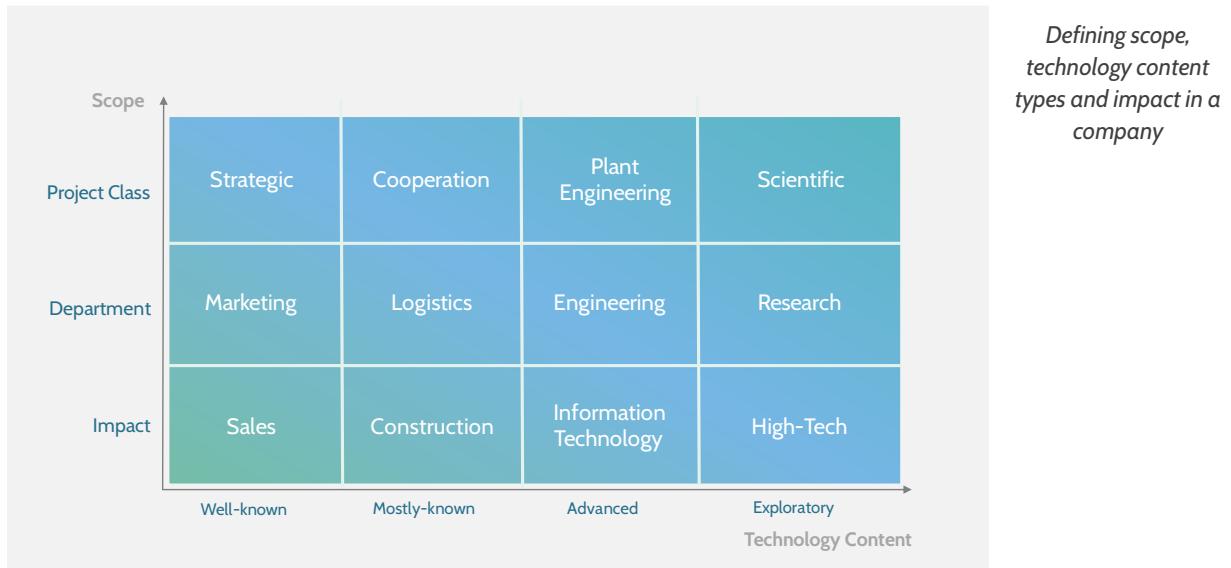
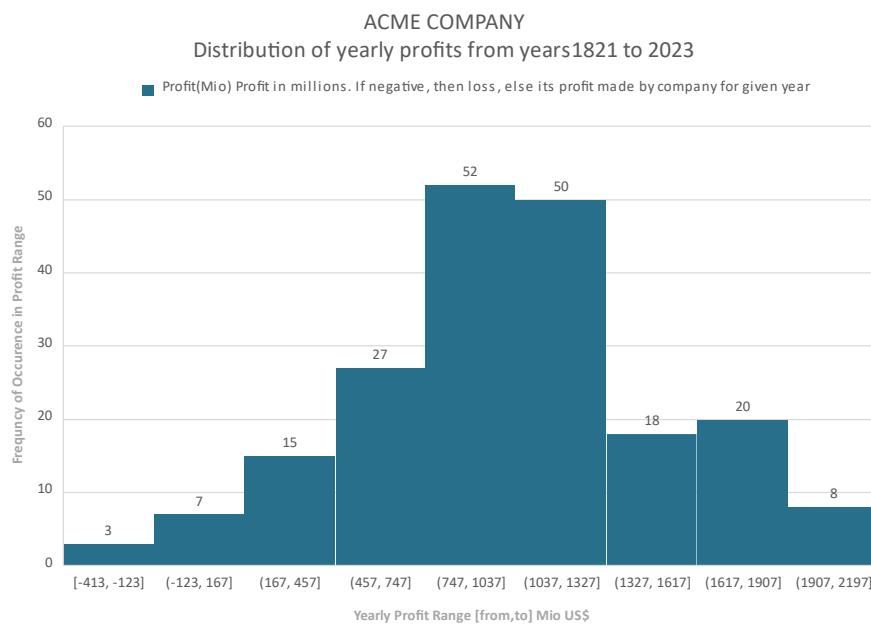


Figure 9.34 Typology chart for scope and technology content

9.6.6 What Chart Elements are Expected?

A chart should include a title, axis labels, data points, and a legend (if applicable). The most common flaws of charts include using too few or too many colours, confusing or inappropriate chart types, failing to label the data points, and providing too little or too much information. If you are unsure what elements a reader expects, follow the checklist in Table 10.3. As an exercise, check the following chart for completeness.

Readers have expectations.

Figure 9.35 Example distribution chart²⁰³

²⁰³ Raw data set from (TinaSoni, 2023)

9.7 SOURCE CODES

The source code helps to illustrate development.

Incorporating source code in academic theses has become increasingly prevalent, primarily due to the pervasive influence of computation and data analysis in various research disciplines. The digital revolution has transformed research methodologies, with many fields now relying heavily on computational models, data analytics, machine learning algorithms, and software development.

Consequently, these computational processes' source code is vital to research and development²⁰⁴. Including source code in theses not only increases the transparency and reproducibility of the research but also serves as a detailed record of the methodologies employed, facilitating better understanding and further development. This trend reflects the evolving nature of academic research in the digital age, where source code has become as integral to the thesis as traditional text-based content.

Readers may use the source code to reproduce experiments and analyse data. Additionally, source code can provide valuable insights into how a specific algorithm or system works or how it can be extended or improved.

Including source code in a thesis can effectively demonstrate your research or development. Source code can show the implementation of the algorithms and techniques you have researched and discussed in your thesis.

To incorporate source code into your thesis, you must format the code consistently and use a citation style to reference the source code correctly. You can also have screenshots or diagrams to demonstrate the program's output or performance.

9.7.1 Monospace Fonts

Monospaced fonts enhance source code readability.

It is best practice to use monospace (non-proportional) fonts with a fixed character width since they retain the indentation and original format of the development software. They make the listing easier to read and understand.

Here are a few examples of monospace fonts (name and look):

Consolas

Lucida Console

Courier

An excerpt of a Python code listing using the Consolas font family is shown below.

²⁰⁴ Source code functions as both research and development because it encapsulates the computational methodology employed in research, while simultaneously serving as the basis for creating, testing, and improving software tools and applications used in that research.

```

def pearsons_r(x, y):

    # calculate the means
    x_mean = sum(x)/len(x)
    y_mean = sum(y)/len(y)

    # calculate the standard deviations
    x_std = (sum([(i-x_mean)**2 for i in x])/len(x))**0.5
    y_std = (sum([(j-y_mean)**2 for j in y])/len(y))**0.5

    # calculate the covariance
    covar = 0
    for i in range(len(x)):
        covar += (x[i]-x_mean)*(y[i]-y_mean)

    # calculate the Pearson's correlation coefficient
    r = covar/(len(x)*x_std*y_std)

return r

```

9.7.2 What Code to Show and Where?

There is no rule of thumb on how much code to show to illustrate your program. Below, you can find Table 9.4 with different cases and recommendations that you may consider, assuming source code in the running text is required at all.

Table 9.4 Recommendations for source code listings

<i>Case</i>	<i>Recommendation</i>
Code is short up to a maximum of one page	Insert code completely.
Code is extensive, up to a maximum of four pages	Show code snippets or pseudo code ²⁰⁵ in the text and refer to the Appendix of your thesis. Place the entire code there.
Code is pervasive; more than four pages	Point out already in the research design that the code is available electronically and where it is available, for example, GitHub ²⁰⁶ or download link. Show code snippets or pseudo code in the text.

²⁰⁵ Pseudo code is an informal way of expressing a program or algorithm that uses natural language elements and common programming constructs, such as if-then statements, loops, and assignment operations. It is a way of expressing a program in a more human-readable manner and can be used to help begin coding a program.

²⁰⁶ GitHub is a web-based hosting service for version control using Git. (GitHub, 2023)

9.8 THE WORST PRACTICE

The following (not so seriously meant) examples provide some insights on the skilful use of impressive yet meaningless visualisation.

Types of Visual Distraction

The plain illustration captivates through a targeted use of the figure caption and its unique relationship to the object depicted.



Figure 15. A tube

The exhibitionist illustration – particularly popular among engineers and natural scientists – explains complicated technical issues with an emphasis on a detailed figure number and a comprehensive labelling.

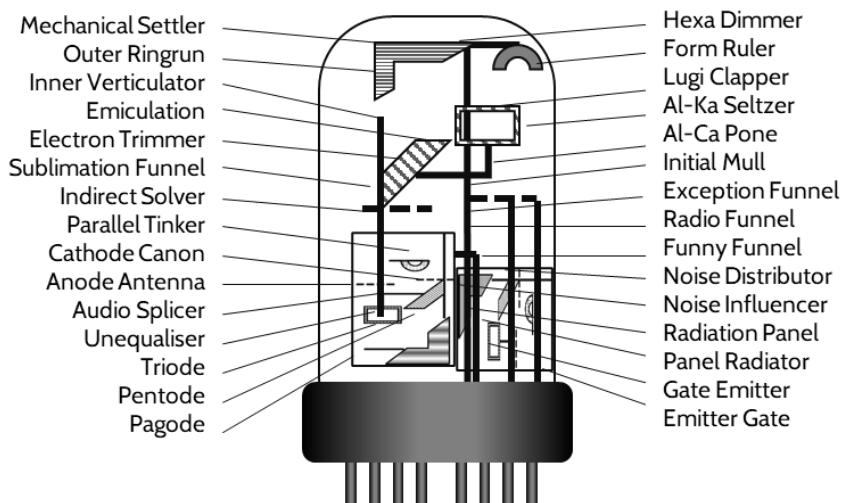


Figure 12.43.3-a. Layout of the regulated form trimmer

If you intend to simplify the figure and focus present the details in the figure captions, you use the **chatter figure**. Although it does not immediately reveal the relationship between the chart and the figure caption, the latter carefully elaborates on the necessary details.

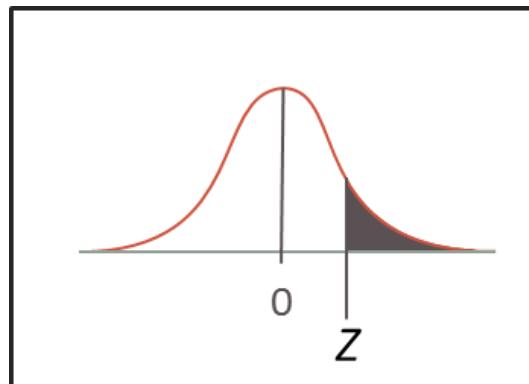


Figure 6. In the Hollmann test, the variable p shows a pronounced dependence of the invention rate with the decision-making ability regarding the balancing parameters ξ and $\zeta(x)$. The values are group-normalised to the base-pair correlation of the alternative hypotheses of Helm's tension environment (own illustration based on Cherwonowitz & Radermacher-Beulen, 2011, pp. 345-632).

The **sloppy illustration**. This self-created graphic shows the talent of the unconventional individualist. Here, care should be taken that the message is not compromised by exaggerated conformism, such as straight lines, even spacing, unique fonts, or spell-checking. The additional note "(Source: own representation)" is dispensable here.

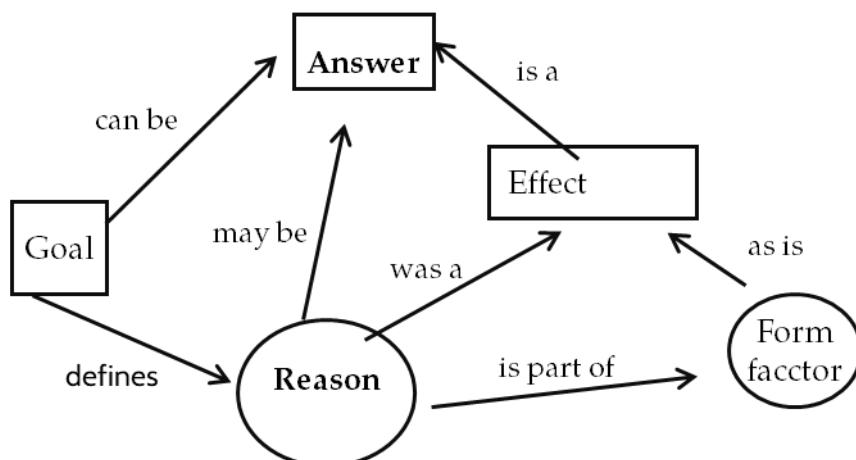


Figure 16. The structural equation model for reasoning

The **conceptual illustration** exhibits an even higher level of abstraction and is favoured in the educational sciences and by sociologists to convey complex relationships between concepts that nobody has heard about before. It emphasises a new terminology and is preferably used in a centred style with font sizes of 24 pt and above.

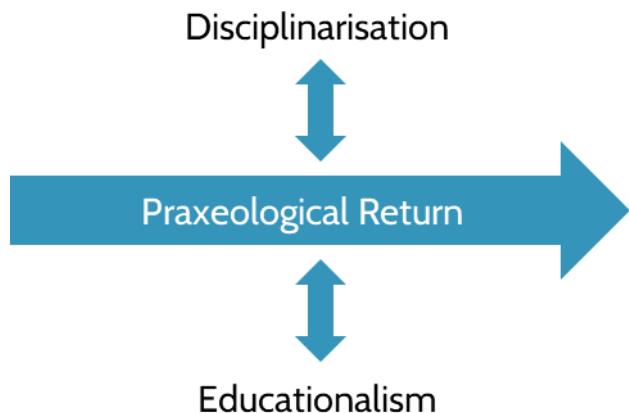


Figure 14. Relationship between disciplinarisation and praxeological educationalism as existential fundamentology of higher ontodeological education.

The **business illustration** is the corresponding variant in business and exists typically in two forms: the cycle and the funnel, both of which reflect the manager's distinct imaginative diversity.

Those captivating funnels and cycles, elegantly devoid of any meaning or charm. They are masterpieces of visual apathy expertly navigate the realm of perplexing ambiguity, where even the most straightforward processes become as clear as the cryptic messages from a fortune cookie. The finesse with which they transform vibrant ideas into visually lacklustre patterns is indeed a stroke of artistic wonder in the world of professional befuddlement.

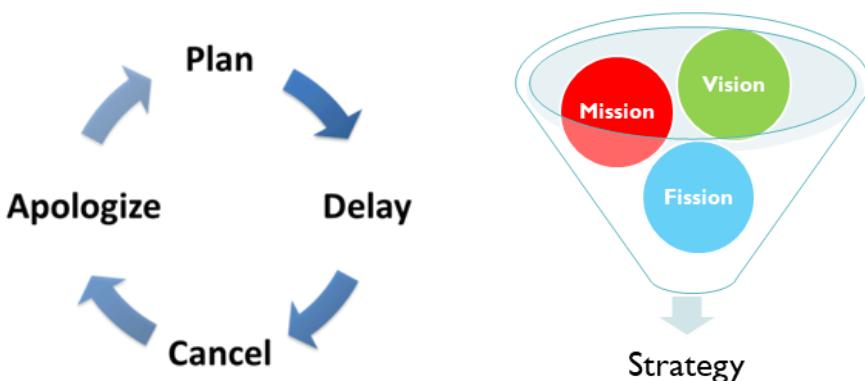


Figure 19. The PDCA cycle (left) and corresponding strategy development (right).

The **excessive pie** is the preferred chart for salespeople to show proportions of more than ten categories that do not add up to 100%.

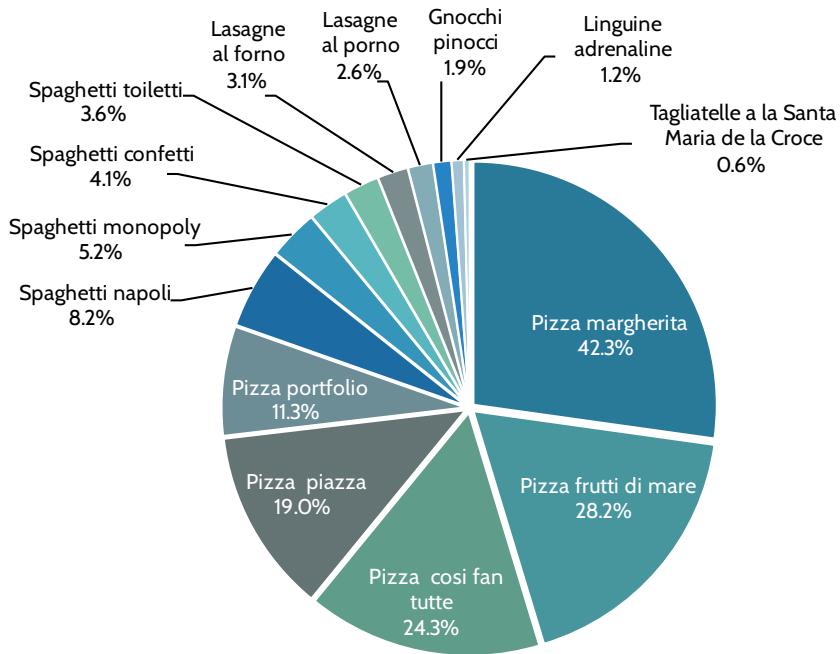


Figure 11. Sales shares for pasta in the last year

The **marketing forecast** chart is characterised by its reliability and accuracy, which are required to adequately inform decision-makers about future investments.

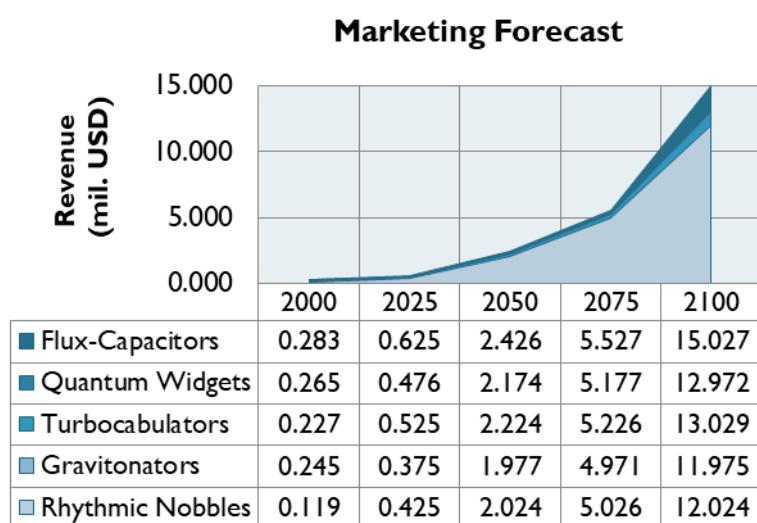


Figure 12. Turnover of the most important product lines in the next hundred years

The **predictive chart** is popular amongst pseudoscientists, conspiracy theorists, and other politicians. Unique characteristics are the innovative starting point of the y-axis and its promising forecasts.

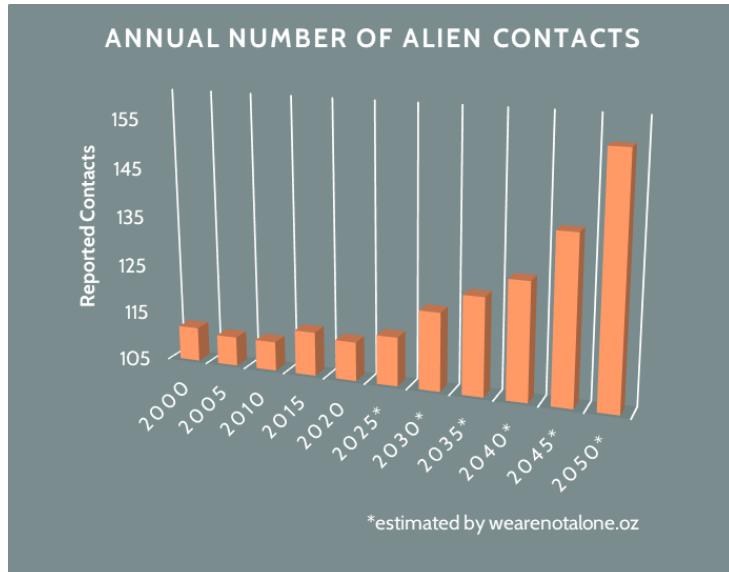


Figure 14. The annual number of reported alien contacts increased dramatically.

The **TV chart** is preferably used by TV senders owned by media tycoons during the election period and serves to reveal critical cause-effect relationships to a broad (and less critical) audience.

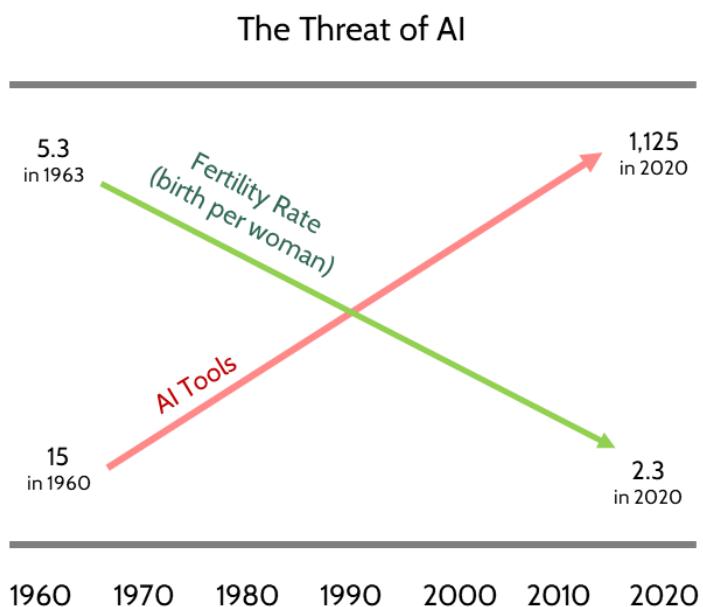


Figure 14. The decreasing fertility rate of women exhibits the threat that AI poses to humankind.

The **representative survey table** shows the inductive relationship between independent and dependent variables in appropriate precision and is perfectly suited for generalising claims.

Table 5. The response to the question of web surfing during sexual intercourse shows that among the divorced respondents, 57.14% admitted sometimes surfing during sexual intercourse; this is 285.71% more than with married couples.

Respondents	Often	Sometimes	Never	Total
Unmarried	2	3	1	33.33%
Married	3	1	1	27.78%
Divorced	-	4	3	38.89%
Deceased	-	-	-	0.00%

The **table for self-guessing** gains exceeding popularity amongst puzzle lovers since neither the table nor its caption confuses with a central message.

Table 6. The relationship between empathy and big data considering the integration of sewing boxes.

	Initial	Vertical	Diagonal	Medial
Risk	High	Affirmed	90%	Yes
Option	High	Certain	60%	Maybe
Qualification	Medium	Certain	80%	No
Sustainability	Low	True	80%	Yes

The **SAP table** is a variant that shines through its condensed presentation in a complete framing of various lines. Note the innovative selection of delightful abbreviations cleverly integrated into the ensemble, reminiscent of the input screens of certain industrial software products.

Table 6. The input data

	Dev.	PT1	Conn.	KP2	Pers. cst.	Mat. cst.	Tot. cst.
Mult. regr. coeff.	115.2522	19.17	?	-	11590.94	5522	17112.94
Cumul. Std. Dev.	112.6302	9.58	?	-	4569.51	5235	10091.51
Var. regul. softw.	46.1231	7.67	0	-	4636.38	12239	16875.38
Correl. coeff.	12.5412	2	2	yes	953.64	392	1345.64

PART III

THE CREATOR'S GUIDE



10 FROM THE IDEA TO THE TOPIC

Curiosity might kill the cat, but it keeps science alive.

The progress of humankind was always a result of someone being curious, raising questions about what was being observed, what was happening, or what people thought about it. Curiosity is the driving force of science.

Consequently, finding a thesis topic – probably the most exciting phase of your academic journey – is driven by you being curious about something. You will explore new territories, discover the unknown and raise unanswered questions. See it as a *Star Trek* episode: you boldly go where no one has gone before.²⁰⁷

You need a starting point, an inspiration that derives from your personal goals and your interest in your study program. Engaging in conversations with professors and fellow students, looking at videos, and reading textbooks or papers will spark first ideas. Inspiration emerges whenever you encounter things that:

- *fascinate* you, such as the performance of quantum computers.
- *make you smile*, such as when rats let out ultrasonic giggles when tickled.²⁰⁸
- you find *peculiar*, such as that male seahorses become pregnant.
- you find *amazing*, such as that a submerged continent exists.²⁰⁹

²⁰⁷ Derived from the famous *Star Trek* tag line at the beginning of every episode (Day, 2005)

²⁰⁸ (Chain, 2016)

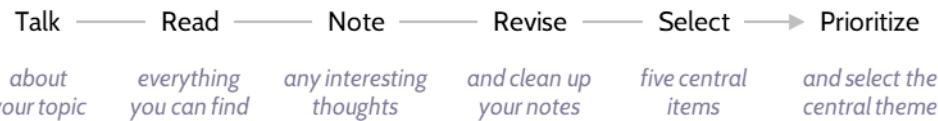
²⁰⁹ (see Mortimer, et al., 2017)

- *arouse your disapproval*, such as the extent of bribery in politics.
- you are *concerned about*, such as climate change.

In any case, you need to generate questions around such inspiration and a strong interest in answering them. Otherwise, the months of thesis writing become an annoying and tedious experience.

10.1 HOW TO GENERATE A TOPIC

Raising questions about inspiration requires a period of discussion and reflection. You could use the following approach:



Firstly, you should *talk* about your idea to anyone willing to listen at any opportunity. And that means anyone, whether a specialist or not. Often, non-specialists contribute questions or statements that a specialist would not have considered.

Besides talking, you *read* everything you can find in your area of interest. Use any source; at this stage, there is no need to concentrate on scientific sources. Take *notes* on anything you find fascinating, amazing, unusual, peculiar, attracts your attention, or arouses your disapproval. Keep notes using your smartphone notes app or a small hardbound notebook you always carry. Don't forget to note the source.

When you arrive at around fifty or more statements, you can *revise* them. Go through your notes and discard the items that are no longer interesting. Among the others, *select* five remaining items, *prioritise* them, and choose one as the central theme. At this point, you should be able to phrase a research topic around the central theme and link the remaining items to it. (see Figure 10.1)

Consider value and audience.

Once you have identified a central theme, ask yourself what its value might be and who would be interested. It would be best if you had an audience that ideally shows the same interest that you have. In our example, the value could be: if we can predict conflicts, we can probably derive conflict prevention and resolution strategies. And this would be interesting for any team manager.

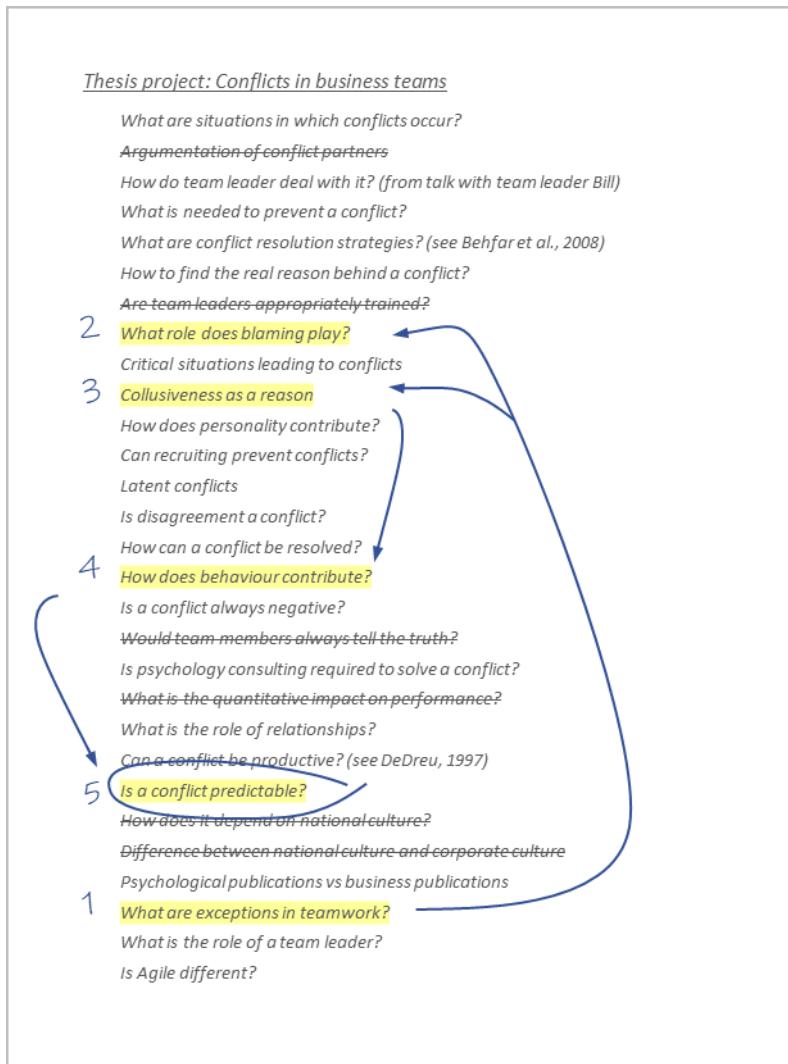


Figure 10.1 Example of notes taken from discussions about conflicts in business teams. After collecting notes, five were selected and prioritised, leading to the central theme: 'Is a conflict predictable?'

Focussing on conflict prediction, you can rephrase the central item to a preliminary topic:

Possibility of conflict prediction in business teams

Keep the remaining items on the list; you might need them later to refine your research objectives.

10.2 FINDING LITERATURE

You now possess a topic and an audience. The next step is to ask what is already known about this topic. At this point, you do a *programmed literature search*, programmed in the sense that you delimit the search to specific

criteria, such as the period and the search terms. Now, you only consider valid scientific sources.

10.2.1 Academic Search Engines

Google is not sufficient. Using a standard search engine (like Google) for searching academic literature does not suffice since most results do not link to reliable information. It would be best to use scholarly search engines that delimit their search to academic texts. Table 10.1 provides examples of scholarly search engines.

Table 10.1 Selected Scholarly Search Engines

Name	Focus	Publisher
BASE - Bielefeld Academic Search Engine	Multidisciplinary	University Library Bielefeld, Germany
CORE Connecting Repositories	Multidisciplinary	The Open University, United Kingdom
ERIC Educational Resources Information Center	Education	United States Department of Education
Google Scholar	Multidisciplinary	Google Inc.
Internet Archive Scholar	Multidisciplinary	Internet Archive
LIVIVO - The Search Portal for Life Sciences	Life Sciences	ZB MED – Information Centre for Life Sciences, Germany
PubMed Central	Life Sciences	United States National Library of Medicine
ResearchGate	Multidisciplinary	ResearchGate GmbH, Berlin
Science.gov	Multidisciplinary	Office of Science and Technical Information, US
Semantic Scholar	Computer Science	Allen Institute for Artificial Intelligence
Wolfram Alpha	Mathematics Computer Science	Wolfram Research, Inc.

These search engines provide further functionality for literature research, such as generating citations in multiple styles.

10.2.2 Search Phrases

Selecting keywords for searching Before you go ahead, collect the keywords from your chosen statements, such as:

team conflict prediction prevention resolution reasons psychology business

Search engines allow you to distinguish between individual words and phrases. Most search engines interpret words in double quotation marks as a phrase; that is, the words in the phrase must match exactly. To refine your search, you can define the key terms individually or as phrases, for instance:

conflict “team conflicts” “conflict prediction” “conflict prevention” “conflict resolution” reasons “conflict reasons” psychology business “conflicts in psychology”

The term *conflict* appears as a word and in phrases. The refined expression ensures finding documents with the phrases as well as those that contain the just word *conflict*. When you enter multiple words or phrases, the search engines combine them with a *logical and*, finding only documents that contain all items. However, phrase searches may be too limited. For instance,

“conflicts in psychology vs business conflicts”

might not show any results since the exact phrase does not turn up in any publication. In this case, we can reduce the phrase to obtain more results:

conflicts psychology “business conflicts”

A further refinement of a search is achieved by:

- exclusion of key terms that regularly turn up in the hit list but are not of interest.
- searching for key terms just in titles.
- delimiting the publication period.
- searching for PDFs, which are usually generated if a document reaches a final state.

Search engines provide advanced search options for further refinement. With these, you can exclude words, delimit the search of keywords to the title or the text body, or define the publication period (see Table 10.2).

10.2.3 How to Screen an Article

The first criterion to assess the value of an article for your research objective is its title. A vague title could already indicate a weakness in the editorial process of the publisher. A specific title would guide you to the abstract, which provides a summary.

Most often, authors write abstracts as running text. Journals in healthcare often present abstracts with labels (such as value, method, results, and conclusion), which ease the assessment of an abstract. If the abstract fits your research objective, you can screen through the articles' introduction. Again, any vagueness could indicate a lack of quality.

Table 10.2 Common options in search engines

	<i>Key or Symbol</i>	<i>Used for</i>	<i>Example</i>	<i>May find</i>
Boolean operators	AND	finding multiple words or phrases	logic AND illogic	any source containing 'logic' and 'illogic'
	OR	finding first, second or either	logic OR illogic	any source containing 'logic' and/or 'illogic'
	- (NOT)	exclude words or phrases	meta-analysis	any source containing 'meta' but not 'analysis'
Phrase	" "	phrase search	"meta-study"	any source containing 'meta-study'
Wildcards	*	truncation	logi*, phil*ist	logical, logistics, login; philanthropist, philatelist
	#	optional character in alternative spelling	leuk#emia	leukaemia, leukemia
	?	missing inner character	inten?ional	intensional, intentional
	AROUND (n)	Finding words in the vicinity	theory AROUND (3) method	theory and method, theory, and a method,
Search operators	intitle:	delimit to title	intitle:"systematic review"	sources containing 'systematic review' in the title
	intext:	delimit to boy text	intext:review	sources containing 'systematic' in the text
	author:	delimit to author	author:hawking	sources containing 'hawking' in the author's name
	site:	delimit to web site	site:journals.plos.org	sources from web site journals.plos.org
	filetype:	delimit to filetype	filetype:pdf	Portable document formats

Then, jump to the conclusion to see whether the article contributes to your research objectives or delivers essential background information. Finally, check whether the research design is comprehensive and replicable. If you are convinced about the quality, archive the source.

We recommend using an electronic tool for literature review and synthesis. Besides archiving, such tools provide features to emphasise relevant passages in the texts, assign them unique names (codes), and establish relationships between them. The *New York University Division of Libraries* provides a comprehensive overview of tools and links to further resources.²¹⁰

If you don't use a tool, archive the source in your file system using a sub-folder of numbered topics (Figure 10.2). Rename the file according to a scheme, for example, *author (year) short title*.

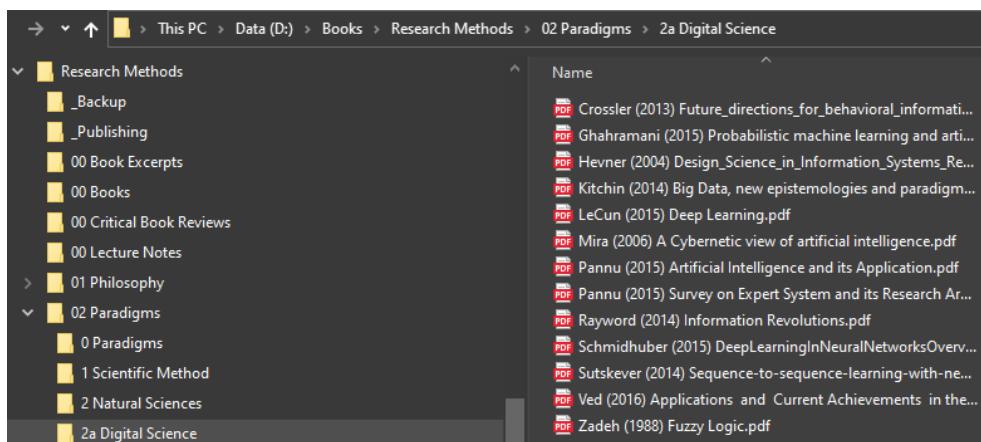


Figure 10.2 Example of a folder structure and file names for archiving literature

10.2.4 Beware of Predators

Although scholarly search engines delimit their search to academic databases, they do not necessarily ensure the source is reliable. Unfortunately, there are black sheep in the publishing business, the so-called predatory publishers.

Predatory publishing is a fraudulent business model of (mainly web-based) publishers that charge authors of publications without providing appropriate academic editorial services. The consequence is that the articles contain incomplete, misleading, or even false information.²¹¹

²¹⁰ (New York University Division of Libraries, 2022)

²¹¹ A nice article, published in *Nature* by not less than 35 authors, details out the threats coming with predatory journals (Grudniewicz, et al., 2019).

Judging the reliability of a publisher

Fishy journal names You may be able to identify a predatory journal already by its name. For example, judge for yourself the following journal names:

Acta Scientiae et Intellectus
 American International Journal of Contemporary Scientific Research
 International Journal for Innovative Research in Multidisciplinary Field

The first example translates to ‘Transactions of science and understanding’. While a Latin journal name is not unusual (for example, *Acta Mathematica*), this title seems intended to exaggerate the journal’s intellectual value rather than to distinguish a scientific discipline. In the second case, you could ask why it is about *Contemporary Scientific Research*. What sense would it make to publish *Out-of-date* research? The last example – apart from the missing plural in the last word – seems to accept any discipline. Such publishers would probably need thousands of reviewers to cover all fields adequately. A credible contemporary journal publisher would carefully select a name identifying a concrete scientific discipline and its audience.²¹²

A predatory journal often reveals itself already in the abstract or introduction, as the following excursus shows.

Excursus: Bad and Good Abstract

Let us look at the abstract of the article *Research Methodology: A Scientific Tool for Research Work*, published in one of the previously mentioned journals:²¹³

“When doing research, it’s important to know how to do it methodically. It may be described as the study of how scientific research is really carried out. Investigating a study issue involves going through a number of stages, each with its own set of assumptions and rationales. The researcher must be well-versed in both the research methodologies and procedures and the strategy. Researchers must not only know how to compute the mean, mode, median, standard deviation, or chi-square, but they must also know which of these methods or approaches are important and which are not, and what they signify and signal, in order to be successful in their study. Understanding the assumptions and criteria for determining whether methods and processes are appropriate for a given problem is also critical for researchers. This implies that the researcher must

²¹² An exception are names of long-established journals, such as *Nature* (founded in 1869), *Science* (founded in 1880), and *The Lancet* (founded in 1823), three of the most renowned scientific journals. However, the increased diversification of scientific disciplines nowadays requires a journal to cover a specific field and target audience to ensure the availability of adequate reviewers.

²¹³ (Chand, Mahali, & Singh, 2022, p. 7)

develop a technique specific to his or her issue since the same may vary from problem to problem.”

Apart from the dreadful English style, you will find that the abstract does neither address a particular issue nor any method or results of the research. Any textbook on research states the lengthy trivialities contained. A look at the conclusion shows the following:²¹⁴

“All the above methodical approaches shows [sic] that research methodology is really very helpful in research work. Research methodology tells to [sic] researcher [sic] a next step of research in the scientific way or We [sic] can say research methodology works as a scientific tool in research work.”²¹⁵

The text already exhibits the authors’ lack of proficiency in the English language. Again, the outcome is trivial and barely contributes to the scientific community’s knowledge. You wouldn’t want to waste your precious time reading the article. On the other hand, a good abstract states the research problem, the outcome, and how it was achieved:

“A fundamental question in information theory and in computer science is how to measure similarity or the amount of shared information between two sequences. We have proposed a metric, based on Kolmogorov complexity to answer this question, and have proven it to be universal. We apply this metric in measuring the amount of shared information between two computer programs, to enable plagiarism detection. We have designed and implemented a practical system SID (Software Integrity Diagnosis system) that approximates this metric using a heuristic compression algorithm. Experimental results demonstrate that SID has clear advantages over other plagiarism detection systems.”²¹⁶

The most important criterion for credibility of a scientific journal is that it follows a straightforward review process using double-blind peer review. Double-blind peer review means that the identities of reviewers and authors are concealed to ensure an objective assessment and prevent personal affiliations or relationships from affecting the review outcome.

A look at the website of the publisher helps to obtain this information. An unprofessional website design and aggressive marketing are already indicators for dubious publishers.²¹⁷ The same applies if owners of the publishing organization, editors, or reviewers are identical persons or reviewers are related to the publishing company. You may also find meaningless academic titles on the editorial board; check their names for information about their academic and professional backgrounds.

²¹⁴ Spelling mistakes in quotations are indicated with a [sic]. The Latin word *sic* translates to *thus* or *so*, meaning the source stated it like transcribed.

²¹⁵ (Chand, Mahali, & Singh, 2022, p. 9)

²¹⁶ (Chen, Francia, Li, McKinnon, & Seker, 2004, p. 1545)

²¹⁷ see, for instance, <https://www.ijirmf.com/>

Fraudulent publishers often pretend to provide open-source content, but not free of charge, or announce publication charges only after submission and accept publications in less than a month; usually, it takes at least more than a month. Table 10.3 contains a checklist for the publisher's website.

Table 10.3 Checklist for reliable academic publishers

Publisher Criterion	
The journal name is error-free and indicates a delimited scope*	<input type="checkbox"/>
Website of the journal is easy to locate	<input type="checkbox"/>
Website refrains from aggressive marketing or advertisement	<input type="checkbox"/>
Information about the publishing organization is easy to find	<input type="checkbox"/>
Editorial information is easy to find	<input type="checkbox"/>
Editors are independent of the publisher and are recognised experts in the field	<input type="checkbox"/>
The peer-review process is explained	<input type="checkbox"/>
Instructions for submission are clearly stated, including possible fees	<input type="checkbox"/>
Rights for use and reuse of articles are clearly stated	<input type="checkbox"/>
Articles are within the scope of the journal	<input type="checkbox"/>

*Except for older journals

Lastly, you can check whether the journal's name appears on one of the listings of potentially predatory journals on the web. An archived version of the original list created by the American library scientist Jeffrey Beall (who coined the term *predatory publishing*) is still available.²¹⁸

A remark on journal rankings and impact factors

Journal rankings based on impact factors and CiteScore²¹⁹ reflect the ratio of the number of citations to the articles published. Although the number of citations is an indicator of the popularity of scientific works and can be understood as an endorsement, such numbers cannot reflect the validity of a source.²²⁰ Judgements on validity can only be made by reading the article.

Table 10.4 provides a checklist for further reliability criteria to look for. If you consider those indicators signs of poor quality, you already know what you want to avoid in your writing.

²¹⁸ (Beall's List of Potential Predatory Journals and Publishers, 2021). Unfortunately, Jeffrey Bell felt forced to discontinue the list due to the attacks he had to face. He provides his insights on the scholarly publishing industry in an article (see Beall J., 2017).

²¹⁹ CiteScore measures the number of citations for a scientific journal developed by Elsevier.

²²⁰ For critical reviews on journal rankings, see (Brembs, 2018; Brembs, 2019) and (Smedsrød & Longva, 2020)

Table 10.4 Checklist for reliable academic papers

<i>Article Criterion</i>	
The abstract describes the goal, methodology, and outcome	<input type="checkbox"/>
Research objectives are clearly stated	<input type="checkbox"/>
Methodology is understandable and reproducible	<input type="checkbox"/>
Quotations are assessed rather than just stated	<input type="checkbox"/>
Results are original rather than redundant	<input type="checkbox"/>
Conclusions are concrete rather than vague or trivial	<input type="checkbox"/>
Abstract, introduction, review, results and conclusions are interlinked	<input type="checkbox"/>
Relevant literature is addressed	<input type="checkbox"/>
Number of sources is adequate for the context	<input type="checkbox"/>

10.3 REFINING YOUR TOPIC

The next step to refine your topic is using the literature to see what is already known and what is not. The number of available sources is the first indicator. Few sources are the best arguments to investigate a topic. It is not a disadvantage; it provides you with more freedom to decide on your own focus.

If literature already covers your idea extensively, you can still find gaps that you can address. You can repeat a study in a different setting, concentrate on study limitations, or on recommendations for future research. Table 10.5 provides more approaches to using the existing knowledge to refine your topic.

If you find that there is no unique approach to predict conflicts in business, then you could refine your original idea to:

Approaching a meaningful topic

Approaches to conflict prediction in business teams

If conflict prediction strategies exist, you may find a missing link between prediction and prevention or between prediction and resolution:

Conflict prediction in business teams and its impact on conflict prevention

If conflict prediction strategies and links to prevention were covered, you could search for whether systematic procedures and logical or mathematical models to predict conflicts exist. If not, you could work on:

A modelling approach to conflict prediction in business teams

Whatever you decide, with such a refined topic, you can approach the next phase in your research project: the generation of a research proposal.

Table 10.5 Examples of research approaches utilizing existing studies

	<i>Description</i>	<i>Example</i>
Repeat a study	Look for whether studies have been applied in all relevant settings or not. You may either refine the results of an existing study or apply the study in a different context	Repeat a survey on conflict behaviour in another country.
Address limitations	Researchers typically describe the limitations of their study and recommendations for future research in the conclusion, allowing them to find if they already have been addressed.	Improve a machine learning technique by applying other neural network types.
Apply a theory	Apply an established theory or model to a context or setting that has not been investigated yet.	Apply the <i>Theory of Constraints</i> ²²¹ to governmental forms rather than organizations.
Investigate a theory	Investigate an established theory or model to see whether its underlying assumptions still apply today or apply in a concrete scenario.	Assess whether <i>market equilibria theories</i> are founded on market preconditions that are no longer valid.
Identify links	Identify links between theories, models, practices, policies, approaches, and the like.	Find relationships between shareholder investment models and emerging sustainable management practices.
Identify gaps	Identify gaps or contradictions in or between existing theories or between theory and practice.	Investigate the gap between knowledge management theory, which assumes knowledge is manageable and practice, which shows that the more manageable knowledge becomes, the less its strategic value.
Review systematically	Generate a systematic review on a certain topic using literature of a certain recent period	Summarise and assess theoretical works on cultural models over the last years.

²²¹ *Theory of Constraints* states that complex systems incorporate a main constraint as limiting factor. Processes can be improved by identifying and eliminating that constraint.

Table 10.6 Worksheet for topic generation

First idea

	Not started	In progress	Completed
Talks and discussions performed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Initial reading done	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Notes completed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Notes revised	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Unnecessary items discarded	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Five items selected	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Prioritised items

1.
2.
3.
4.
5.

Central theme

	Not started	In progress	Completed
Link to other items ensured	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Keywords selected	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Systematic literature review performed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Refined theme

--

Preliminary title

--

11 WRITING A THESIS PROPOSAL

Theses and marriages have two things in common: you never know for sure whether the proposal will be accepted, and if accepted, neither party knows how things will turn out.

Unfortunately, a marriage proposal may be rejected even if perfectly formulated. That is different with a thesis proposal: if it is well formulated, you not just have a high chance of acceptance but of a long-term valuable outcome.

A thesis proposal describes an intended research project. It is a planning document that outlines the workflow of your research activities. In fact, it is more of a suggestion since we cannot know the outcome of our research in advance.

Nevertheless, planning is important for several reasons. Without planning, it is likely that your reading lacks direction, your writing lacks focus, and your argumentation becomes flawed. Although a comprehensive plan does not guarantee that you will avoid these risks, it minimises their probability and allows you to detect them at an early stage.

11.1 APPROACHING YOUR SUPERVISOR

The examination office of your university usually provides a guideline on the established procedure to approach a supervisor. Such guidelines may even recommend the form of a research proposal. However, keep in mind that your supervisors take the academic lead. They may deviate from established procedures or may have different expectations.

Most supervisors begin with an informal conversation. If your supervisor knows you from lectures, she will already have a feeling about your interests and your way of working. Otherwise, she will use the meeting to find out more about your background and interests to decide the best way to support you. On the other hand, you should use this meeting to find out about her expectations.

In case your supervisor does not know you already, you should provide her with a summary of relevant information about your studies, such as a transcript of records, including your study program, your course grades, and the credit points you achieved.

Even if your supervisor does not expect an extensive research proposal, it is a good idea to prepare a short version of one or two pages describing *what*, *why* and *how* you want to research. Figure 11.1 shows an example.

If your supervisor feels that your research idea does not fall within her area of expertise, she will recommend you to a suitable colleague. Otherwise, she will steer you in the most promising direction with your idea. You will then refine your idea and prepare a comprehensive research proposal.

11.2 COMPONENTS OF A PROPOSAL

Research proposals differ depending on the scientific discipline. The following recommendations address the minimal requirements. A typical structure is shown in Table 11.1 and explained in the following sections.

Table 11.1 Minimal components of a research proposal

Component	Description
Author	Full name, student ID, study program
Title	A working title reflecting the research objectives
State	Basic context and literature.
Objectives	General research objective, research questions, hypotheses, and/or theses
Value	Contribution to knowledge and anticipated outcome, scope, and delimitations.
Design	General overview of the research project; research design matrix proposed timeline including milestones as graph
Bibliography	References to important literature

Research Proposal

Ben Cartwright (5202365), cand. M.Sc. IT Management

Preliminary Title

A modelling approach to predict conflict severity in distributed IT teams

Value and Anticipated Outcome

The study attempts to elaborate on the relationship between exceptional situations and conflict resolution in distributed IT development teams. It investigates how conflicts evolve out of situations perceived as exceptional and identifies behavioural patterns that contribute to conflict evolution. The insights will be used to refine an existing structural equation model and assess its explanatory power.

Research Questions

1. Which scenarios are perceived as exceptional in distributed teams?
2. In which cases do exceptional scenarios contribute to conflicts?
3. Which behavioural patterns contribute to conflict severity?
4. What is the functional relationship between perception, conflict occurrence, and conflict severity?

Methodology/Methods

1. RQ 1: Literature study; observation, interviews
2. RQ 2: Interpretative phenomenological analysis
3. RQ 3: Expert interviews; descriptive statistics
4. RQ 4: Structural equation modelling

Selected Literature

Behfar, K. J., Peterson, R. S., Mannix, E. A., & Trochim, W. M. (2008). The critical role of conflict resolution in teams: A close look at the links between conflict type, conflict management strategies, and team outcomes. *Journal of Applied Psychology*, 93(1), 170.

Hinds, P. J., & Mortensen, M. (2005). Understanding conflict in geographically distributed teams: The moderating effects of shared identity, shared context, and spontaneous communication. *Organization Science*, 16(3), 290-307.

...

Figure 11.1 Example of a short research proposal

11.2.1 Describing the State

The first section contains a condensed version of the research background. We recommend not using extensive paragraphs. Use headings or emphasis to direct the reader to the relevant portion (like we do in the following). The typical aspects to cover are:

- **Current state:** the state of knowledge or the starting conditions, situation, or scenario in which you conduct the research. This includes

a brief review of the literature. The review should lead to an open issue.

- **Objective:** includes the generic objective, specific research questions, hypotheses, or theses, and the anticipated outcome, such as recommendations, a design, a typology, a taxonomy, or a model.
- **Relevance** of the study in terms of its contribution to knowledge. Potential contributions could be filling gaps in the literature, critique of existing theories, and links between theories (see also Table 10.5, p. 274).
- **Value** of the study, including the *importance* of answering the research questions, the *significance* of the anticipated findings, the *implications* for theory, methodology, or practice; and the *limitations* of the study to generalization.
- **Audience:** who will take advantage of the study, and who should read it? Describe roles, professions, or communities.
- **Scope and delimitations:** what you want to cover and what you intentionally exclude. The purpose closes with setting the scope of the study by defining what is not covered and what are anticipated limitations of the study.
- **Ethical considerations:** make sure neither the implementation nor the outcome has negative consequences. Otherwise, describe how to prevent them.

11.2.2 Phrasing the Research Objectives

The *research objectives* section states the clearly phrased questions, hypotheses or theses, and their underlying assumptions or theories. Details and examples of how they turn up in the introduction section of your thesis are given in Chapter 1. At this point, we just want to address some flaws to avoid.

Don't mix up words.

It is not advisable to use multiple synonyms that express more or less the same. You also wouldn't write:

The **motivation** behind the research **objective** is to **aim** at a **goal** with the **intent** to **target** key factors for the **purpose** of generating insights.

Decide on one of the terms and stick to it. In this book, we use the term objective to describe what we want to achieve (or aim at). An objective includes the motivation (or reason to conduct the research) and describes the purpose (the outcome). However, an objective is not a research question.

Refrain from phrasing just an objective as a generic statement, such as

To investigate how conflicts evolve in distributed development teams.

Don't state generic objectives.

The issue is that you need to show at the end of your thesis that you achieved the objectives, which is barely possible if you state them in a general form. Therefore, we prefer concrete research questions.

Research questions require a scientific research approach. For instance, the review of literature is not research but a collection of existing knowledge. Answers to research questions generate new knowledge.

Don't state trivial questions.

If you phrase a question like:

Can conflicts in distributed development teams always be avoided?

Ensure your question is researchable.

you will have a hard time approaching an answer at all. Instead, identify specific criteria you could ask for, such as preconditions, requirements, demands, parameters, factors, and the like.

We phrase research questions in a way that they can be comprehensively answered with a few statements at the end of your thesis. If you begin a research question like:

Avoid 'How' questions.

How do exceptional situations in distributed teamwork lead to conflict?

you will not be able to answer it comprehensively because there are too many aspects to consider. If you take a step back and ask what is needed to answer this question, you will find, for instance, that you first need to know which scenarios are exceptional.

Since we want to obtain an answer that can be easily formulated, two questions like:

Avoid two questions in one.

What are exceptional situations in distributed teamwork, and how do they contribute to a conflict?

will just complicate answering it.

Although a research question should be explicit, do not state a question by including every parameter and limitation in a single statement, such as:

Don't include every detail in a question.

What exceptional situations occurring in internationally distributed software development teams working on laboratory software projects for the European pharmaceutical sectors are interpreted by the team members in individual countries as decisive, uncertain, risky, or critical?

If your reader needs to read it twice, it misses the goal. The context conditions should have been stated in the purpose section, and any additional

parameters applying to all questions can also appear in an introductory paragraph preceding the questions.

Taking these recommendations into account, you could simplify the latter question and turn it into a specific form:

1. Which scenarios in distributed teamwork are perceived as decisive, uncertain, risky, critical, or otherwise exceptional by the team members?

Finding the answer to this question could lead to the next:

2. To what extent does the perceived uncertainty of an exceptional situation contribute to the probability of conflict occurrence?

In the same way, you go ahead with the remaining questions. To refine a more comprehensive question, you can divide it into researchable sub-questions, for instance:

1. Which scenarios in distributed teamwork are perceived as decisive, uncertain, risky, critical, or otherwise exceptional by:
 - a) team members
 - b) project managers
 - c) customers.
2. To what extent does the perceived uncertainty of an exceptional situation contribute to
 - a) the severity,
 - b) the probability of detection and
 - c) the probability of occurrence
 of a conflict.

Such questions have a logical sequence and can be answered concretely.

11.2.3 Defining the Research Design

In the research design, you identify what is necessary to conduct the research and to deliver the information required to answer the research questions.

The research design includes multiple aspects, such as research methodology, methods, sampling, analysis and synthesis procedure, and validation, each of which is described in Chapter 15 for different disciplines and research goals.

The most comprehensive way to describe it is a *research design matrix* that shows the parameters and their relation to the research objectives. Table 11.2 shows a design matrix for a study of team conflicts.

Table 11.2. Example of a research design matrix for a study of team conflicts

Research question	Strategy	Methodology	Methods (Instruments)	Samples	Data Type	Analysis/Synthesis
Perception of exceptional scenarios	explorative, nomothetic	Survey	Questionnaire	120 (2x4 strata*)	Qualitative, derived quantitative	Frequency analysis
Impact on conflict potential	explanatory, nomothetic	Survey	Questionnaire Structured interview	120 (2x4 strata*)	Qualitative, derived quantitative	Regression Correlation
Behavioural patterns	descriptive	Field Study	Concealed observation	24 (2 strata**) Qualitative	Content analysis	
	explanatory, idiographic	Field Study	Unstructured interview	24 (2 strata**) Qualitative	Grounded theory	
Conflict-behaviour relationship	explanatory	Modelling	Structural Equation Modelling (SEM)	n/a	Quantitative	n/a
Operational conditions, validation	descriptive	n/a	Semi-structured expert interview	2	Qualitative	Content analysis

*Strata: gender, age group, experience, training level

**Strata: gender

11.2.4 Research Schedule

Again, breaking a rule We regularly find that universities or supervisors expect a table of contents to be part of a research proposal. To us, it contradicts research practice. What we could provide as the table of contents goes barely beyond the anticipated and established structure (introduction, literature review, research design, etc.).

Research is a dynamic process. While we begin with stating research objectives as a guiding principle for our procedure, every new literature source and every discussion will affect the research objectives. On the one hand, we plan as much as possible. On the other hand, we need to accept that the plan will change.²²²

What is more important is the procedure of our research project, which is much better represented by a graphical workflow. It is helpful to include a visual roadmap of the tasks you want to accomplish. You can reuse such a diagram later in your thesis.

The *research schedule* is best visualised using flow diagrams, Gantt charts, or milestone plans (see Figure 11.2). It includes a schedule for data collection, data analysis, and intermediate revisions.

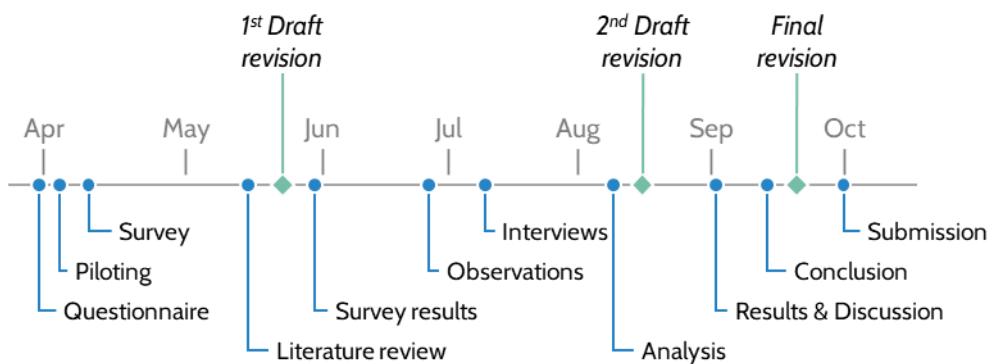


Figure 11.2 Example of a milestone plan for a research proposal

To define your timing, take a reverse approach: decide when you want to finalise your studies with the thesis defence and count back your processing period plus the typical period between submission and defence; the result would be the latest point in time to enrol. Please keep in mind timing and keeping the deadlines are usually up to you. Your supervisor may not track your progress or remind you of deadlines.

²²² A fundamental rule of good project management: planning is necessary, sticking to the plan is not.

Table 11.3 Checklist for a Research Proposal

<i>Topic</i>	
Name, student ID and study program	<input type="checkbox"/>
Preliminary title	<input type="checkbox"/>
Current state	<input type="checkbox"/>
Objective	<input type="checkbox"/>
Research questions	<input type="checkbox"/>
non-trivial	<input type="checkbox"/>
researchable	<input type="checkbox"/>
unambiguous	<input type="checkbox"/>
easy to understand	<input type="checkbox"/>
concrete answer possible	<input type="checkbox"/>
Ultimate outcome	<input type="checkbox"/>
Value	<input type="checkbox"/>
Relevance	<input type="checkbox"/>
Audience	<input type="checkbox"/>
Scope and delimitations	<input type="checkbox"/>
Ethical issues	<input type="checkbox"/>
Research design matrix	<input type="checkbox"/>
Timeline	<input type="checkbox"/>
References	<input type="checkbox"/>

11.3 DEFENDING YOUR PROPOSAL

When you approach your supervisor (or a committee²²³) with your final research proposal, you need to defend it. Be prepared for a mutually challenging debate. Your supervisor will scrutinise your title, your research objectives, and your methodology, and you will defend your idea by arguing against critical comments and statements.

It all depends on your preparation. If your supervisor feels you are not convinced about your design or not able to cope with it, she will discard your topic or even reject your request. If you can convince her, she will discuss final adjustments and decide on the title so that you can enrol for your thesis.

²²³ If a presentation is expected, have look at chapters 18 and 1.

11.4 THE WORST PRACTICE

Did you ever ask yourself why you must write a thesis rather than an anti-thesis? If you want to try out the latter, just refer to the following guide.

Writing the Anti-Thesis

Unfortunately, you cannot finalise your studies without writing a thesis. To overcome this entirely unpleasant situation, you need to get in touch with a supervisor at least once. However, there is no need to prepare for a topic. If asked, just tell me you would like to write about ‘something in [insert your study program here]’.

If things turn bad, your supervisor expects you to present a research proposal. Fortunately, there are enough examples on the web you can copy from. Just replace some words with terminology fitting your study program.

If you cannot avoid further contact with your supervisor, smile, be polite, and leave the impression you are taking notes while your supervisor unnecessarily explains petty details. In online meetings, it is advised to use a headset for playing your favourite background music while your supervisor talks and to utter from time to time a definite: “Yes, Sir!”

After you enrol, keep in mind strength lies in calmness. Take your time in the first months to think about your topic. Talking to others about your thesis is counterproductive and just leads to confusion. Instead, use social media blogs, Twitter messages, and YouTube videos from pseudo-experts to gain insights into your topic.

After several months of contemplation, you can have a look at the online resources. There is no need to visit the university’s online library, let alone the physical one. A fundamental rule: What Google can’t find isn’t worth a look. The most important source is Wikipedia, anyway. Simply copy the text passages that seem to fit your document.

In the ideal case, you don’t research anything and just replicate what others wrote. You can easily generate stylistically modest content with a minimum of intellectual participation by using ChatGPT. Another way is to do empirical research with surveys. The advantage is that most supervisors don’t ask for the raw data. Consequently, you don’t even need to send out a questionnaire as long as you can master the random number generator in your spreadsheet software and create fancy and colourful 3D charts.

If your fingers are itching to do something yourself, set up a questionnaire with Google Forms asking customers about how they feel or why they do whatever they do. For the analysis, the pie charts provided by Google Forms are sufficient. However, avoid statistics in empirical research. As an argument, you can refer to the valuable quote “Never believe any statistics” and cite it from a well-

renowned author, like Winston Churchill, Mark Twain, or Shakespeare (the source is irrelevant since nobody knows who said that).

The critical phase begins several days before the submission when you recognise that you forgot to copy the citations from Wikipedia. Look at any websites that provide references for articles whose titles sound fitting. Copy the references one after another behind your text. Having more than a hundred references ensures that your supervisors do not follow up on each.

The last days before the submission are also the period to clarify any remaining questions with your supervisors, such as what they think about the thesis or whether they can do a plagiarism check for you. Write them an email, and don't forget to remind them of urgency by finalising your request with a cordial 'Please answer asap'. The smaller the period for feedback, the easier it is for you to blame your supervisor during the thesis defence (and in front of the committee) that your questions haven't been answered appropriately and on time.

12 CREATING A STORYBOARD

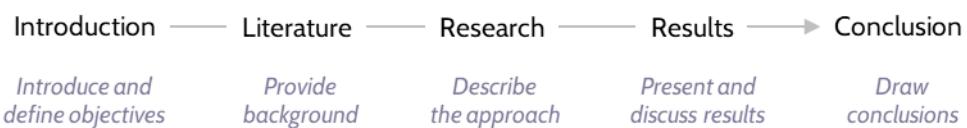
Writing without a storyline is as helpful as driving with the handbrake on: you barely reach a goal.

Any narrative requires a storyline, whether a fictional story, a movie, or a documentary. That is not different for academic writing. Academic texts also need a narrative following a storyline, although the purpose is different.

Academic writing tells a story about acquiring new knowledge. We achieve a convincing storyline by engaging with the perspective of the reader. That is, the expectations of our audience come into play, which is set with the title of our thesis. Although our storyline will probably change during the research process, we need an initial structure to organise our study efficiently.

12.1 THE GENERIC STRUCTURE

Amongst the academic community exists a consensus on the structure for academic papers, whether a journal article or a thesis. Although the focus set by academic disciplines might differ, the generic storyline is:



To create a good storyline for each element, we need to engage with the reader's perspective: what the reader expects or needs to know. Remember that you do not write just for your supervisor but for a community interested in the outcomes. The following subchapters acquaint you with typical storylines for this structure.

12.1.1 Introduction

The introduction acquaints the reader with the context and the research topic. The storyline could be:



The introduction begins with a deliberate statement that addresses the research *context* and consecutively refines it to eventually guide the reader to an open issue. The story could be:

In the context of ... it is known that ... but there is an issue ...

This open issue creates a transition to the *objective*, which states the general goal of the research, refines it by research questions, hypotheses, theses, or a combination of these, and addresses the anticipated outcome:

The general objective is ... to answer specifically ... to achieve ...

To keep your reader engaged, you need to convince him about the *value* of your investigation for a particular audience:

The value of the results is ... for the audience ...

What is left is to define the *scope*: explaining what you want to cover and what you want to exclude. You can delimit the scope, for instance, to application scenarios, countries, regions, or industry sectors:²²⁴

The study covers ... but will exclude ...

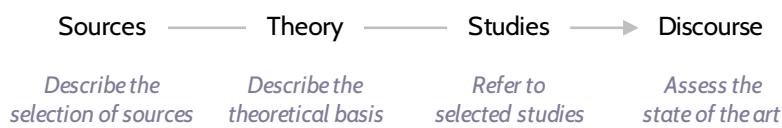
All this information allows a reader to make a rapid decision on the usefulness of reading on and ensures the reader's expectations for the upcoming content are appropriately delimited.

²²⁴ If you think your reader would expect something in the given scope that you explicitly want to exclude, you can state it here; for instance, if your scope covers the automobile sector, but you want to exclude suppliers.

12.1.2 Literature Review

The review of existing literature provides the reader with an overview of knowledge in the field of study. While there is some consensus in the scientific community about the storyline of an introduction, the structure of a literature review depends on your research discipline and topic. Therefore, the following storyline is just an example. Details of different approaches are given in Chapter 14.

A storyline of a literature review might be:



The introductory paragraph of your literature review will address details about the selection, publication period, and assessment of *sources*:

Sources were selected from ... from period ... using ...

Afterwards, you can address *theories* that are relevant to your study. The theories allow your reader to comprehend your argumentative foundation. Similarly, you describe established approaches or procedures that you utilise or refer to in your text:

Theories, models, approaches, or procedures underlying the study are ...

The next step would be to summarise contemporary knowledge in the field. You present selected *studies* or cases that are meaningful to your investigation and compare them:

Studies found ... but other studies showed ...

In the concluding section, you could engage in a *discourse* about the findings from the literature and the missing aspects:

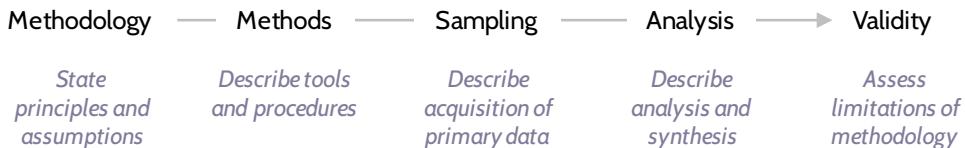
Studies were delimited to ... missed to address ... did not convince ...

At this point, your reader should be prepared to engage with your new results, but we will first describe how we achieved them.

12.1.3 Research Design

The research design describes how you conducted your research. The intention here is twofold: a) to convince your reader of the validity of your study results and b) to allow another scientist to replicate your study.

Although the different scientific disciplines utilise quite a variety of methods and techniques, the storyline behind the research design again follows a commonly accepted scheme:



The *methodology* is about the research principles and the assumptions you made. It helps the reader to understand the premises you begin with:²²⁵

Assuming ... the selected methodology is...

The *methods* section states the procedures to obtain your primary data:

Methods used are ... adapted from ... using tools or instruments ...

The *data acquisition* section addresses the procedure you applied to collect your raw data. It includes selecting primary text sources in interpretative research, instrumentation and instrumental parameters in experimental research, population and sampling in empirical research, or framework conditions and criteria for development projects:

Data are collected from by using ...

The section *analysis & synthesis* addresses the techniques or tools you used to analyse the primary data to derive information:

Data are pre-processed ... analysed using ... to obtain information ...

Additionally, we describe methods to interpret the data and synthesise the results with the existing knowledge:

Information is interpreted using ... to generate ... and compare with ...

The section *validity* explains how we ensure the quality of our results and addresses any delimitations that originate in the selected methods:

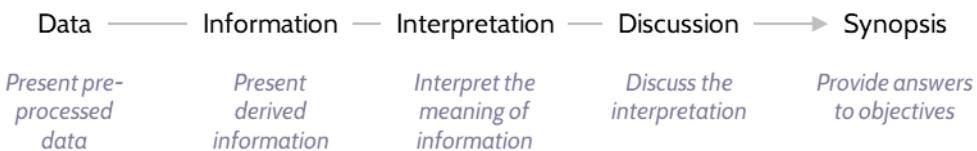
Validity of results is ensured by ... knowing the delimitations of...

Delimitations may either derive from assumptions or limited applicability. It also narrows down the reader's expectations for the anticipated results.

²²⁵ For instance, a typical assumption for parametric statistics is that either the sampling distribution or the distribution of means across samples is normally distributed.

12.1.4 Results & Discussion

After explaining the research design, you present your pre-processed data to the reader in an appropriate form. Presenting results typically includes tables, charts, diagrams, or other visuals. Our storyline is the following:



Data include any pre-processed data, such as measurement results, frequencies of questionnaire responses, field notes from observations, parts of interview transcripts, or excerpts from a systematic literature review. Further data generated from your raw data are statistics, statistical hypotheses, text codes from qualitative data, and categories from classifications.

Using these data, you will generate *information* and present it in textual, tabular, or graphical form. Tables or figures always require an *interpretation*, giving them meaning for our context. Following this principle, our story following a figure could be:

Figure xx shows ... which means in this context ...

The core of the chapter is the *discussion* of your interpretations. To make the difference clear, the interpretation is a way of reading your results in a particular manner. The discussion merges the interpretation with results from your own study *and* from the literature review to achieve conclusions that go beyond existing knowledge.

The discussion may follow the interpretation of data or appear in a separate main chapter; this is useful if you have a reason to extend your discussion beyond your initial research objectives. The story could be:

The findings indicate ... resemble ... contradict ... support ...

The final *synopsis* provides the reader with concrete answers to the research objectives stated at the beginning:

The answers to the research objectives are ...

Now, you approach the last main chapter of your thesis.

12.1.5 Conclusion

The conclusion provides the reader with a high-level summary, focusing on key outcomes and a holistic assessment. A storyline might be:



The *conclusion* answers what – in your opinion – the reader should have learned from the study. You may present selected outcomes and address the overall value they have:

Overall, it was learned that ... meaning we can (not) ...

In the *reflection*, you scrutinise the limitations of your results in terms of applicability, quality, risks, or ethical considerations. You can convince the reader now of your proficiency as a self-reflective researcher:

It was shown that ... but only for ...

The section *research* provides recommendations for upcoming studies to improve the results achieved. Such recommendations may be derived from critical reflection or include new research ideas. For the academic reader, such recommendations may trigger new research projects:

The found limitations suggest to further investigate ...

The *outlook* is an optional section that provides prospective statements on the development or evolution of the field of investigation, thus encouraging your reader to think beyond the current state.

It is expected ...

Table 12.1 shows an example of a final storyboard. The upcoming chapters in this book address each part of the storyboard in detail.

12.2 OTHER FORMS OF STUDIES

Depending on your study program, you may have to write a capstone project report or an academic case study report rather than a thesis. The following sections distinguish these forms of academic writing.

Table 12.1 A storyboard for a study on conflict resolution in distributed teams

<i>Introduction</i>	<i>Context</i>	Conflicts in distributed teams were addressed in numerous studies, but a model for handling and predicting conflicts in distributed teams is missing.
	<i>Objective</i>	What parameters are needed to define the model? How would it contribute to conflict prevention?
	<i>Value</i>	A model would allow preventing conflicts in distr. teams.
	<i>Audience</i>	Team leads and project managers of distributed teams.
	<i>Scope</i>	European project teams; focus on behavioural models
<i>Literature Review</i>	<i>Theories</i>	Theory of Collective Behaviour (Giddings, 1908) Theory of Planned Behaviour (Ajzen, 1985) Emergent-Norm Perspective (Turner & Killian, 1993) Assembling Perspective (McPhail, 1991) Transformative Learning Theory (Mezirow, 2012)
	<i>Models</i>	Structural equation model (different sources)
	<i>Studies</i>	Diversity in transnational project teams (Iles & Hayers, 1997) Communication in virtual teams (Suchan & Hayzak, 2001) Conflict resolution in teams (Shapiro & Dempsey, 2008) Silo mentality in teams (Cilliers & Greyvenstein, 2012) Communication-conflict interaction (Wu et al., 2017) Agile in distributed teams (Khmelevsky & Madnick, 2017) Autonomous agile teams (Stray et al., 2018) Work-life conflict in distributed teams (Sarker et al., 2018)
	<i>Discourse</i>	Conflicts are widely investigated, and behavioural models exist. Why does no model for conflict probability exist?
	<i>Data</i>	Response frequencies, field notes, audio/video recordings
<i>Results</i>	<i>Information</i>	Statistics, regression models, typologies
	<i>Interpretation</i>	Cause-effect relationships supported by correlation coefficients; code categories
	<i>Discussion</i>	Affective, cognitive, and conative patterns contributing to conflict; codes revealing additional model parameters
	<i>Synopsis</i>	Parameters identified; structural equation model generated
	<i>Conclusion</i>	Behavioural patterns can be modelled, and conflict probability can be predicted.
<i>Conclusion</i>	<i>Critical Reflection</i>	Links between idiographic and nomothetic results still need to be clarified.
	<i>Future research</i>	SEM should be refined for varying endogenous indicators.
	<i>Outlook</i>	Predicting conflict probability may become a central tool for team management.

12.2.1 Capstone Project

Capstone project

Like a thesis, a capstone project is typically undertaken at the end of academic studies in undergraduate or graduate programs. The difference to a thesis is that its purpose is to apply the knowledge and skills acquired throughout graduate studies to address a real-world scenario. It emphasises practical application and problem-solving rather than contributing theoretical knowledge to the field.

Capstone projects are, therefore, more focused, and concise compared to theses. They are designed to be completed within a specific period (for example, one semester) and involve applying existing knowledge to address a particular real-world problem or case. While capstone projects involve research, they produce tangible outcomes, such as proposals, designs, business plans, policy recommendations, and prototypes.

The nature of capstone projects can vary widely across disciplines. For example, in engineering, a capstone project might involve designing and building a functional prototype of a product. In business, students may develop a comprehensive business plan for a startup. In the social sciences, the project may focus on the analysis of a social setting. In healthcare, they aim to integrate knowledge with practical skills to improve healthcare outcomes, patient care, or healthcare systems. The format and scope of the project are typically determined in collaboration with faculty advisors or project mentors.

Difference in methodology

The methodological difference between a thesis and a capstone project is that the latter uses *case studies as the only method of investigation*, whereas in theses, the case study is one of many methods to investigate real-world scenarios (see Figure 12.1).

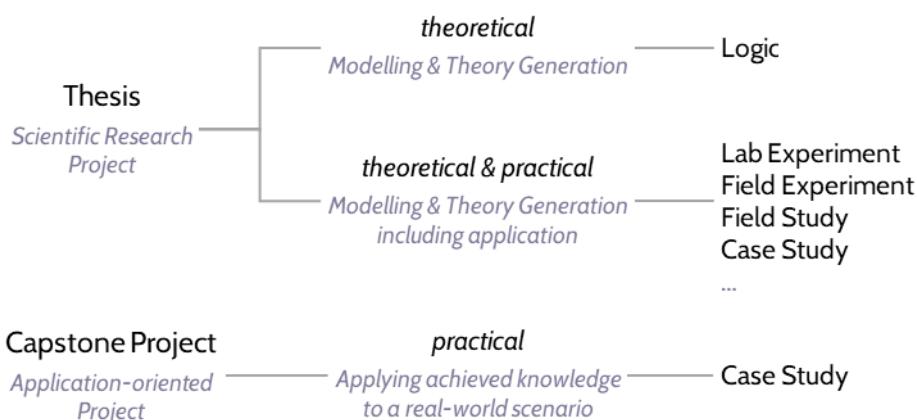


Figure 12.1 Thesis and capstone project

12.2.2 Academic Case Study

As a *research method*, a case study refers to an in-depth investigation of a particular individual, group, organization, event, or phenomenon. For instance, ethnographic studies can be considered a form of a case study. Scientific researchers use case studies to extend their understanding of the subject by investigating a real-world scenario to arrive at contributions to theoretical knowledge.

Case study as a research method

The method of case studies is commonly employed in social sciences, business, education, healthcare, and psychology. The research involves collecting and analysing data from multiple sources, such as interviews, observations, documents, and archival records, to build a holistic picture of the case under investigation. The findings of a case study contribute to knowledge development, theory building, and practical application in relevant fields.

We sometimes find the term *academic case study*. It usually refers to an academic report that presents the findings and analysis of a case study. As in a thesis, such a report outlines the research question, methodology, data analysis, and key insights obtained from the investigation. However, it includes a more detailed description of the case's background, context, and relevant factors.

Academic case study

Academic case studies are frequently used to share research findings with the academic community. In professional settings, academic case study reports are used to inform decision-makers, practitioners, and policymakers about best practices. In this sense, they are equivalent to the requirements of a capstone project.

The typical structure of an academic case study (or capstone project report) is as follows:

- *Introduction:* Presents an overview of the case study's subject and purpose. Identifies the problems or issues that will be analysed.
- *Background:* Provides contextual information essential to understanding the case. This can include information about the organization, industry, geographic location, historical events, or individuals involved.
- *Case Presentation:* Details the specific scenario or problem to be studied. This section should include all necessary data, as well as any relevant events, actions, or decisions.
- *Case Analysis:* Applies theoretical concepts or principles to the case. This is where you dissect the case, discussing its intricacies, drawing connections to theoretical frameworks, and arguing different perspectives.

- *Alternative Solutions:* Outlines potential solutions to the problem. Each solution should be feasible, clearly presented, and supported by evidence or reasoning.
- *Recommended Solution:* Among the alternatives, one solution is recommended as the most effective. It should be justified with solid arguments and evidence.
- *Implementation:* Discusses how the recommended solution can be implemented practically. Details steps, resources required, potential obstacles, and ways to overcome them.
- *Conclusion:* Summarises the case study, the analysis, and the recommendations. This should also provide reflections on the lessons learned.
- *References:* Lists all the sources of information used in the case study in the appropriate citation style.

While the requirements in terms of academic rigour, research design, results presentation, and ethical considerations are the same as in a scientific research project, the contribution to theoretical knowledge is limited.

PART IV

THE WRITER'S GUIDE



13 THE INTRODUCTION

An introduction is like a job interview. If you screw up, you ruin the first impression. Unfortunately, this happens more often with academic theses than with job interviews.

The introduction of a thesis is the first thing your reader might look at, and as the saying goes, you never get a second chance to make a first impression. The intention is to acquaint the reader with the context of the research project. Following the storyline we developed in the previous chapter, we will address context, objectives, value, and scope.

The text immediately following the main heading should not be much more than a page. It is delimited to information that provides the context to the research objective and refrains from extensive explanations and details that are not yet unnecessary. It addresses different aspects relevant to the research objective and, step by step, narrows down to approach an issue to be researched, leading to the first subchapter covering the research objective.

13.1 HOW TO BEGIN

If we remember that the thesis title raises expectations with the reader, it is a good idea to use it as a guide to identify how to begin. Suppose the final title you agreed upon with your supervisor is:

An Approach to Structural Equation Modelling of Conflicts and their Resolution
Strategies for Distributed Teams

This title provides different starting points: (a) beginning with the modelling aspect, (b) beginning with the matter of conflict resolution, or (c) beginning with the topic of distributed teams.

In any case, we make sure that the initial statement – although of a general nature – provides valuable information (see also chapter 7.1).

Structural equation modelling is a valuable approach to discern intricate relationships among conflict variables and resolution strategies.

or

Successful conflict resolution strategies require an understanding of the relationships underlying the emergence and development of conflicts.

or

Distributed project teams are naturally more sensitive to conflicts than localised teams.

In all examples, we begin with a claim that requires immediately present arguments. Using the latter example:

1. Introduction

*Starting with a claim
...and its arguments.*

Distributed project teams are naturally more sensitive to conflicts than localised teams. Limited visibility, personal distance, and team diversity increase the chance of misunderstandings, which may lead to dissents and eventually impede reaching the consensus required for successful teamwork.

Supporting the first argument

In contrast to localised teams, distributed teams rely on virtual communication. The selected media and the technical conditions of remote communication delimit the information transfer if the communicative environment cannot mimic that of a personal conversation.

Supporting the second argument

Decisive, difficult, risky, dangerous, or otherwise exceptional situations pose a conflict potential, which increases if the distributed teams differ in their perception of the situation's severity. This is reinforced if the teams exhibit divergent behavioural patterns, such as seclusion, blaming, conflict avoidance, or competitive attitudes.

Narrowing down the topic

Perceived risk and behavioural characteristics of teams contribute in various magnitudes to conflict aggravation and escalation. This gave rise to studies on the functional relationship between conditions of an exceptional scenario and its conflict potential. Mathematical models, such as structural equation modelling (SEM), have been applied and meanwhile found entry in algorithms for expert systems.

Approaching the issue

Although these models have been widely used, the question of whether they provide explanatory power to predict the effectiveness of a conflict resolution strategy in an exception scenario has been rarely addressed. This deficiency serves as the foundation of this study.

You will find that no citations turn up in the example. This is due to the generality of the statements. In case we include a detailed outcome, a quotation, or a fact, we would cite it. Otherwise, the reader can assume that the aspects mentioned in the introduction are detailed in other chapters where citations are provided.

The last paragraph in the introduction ideally creates a transition to the research objectives.

13.2 RESEARCH OBJECTIVE

The research objective is probably the most carefully formulated chapter in your thesis. If you fail to state objectives unambiguously, you will likely run into issues with answering them at the end of the thesis.

The objective does not just describe what you want to investigate. It also determines your entire storyline: the scope and sequence of chapters, the relevant literature, the line of argumentation, and the coherence of your conclusion.

Although your main research objective may stay the same, your research questions, hypotheses, or theses may vary during your journey through the literature or due to your results. Anyhow, the final version of your thesis needs to be consistent with the objectives.

Don't expect research to be a linear process.

You can use different approaches to state your objectives: research questions, hypotheses, and thesis statements. You may combine these and follow different approaches to achieve your research objectives. In any case, you must explain the objectives and their relationships with each other.

13.2.1 Research Questions

A research question consists of one or more central questions that may be divided into sub-questions. We already addressed the issue that including all conditional descriptions will render it unreadable. Therefore, we recommend stating them in a subchapter and explaining each research question in a succeeding paragraph.

The subchapter should begin with an overall objective, followed by concrete research questions or theses, and present the anticipated outcome at the end of the subchapter (see Figure 9).

Generic Objective**Concrete research questions with explanations****Anticipated outcome****1.1 Research Objective**

This study elaborates on the relationship between conflicts and conflict resolution strategies in distributed teams. It investigates how conflicts evolve in exceptional situations, how risk perception and behavioural patterns contribute to conflict evolution, and their impact on conflict resolution. The found relationships are integrated into a functional model that allows deciding on effective conflict resolution strategies.

To achieve this, the following research questions are raised:

- 1. Which scenarios in distributed teamwork are interpreted as decisive, uncertain, risky, critical, or otherwise exceptional by the team members?**
Exceptions occurring in distributed teamwork are assumed to be reflected by their perceived severity, risk, and uncertainty. By identifying those perceptions, we can estimate their conflict potential.
- 2. To what extent do the perceived severity, risk, and uncertainty of an exceptional situation contribute to the probability of conflict occurrence?**
Conflicts occur due to different perceptions of an exceptional phenomenon that differ in their critical potential, escalation, and persistence. These parameters are assumed to reflect conflict severity.
- 3. Which reproducible behavioural patterns of team members affect the conflict severity in exceptional situations?**
Specific behavioural patterns, such as seclusion, blaming, or accusation, can cause, reinforce, or sustain conflicts. Knowing their impact allows us to select and prioritise options for achieving consensus between the team members as the first step to exception handling.
- 4. What action strategies can be derived from perceived conflict severity and behaviour to reach a consensus on exception handling?**
The relation between perception, behaviour, and conflict resolution is determined by their contribution to achieving a consensus. A consensus is assumed to be reached if mediation occurs and the confidence and motivation of the team members increase.

The parameters and conditions are determined and incorporated into a structural equation model to predict the effectiveness of conflict resolution strategies. This model will be identified, its parameters prioritised, and their contribution to individual constructs quantified.

Figure 13.1 Example of a research objectives subchapter including explanations

If we have complicated relationships between the research questions, we recommend visualising them. For our example, we can use a simplified form of structural equation models.

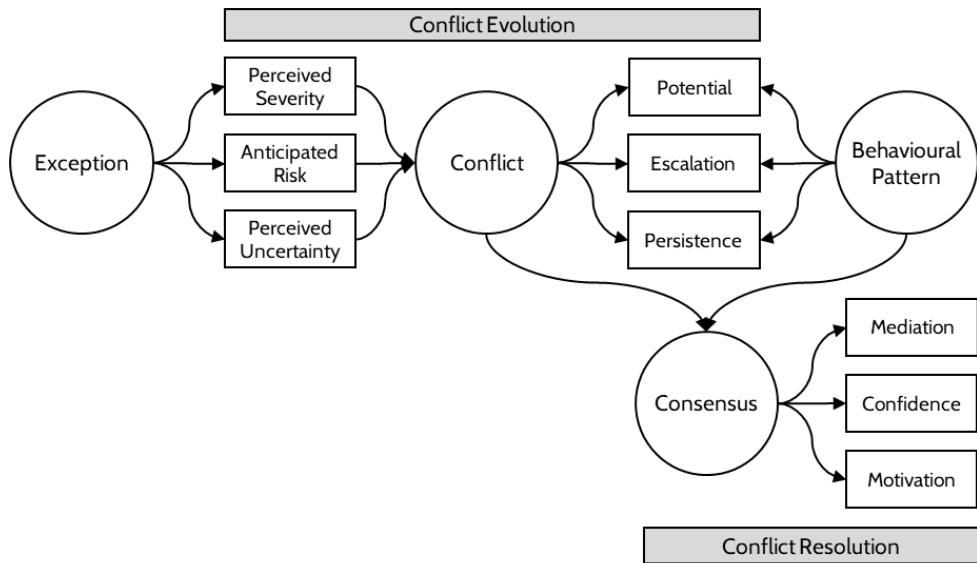


Figure 13.2 Example of a visualisation supporting the understanding of the relationships between research questions

13.2.2 Hypotheses

The research objectives may include either research questions, research hypotheses, or a combination of both. If individual research questions cover the generation of a hypothesis, they do not necessarily appear in the introductory chapter. In this case, the research design section may address them, in particular, if the design is explicitly targeting the hypothesis.

If the evaluation of the results leads to the development of the hypothesis, they occur in the result section. That is, hypotheses occur at the point where they are first raised.

In the example shown in Figure 13.3, we assume they are stated *a priori* in the context of Trompenaars's model of cultural dimensions.²²⁶

Hypotheses 1 to 4 are sometimes called directional hypotheses since they assume the expected direction of the relationship between variables. The last hypothesis is a non-directional case, predicting a relationship without explicitly addressing the direction. The corresponding null hypotheses always state no relationship between the variables.

Directional Hypothesis

²²⁶ Trompenaars' Model of Cultural Dimensions is one of the frameworks proposed to understand cultural differences in various societies. Trompenaars' model has been utilized in cross-cultural research and management studies to gain insights into the complexities of intercultural interactions and awareness; see (Trompenaars & Hampden-Turner, 1989).

*Generic Objective**Hypotheses**Anticipated outcome*

1.3 Research Hypotheses

The thesis explores the cultural dimensions proposed by Trompenaars's Cultural Dimension Model and their implications for conflict resolution in intercultural teams. The following hypotheses seek to shed light on how these dimensions influence various aspects of conflict resolution and leadership patterns:

- H1: Team members from cultures of high power distance will demonstrate a greater inclination towards hierarchical communication of conflicts.
- H2: Intercultural teams with a higher diffuse dimension will experience greater challenges in managing conflicts arising from varying degrees of emotional expressiveness, personal space preferences, and formality in interpersonal interactions.
- H3: Team members from ascription-oriented cultures are more inclined to follow traditional hierarchical approaches to conflict resolution.
- H4: Intercultural teams with a higher degree in the egalitarian dimension will experience challenges in establishing shared norms for conflict resolution strategies.
- H5: Cultural differences in the achievement-ascription dimension will be reflected in team members' motivations and attitudes towards consensus.

By investigating these hypotheses, this research aims to provide valuable insights for organisations seeking to maximise the benefits of cultural diversity within their intercultural teams.

Figure 13.3 Example of research hypotheses

13.2.3 Thesis Statements

When we investigate a complex system of composite phenomena, we might not be able to break it down into concrete research questions or hypotheses. In this case, may consider using a thesis statement.

We cannot answer a thesis conclusively.

We already learned that a thesis statement is an assertion that cannot be entirely validated or invalidated; there will always be an antithesis (the contradicting assertion). Our task is to find solid arguments for the thesis, scrutinise those against the thesis, and ideally reach a synthesis. In contrast to a hypothesis, a thesis does not claim to be part of a theory and might even contradict established views.

Suppose we want to look at the influence of cultural diversity on conflicts in distributed teams. We will barely be able to generate a functional model for two reasons: (a) the number of parameters and variables is too vast, and (b)

we don't have a foundational model that allows for quantifying relationships. In fact, the latter limitation may serve as the basis for a thesis statement. We assume our title is:

Assessing Cultural Conflicts in Intercultural Teams: A Critique of Existing Cultural Models

Since we usually state a single thesis, a subchapter for research objectives is not necessary, and we can end our introductory chapter with the thesis.

1. Introduction

Organizations increasingly rely on intercultural teams, comprised of individuals from diverse cultural backgrounds, which hold the potential for enhancing creativity, problem-solving, and decision-making processes. However, harnessing this potential requires a comprehensive understanding of cultural dynamics and effective conflict management.

To navigate the complexities of cultural diversity in distributed teams, organisations have traditionally turned to existing cultural models. These models provide a structured framework for assessing and managing cultural differences. They offer insights into the distinct values, communication styles, and behavioural patterns prevalent in various cultures, thereby facilitating cross-cultural interactions.

Despite their valuable contributions, existing cultural models fall short of capturing the intricacies of conflicts that emerge within intercultural teams. This limitation arises from several factors, such as oversimplification of cultural diversity, a lack of consideration for individual differences, and an inability to account for the dynamics of intercultural interactions.

This study critically examines the suitability of existing cultural models in overcoming cultural differences within distributed teams. It posits that:

Cultural differences in distributed teams cannot be overcome by a formal assessment of cultural diversity using existing cultural models.

By exploring the complexities of intercultural interactions and the nature of conflicts that emerge in virtual environments, this study seeks to identify flaws in assumptions underlying existing models and exposes their inadequacy to capture the dynamics of conflicts within intercultural teams. The findings of this study will offer insight into alternative strategies for cultural assessment.

*Starting with a claim
...and its arguments.*

*Addressing cultural
models*

Approaching the issue

Stating the thesis

*Explaining the
anticipated outcome*

Figure 13.4 Example of an introductory chapter using a thesis.

Defending a thesis as a research objective is one of the most challenging approaches for research. Then again, it is probably the most fascinating and satisfying path to new insights.

13.3 VALUE AND AUDIENCE

To argue for our research, we need to address the value of the anticipated outcome for the intended audience. Your result may fill gaps in the literature, challenge existing models or theories, confirm or falsify hypotheses, create a typology or taxonomy of observed phenomena, create a new model, or modify an existing one.

In any case, you need to identify who would be interested in the results of your research, either as an interest group (in scientific or theoretical topics) or as stakeholders (in business topics). The audience will determine the style, terminology, and scope of your research. Figure 13.5 illustrates an example stated in an individual subchapter.

Value statement

Audience statement

1.4 Value and Audience

The results of this study support the decision-making for conflict resolution strategies in distributed IT teams. By establishing a model that accounts for the impact of an exception on conflict evolution, the selection of proactive measures in conflict management is simplified.

Such a model allows team leaders, project and program managers, and project management offices to establish operational conditions and practices to detect, mitigate, resolve, or prevent upcoming conflicts at an early stage.

Figure 13.5. Example of a brief *Value and Audience* subchapter

13.4 SCOPE AND DELIMITATION

The scope subchapter aims to acquaint the reader with the application area of the anticipated research results, such as industry sectors, countries, cultures, departments, sites, units, exceptional cases, settings, or phenomena.

Delimiting the scope also delimits the literature review, the methodology, and the conclusions or recommendations. A narrower scope is usually preferred because of the limited period for writing.

The thesis title raises expectations.

Since the title of your thesis raises expectations, your reader might expect you to cover aspects you don't want to address. The delimitations part of this section allows you to clarify early what you intentionally want to exclude. Delimitations may address the exclusion of theories, models, techniques, or application areas. Consequently, your literature review, results, argumentation, and conclusions should not exceed these constraints.

<p>1.3 Scope and Delimitation</p> <p>The thesis addresses scenarios occurring in distributed project teams in businesses of selected European countries. The selected context conditions apply to typical scenarios occurring in development projects of medium-sized enterprises (MEs).</p> <p>Although alternative models exist, the behavioural interpretation rests on assumptions of the behavioural theory since its validity is confirmed by numerous studies. The study does not incorporate an investigation of cultural issues and refrains from taking specific industry sectors into account.</p> <p>Due to different conditions in scaled and large-sized projects, a generalization to other forms of projects is neither intended nor discussed. Furthermore, a generalization beyond the field of business projects is intentionally omitted.</p>	<i>Scope statement</i> <i>Delimiting statements</i>
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Figure 13.6. Example of a brief *Scope and Constraints* subchapter

Don't confuse *delimitations* with the *limitations* you encounter during the study. Since this subchapter occurs in the introduction, it would be inappropriate to address a limitation encountered during the study before you present any results. Limitations occurring as a result of the study are addressed in the critical reflection at the end of the thesis. The following table shows examples of both.

*Delimitations vs.
limitations*

Table 13.1 Examples of delimitations and limitations

<i>Delimitations defined before the study</i>	<i>Limitations found during the study</i>
Assumptions	The sample size was found to be too small.
Methodology	Participant dropout
Study population	Violation of assumptions found.
Application area	Confounding variables were identified but not investigated.
Geographical region	Limitations of measurement instruments found.
Culture	Resource dropout
Organisation	Time constraint
Industry sector	
Technology	

13.5 THE WORST PRACTICE

If you do not consider the value of first impressions to be quite as important as described and prefer to leave an impression of pronounced intellectual modesty, you can easily achieve this by following the advice below.

How to earn the 'Intellectual Modesty Award'

It is time to write the introduction. You are sitting in front of your computer, and your head is as empty as the nutshells remaining from the last winter squirrel's field trips in your garden.

But don't worry if you don't have valuable thoughts. You can simply begin with one of these deep-thought quotations you regularly see in books and articles. Just look up Google for 'famous quotes' or use a Latin phrase that no one ever understood, like "*Ego cogito, ergo sum*"²²⁷

There is no need to bore your reader with uncomfortable details about the quote's translation, its meaning, or its origin. Just assign it to a famous author, like Albert Einstein, Neil Armstrong, or Louis Armstrong. Leave the quotation as a trigger for the reader to intensively think about its meaning to prepare for the epic proportion of your groundbreaking research.

Since you don't want to overwhelm your unsuspecting reader right at the beginning, you start your introduction with intellectual modesty, such as

Since the beginning of time, the question of [insert your topic here] has been debated.

To avoid your reader mentally excluding you from the scientific community, you should back up such nonsense with a quote from an author of equal intellectual modesty, preferably from one of the predatory journals. Alternatively, you can use the other popular beginning:

This study is about [insert your topic here].

On the following twelve pages, you describe multiple ideas that come to your mind and combine them into never-ending sentences that leave your readers gasping for breath and longing for a full stop.

²²⁷ In fact, a valuable statement from René Descartes' *Principia Philosophiae*, reading "...repugnat enim, ut putemus id quod cogitat, eo ipso tempore quo cogitat, non existere. Ac proinde haec cognitio, ego cogito, ergo sum, est omnium prima et certissima, quae cuilibet ordine philosophanti occurrat."; translated: "...for it is contrary to our nature to believe that what thinks does not exist at the very time it is thinking. And consequently, this knowledge, *I think, therefore I am*, is the first and most certain that occurs to anyone philosophising orderly (Descartes, 1722, pp. 2-3).

End your introductory statements by suddenly and without prior notice coming up with the subchapter *Research Objectives*. This ensures your readers are surprised enough to wake up from their impending slumber.

As you approach the research goal, you can show that you have mastered the diversity of your language by using colourful terminology and the following subchapters:

- 1.1 Research Objectives
- 1.2 Purpose of the Study
- 1.3 Goals to Achieve
- 1.4 Target of the Examination
- 1.5 Intention of the Thesis
- 1.6 Aims of the Investigation
- 1.7 Research Agenda

However, avoid stating clear research questions that just delimit your creativity in answering them. Use generic objectives that provide you more freedom to obscure the value of your answers. Begin with 'To...' and call it a research question (you may emphasise it by adding a question mark):

To explore the impact of various factors on phenomena in the context of their potential effects?

You can also use the popular A-D-style, like:

To examine the advantages and disadvantages of [insert your topic here].

To please the academic part of your audience, you may state scientific trivialities that are taken for granted, such as:

To carefully review the literature and to thoroughly investigate the issue.

If you do feel obliged to formulate real research questions, make sure they are not immediately researchable. Ideally, you begin a question with 'How...' and include multiple questions in one:

How is it possible that electrons do not make scratching sounds when they rush through the wires of a coffee machine, and how does this account for my coffee being always cold?

When stating a hypothesis, you need to ensure that it is testable:

H1: Electrons must be waves since they don't make scratching sounds.

This is a valid hypothesis since it can be falsified by finding at least one coffee machine that makes scratching sounds. The null hypothesis states the opposite:

HO: Electrons must be particles since we cannot surf on them.

It is obvious that you can falsify this simply by surfing on the coffee machine.

When stating statistical hypotheses, make sure they express a clear cause-effect relationship using appropriate statistical terminology, such as:

H1: Not every average fellow is a mean guy.

and don't forget to state the corresponding null hypothesis:

HO: Being in mean mood does not mean a median mode.

In case you prefer a thesis statement, you need a more convincing style:

The world would need less tranquilisers if someone finally decided to kill the frogs in my garden.

An antithesis could be:

The world needs more tranquilizers to endure another round of reality TV.

The easiest way to address the value and audience is:

The study is of such mind-blowing significance that even the most disinterested guy would suddenly become a devoted follower.

Define the scope as generally as possible and immediately address the limitations to defend your poor outcomes:

The study would cover every conceivable scenario if it were not limited by the strange ideas of my supervisor.

If you think this sounds too unpretentious, you can use a more scientific form:

In accordance with the principles of probabilistic inference and cognitive restraint, it is advised to abstain from excessively optimistic anticipations, as such undue optimism may give rise to suboptimal psychological and affective states, potentially hindering one's ability to effectively appraise and assimilate reality-based outcomes.

Since you can be sure that your reader has already forgotten about the reason for this text, it is about time to remind him of the contents of this chapter by providing a comprehensive summary of the chapter in the style:

As we have already seen, this study is about [insert your topic here] since it intends to investigate [insert your topic here] to gain valuable insights about [insert your topic here].

What is left is to carefully announce the upcoming chapter:

With the knowledge of the study of [insert your topic here] that we described above, we can now approach the literature review for the topic of [insert your topic here]. Therefore, the next chapter clearly describes the literature that is relevant to [insert your topic here].

14 THE LITERATURE REVIEW

Who needs libraries anyway? Our global network provides enough contributions of such keen intellectual modesty that one can sail blissfully along on a diffuse cloud of vague conjecture. That's probably where the term 'cloud' comes from.

One cause for unreliable information occurring on the World Wide Web is misunderstandings. The real problem arises when misunderstandings are repeated until they become established. We will not prevent them from ending up in those knowledge bases that are used by AI software and finding their way even into textbooks and journal articles.

We would be irresponsibly negligent if we underestimated the influence of the web on our collective beliefs, understanding, and knowledge. Without a doubt, freedom of expression is one of the most valuable achievements of humanity, and the web certainly contributes to this. But there is a difference between expressing one's thoughts and claiming validity.

While we might assume that peer reviews are the solution, they are risky for another reason. If we just rely on sources that are considered valid by a particular science community, we become trapped in the cage of the scientific establishment of a discipline.

A central task of a scientist is, therefore, to question established knowledge – whether verified or not – and to use the remaining one, withstanding logical argumentation, as a basis for generating more valuable insights. This is the primary goal of a literature review.

14.1 THE MEANING OF A LITERATURE REVIEW

Before we present new insights, we want to acquaint our readers with the knowledge base for our argumentation. The scope of this endeavour relies on three prerequisites: the research objective, the audience, and a critical assessment of existing knowledge.

We address the *research objective* and the *audience* in our thesis introduction. The research objective delimits our review to those sources that are relevant to our assumptions and have a meaning for our argumentation. The audience determines what our reader already knows and expects.

Apart from that, we *critically assess* the sources not just for their scientific validity but for their contemporary value. While we can still refer to less reliable sources, such as an opinion expressed in a newspaper article, we must clearly state our doubts about its validity and be aware that it cannot serve as a basis for our argumentation.

While it is comparatively easy to assess the scientific validity of sources (compare chapter 10.2.3), it is more challenging to judge their contemporary value and relevance for our study. One way to approach this is to follow a systematic procedure of coding, analysis, and synthesis.

14.1.1 Coding, Analysis, and Synthesis

Coding

Coding is the process of assigning unique identifiers to relevant text passages. As an example, let us look at a statement found in an article about the environmental impact of waste electrical and electronic equipment (WEEE):

“Atmospheric pollution due to burning and dismantling activities seems to be the main cause for occupational and secondary exposure at WEEE recycling sites. Generally speaking, a growing body of epidemiological and clinical evidence has led to an increased concern about the potential damaging effects of ambient air pollution on health (Brook et al., 2004).”²²⁸

The key terms describing the message of these statements could be *atmospheric pollution*, *occupational exposure*, or *damaging effects*. Such codes do not just allow us to find passages again quickly, but they simplify identifying patterns in multiple sources and allow us to relate them to other patterns.

We can conduct coding according to disciplines, publication date, research goals, methodological or linguistic criteria, or use quantitative data. We derive codes for phrases, sentences, paragraphs, or themes from understanding the text (extensional classification), or we can define them in advance

²²⁸ (Sepúlveda, et al., 2010, p. 36)

through conceptual elaboration (intensional classification). Which code categories are helpful depends on the research objective. Saldana provided a comprehensive guide for coding in multiple disciplines.²²⁹ Software that supports the coding, categorisation, and synthesis process is also available.²³⁰

The goal of an *analysis* (Greek: *analúō*, breaking up, dissect) is the aggregation and categorisation of knowledge. We assign codes that share characteristics to categories that can relate to each other. Gaur & Kumar provide an overview of potential code categories.²³¹

Analysis

Synthesis (Greek: *sύνthesis*, compose) is a creative approach to generating insights beyond the existing knowledge. The type of synthesis depends on the intention. It can be either *harmonising* to unify concepts of different studies to generate a universal set of concepts or *dividing* to explore opposition, contrast, and contradiction between studies to identify discrepancies in underlying assumptions, theories, or ideologies.

Synthesis

While the coding is largely subject to logical considerations, the analysis and synthesis may differ in their underlying epistemologies.

14.1.2 Definitions

It is usually necessary to define terminology or concepts to prevent misunderstandings and lay out the theoretical basis of argumentation. We already distinguished between lexical and conceptual definitions (see also subchapter *A Matter of Definition*, page 25).

If a unique lexical definition exists (usually in mathematics, technology, and the natural sciences), we cite a dictionary or another authoritative source. For instance:

Linguistic and conceptual definition

Exobiology: “a branch of biology concerned with the search for life outside the earth and with the effects of extraterrestrial environments on living organisms”.²³²

We use such lexical definitions if we assume the term is not well-known by the audience or could be misinterpreted. Otherwise, we refrain from defining trivialities (such as what *extraterrestrial* means).

This becomes more complicated with *conceptual definitions*, which often exist in multiple variants, even in dictionaries. We use conceptual definitions to

²²⁹ (Saldana, 2021)

²³⁰ A comprehensive procedure including software support is described by (Bandara, Furtmueller, Gorbacheva, Miskon, & Beekhuyzen, 2015)

²³¹ (Gaur & Kumar, 2018)

²³² (Merriam-Webster, 2022)

identify a concept's characteristics to distinguish it from similar concepts in the same domain. However, we provide a conceptual definition only if the conceptual difference affects our argumentation and we provide a reason for our selection.

Definitions may appear in a separate subchapter of a literature review or in their respective chapters. Figure 14.1 shows an example of linguistic and conceptual definitions presented before the review begins.

These are lexical definitions...

...and this is a conceptual definition.

Ambiguity (uncertainty) aversion: the tendency to prefer known risks over unknown risks.²

Black sheep effect: the phenomenon that subjects judge likeable ingroup members more positively than similar outgroup members.³

Innate behaviour: an unlearned, genetically inherited, and stereotyped behaviour possessed and controlled by all members of a species.⁴

Intuition. This term is used inconsistently in the literature. In the context of this study, intuition is relevant as an alternative to rational thinking in conflict resolution. Amongst the different definitions, the one of Shirley et al. was found to be most appropriate. They define intuition as a “feeling of knowing with certitude on the basis of inadequate information and without conscious awareness of rational thinking”.⁵

Figure 14.1 Excerpt of a subchapter containing linguistic and conceptual definitions. Note that the decision to select a conceptual definition requires a reason.

14.2 TYPES OF REVIEWS

While a literature review is part of any research project, sometimes it *is* the research project. Although the goal of most literature reviews is to provide an overview of existing knowledge, other types of reviews generate new insights and consolidate or interpret existing knowledge from new perspectives. This may affect the logical sequence of the research design and literature review chapters.

The terminology to distinguish types of literature reviews is not consistent. We find terms like narrative review, qualitative review, content analysis, meta-study, meta-analysis, and more exotic species.

Several publications distinguish types of literature reviews, ranging from two categories to fourteen.²³³ Since we want to differentiate but refrain from

²³³ Khoo et al., for instance, investigated the discourse structure of literature reviews and identified two predominant styles (Khoo, Na, & Jaidka, 2011, p. 257). On the other hand, Grand & Booth compiled a more sophisticated typology distinguishing not less than fourteen types of reviews. (Grant & Booth, 2009)

extensive classification, we provide a decision tree (Figure 14.2). We developed our typology by distinguishing between:

- *informative* reviews with a focus on (a) selective or (b) comprehensive summaries.
- *interpretative* reviews with a focus on (a) inconsistencies or (b) verbal expression.
- *abstracting* reviews with a focus on (a) conceptual patterns or (b) statistical effect size.

Table 14.2 shows a more comprehensive typology.

We will see in the following subchapters that all approaches are systematic, but some are more rigid. But before we describe the review types, we like to address a frequently asked question.

14.3 HOW MUCH LITERATURE IS REQUIRED

A common question to a supervisor is: 'How much literature do you expect?' To a supervisor, such a question sounds like a rhetorical one. Although your supervisors grade your thesis, they are not your audience. But they can judge whether you satisfy the expectations of the audience stated in your introduction. Criteria determining the expectations are:

- *the audience perspective*: readers in the scientific community would expect you to cover more aspects than a manager of a company.
- *the field of investigation*: the longer and the more the field has been investigated, the more literature your reader would expect.
- *the scope of your research*: the wider your scope, the more background information is expected, and the more studies, theories, and models need to be addressed.
- *the fuzziness of your research objective*: the vaguer you formulate your objectives, the more aspects your reader can imagine, which increases the number of sources you would have to address.

Since all these criteria appear in your introduction and underlie your control, you are able to estimate the adequate number of sources. Let us look at a thesis of 100 pages. A page using the layout recommended at the beginning of this book consists of about 400 words of body text. If we consider headings, figures, tables, and footnotes taking up extra space, the number will reduce to about 300 words per page.

If we assume a cited statement, including a short comparative assessment after each citation takes up 60 words (five lines), each page may contain about five citations.

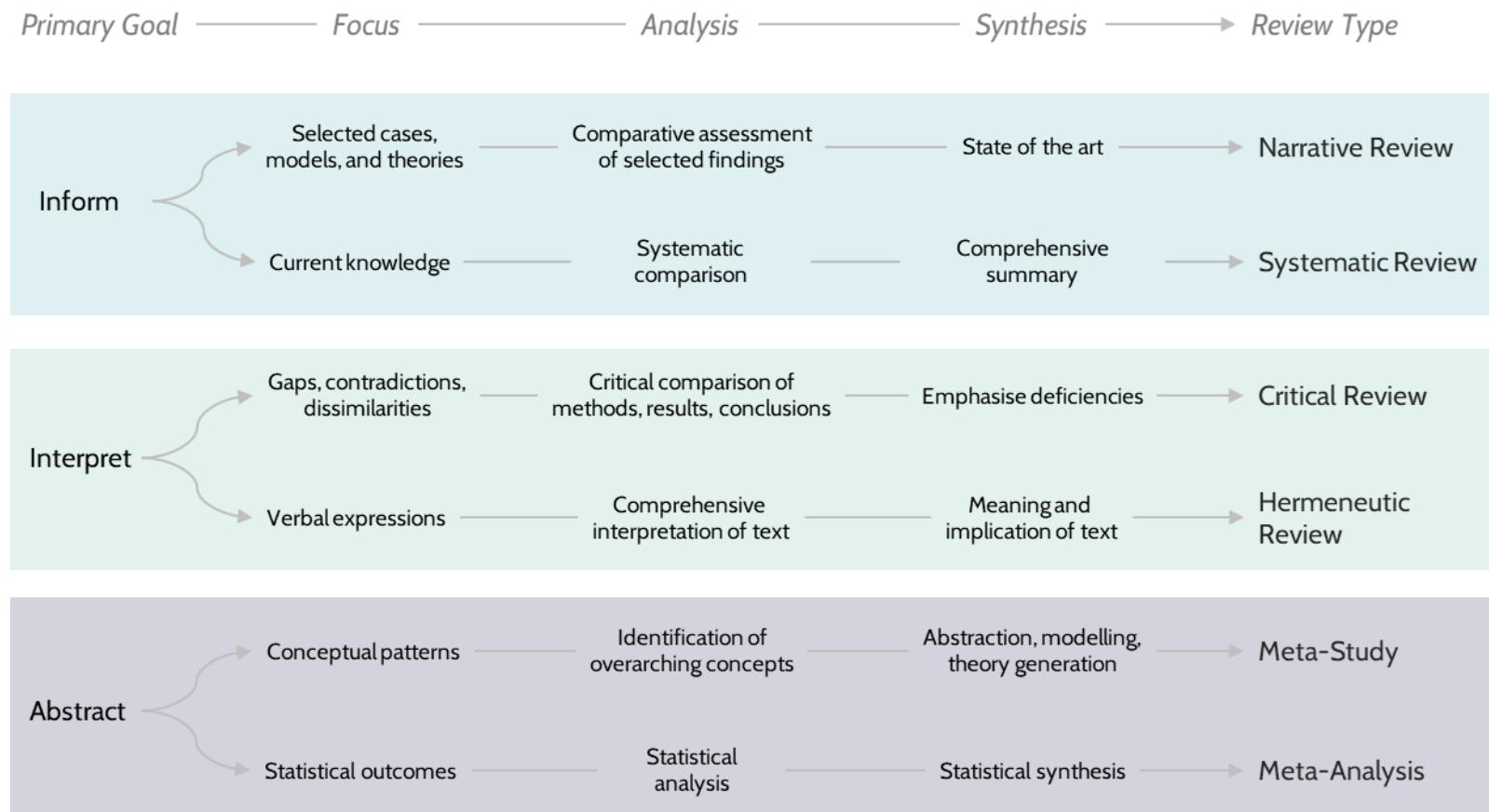


Figure 14.2 Decision scheme for literature reviews

Table 14.1 A typology of literature reviews

	<i>Narrative</i>	<i>Systematic*</i>	<i>Critical</i>	<i>Hermeneutical*</i>	<i>Meta-study*</i>	<i>Meta-analysis*</i>
Purpose	Inform	Condense	Validate	Interpret	Abstract	Synthesise
Strategy	descriptive	comprehensive	exploratory	explanatory	comparative	predictive
Approach	semi-systematic	systematic	semi-systematic	non-systematic	semi-systematic	systematic
Typical proportion	20%	80%	40%	80%	70%	80%
No. of sources	>50	>100	<10	<5	<40	2-3 ²³⁴
Typical sources	Studies in the research context	Ideally, all studies in a period	Studies in the research context	Single or few studies	Selected studies in the context	Statistical studies
Selection criteria	Validity	Validity	Validity	Purpose	Validity	Statistical significance
Focus of analysis	Existing knowledge	Knowledge gaps	Inconsistencies	Linguistic expressions	Interpretations	Effect size
Form of synthesis	Narrative	Condensed	Critical narrative	Interpretative	Conceptual narrative	Forest plot
Outcome	State of the art	Summary and recommendations	Recommendations for improvement	Meaning and implication	Higher-level insights	Overall effect size

*typical primary research objective

²³⁴ see also (Valentine, Pigott, & Rothstein, 2010)

A narrative literature review should not exceed 20% of your thesis; otherwise, your supervisors could interpret it as a lack of your contribution. For 20 pages of literature review, you will end up with about 100 citations.

A systematic review is usually the main research objective and typically occupies 80% of your thesis. Then again, you will scrutinise the found statements more extensively. Let's assume you write 80 pages for a systematic review and discuss the found statements extensively so that you end up with just 2–3 citations per page; you would have to cite around 200 sources.²³⁵

Critical reviews and meta-studies interpret and discuss literature findings far more extensively and typically focus on less than 40 sources. Meta-analysis typically covers less than ten sources, and hermeneutical studies may concentrate just on a single source. However, they are usually accompanied by a preceding narrative or a succeeding comparative review.

Of course, these figures are only indicative. Depending on the research area, you might find fewer sources. The number of references cited in existing systematic reviews is often a good indicator of the coverage of a field. However, filling up the reading list just to meet the supervisor's expectations cannot be the point. The rule to just refer to relevant sources is the guiding principle.

When to stop

The more pertinent question to your supervisor would be: 'When to stop searching for literature?' The more closely you look at the references of the literature you found, the more often you will notice that they cite the fundamental papers repeatedly. That ensures you do not miss established views, concepts, or theories. However, the longer you search, the more redundancy you will find. A rule of thumb is to stop your literature review when you reach a point of theoretical saturation, where topics become repetitive and new insights become harder to find.

14.4 NARRATIVE REVIEW

A narrative literature review is the most common approach and often accompanies other review types. It emphasises what is currently known (state of the art), what theories or models are established and referred to, and what gaps exist in research. Consequently, the narrative review does not underlie a particular research paradigm or discipline.²³⁶

²³⁵ Equip yourself with food and drinks, head into your cave, close the entrance, and read, read, read... Systematic reviews are challenging, but the best way to learn more about a field of interest than you ever learned during your studies.

²³⁶ For simple rules to follow when writing a narrative review, see (Pautasso, 2013). See also the editorial remarks on writing review articles found in (Webster & Watson, 2002).

The goal is to acquaint the reader with the assumptions *before* you present any results, arguments, or conclusions. In other words, the actual study is an extension of the narrative literature review, providing new knowledge that adds to the existing one. As the name suggests, the narrative review is written in narrative form: it tells a story and requires a strong storyline.

14.4.1 Storyline

The introductory paragraphs in the narrative literature review – the text following the heading – address anything of interest concerning the review, such as the sequence of presentation, the publication period covered, the selection and exclusion criteria for the sources, or a reference to a chosen review methodology. Figure 14.3 shows an example of an introductory paragraph.

3 Literature Review

The following chapters present excerpts from theoretical works of behavioural science, comparative psychology, and selected case studies using structural equation models.

The citations cover works published between 2010 and 2023. Older sources were used when recent literature was not available or where fundamental models were referred to that had not undergone notable change. The literature was selected according to validation criteria published in *Preferred Reporting Items for Systematic Reviews and Meta-Analyses*.¹²

Figure 14.3 Example of introductory paragraphs in a narrative literature review

Such statements serve as the short form of the *literature research design* and are sufficient for a narrative review since it does not generate any significant new knowledge.

The structure of a narrative review primarily depends on your research objectives. For instance, if the thesis introduction states three research questions in an adequate priority, the reader would assume that the literature review follows a similar approach. Depending on such priority, you could organise your subchapters (see also Table 14.2):

- *chronologically*: useful if the evolution of the topic over time is of interest, for instance, if the research objective covers the future development of artificial intelligence.

- *thematically*: if multiple theoretical categories or application areas should be addressed; for instance, if the research objective covers the application of artificial intelligence in the healthcare sector.
- *methodically*: if conceptual categories should be addressed; for instance, if the research objective covers the accuracy of predictions with artificial intelligence in one or more application areas.

Table 14.2 Examples of the substructure of a narrative literature review

<i>Chronological Future of AI</i>	<i>Thematical AI in Healthcare</i>	<i>Methodical Accuracy of AI</i>
2.1 Origins of AI	2.1 Medical Diagnostics	2.1 Definitions
2.2 First AI Winter	2.2 Clinical Practise	2.2 Theoretical Works
2.3 Expert Systems	2.3 Emergency Medicine	2.3 Modelling Approaches
2.4 Second AI Winter	2.4 Biomedical Research	2.4 Studies on Accuracy
2.5 Machine Learning	2.5 Public Health	2.5 Case-based Studies
2.6 The Age of Big Data	2.6 Administration	2.6 Critical Reviews

A methodical review of the priority of the research objectives is often adequate. In this case, we can further divide the chapters into theoretical studies followed by empirical studies since understanding the theory is necessary to comprehend the empirical scenarios. Table 14.3 shows a concrete example.

A part of the narrative literature review must cover established propositions, premises, or assumptions that apply to our context, as well as the models and theories we use. While we do not explain these if they are comprehensively described in original publications (we just cite them), we need to address their meaning in our study context. In any case, we prefer the original sources to avoid misinterpretation and newer sources only if they considerably contribute to the established theoretical basis.

If we study a contemporary issue of a company (for instance, during an internship), we keep in mind that our reader is unfamiliar with what we have experienced. That is, we need to describe the setting of the scenario, explain each step in a process and support it with workflow diagrams. Although the case description may occur in a separate main chapter, we need to refer to comparable case studies or similar scenarios described in the literature.

14.4.2 Analysis

When you screen the articles, you focus on whether the article's purpose fits your topic and whether the findings contribute to the knowledge base. After screening and archiving the relevant articles, you can start reading.

Table 14.3 An example of subchapters for the topic: *Potentials of Photographic Image Analysis in Post-Mortem Examination (PME)*

<i>Research objectives</i>	<i>Themes</i>	<i>Subchapters of Literature Review</i>
The meaning of visual information in PME	What visual information does the forensic pathologist use in PME?	2.1 Visual Indicators in Post-mortem Examination ↳ Wounds, Histological Samples, ...
Misinterpretation in PME	What are the reasons for misinterpretation? Which cases are known? What were the consequences?	2.2 Reasons for Misinterpreting Visual Information 2.3 Cases of Misinterpretation and Their Consequences
Applicable image analysis techniques	What can be analysed in an image? Which of the analyses apply to PME? Which techniques were successfully applied?	2.4 Image Artefact Analysis 2.4.1 Visual Artefacts in PME 2.4.2 Case Studies of Artefact Analysis
Predictive quality of automated image interpretation	What errors can occur in image analysis? What are quality criteria?	2.4.3 Errors in Image Artefact Analysis 2.4.4 Error Assessment and Countermeasures
Limitations of image analysis in PME	What are the limitations of technical nature, implementation, maintenance, and cost?	2.5 Technical Limitations 2.5.1 Implementation and Maintenance 2.5.2 Cost Aspects

When you read the statements, mark the relevant ones and assign a code. You can already use some of your search terms as codes. If you identify a pattern behind codes, create a category to group related codes together. Indicate any relationships you find between the codes or code categories. You use the code categories later to assign the sources to their most appropriate subchapter and to achieve a synthesis of the found knowledge.

With each new source, you will identify other keywords for search, which will probably change your initial storyline.²³⁷ Limitations and recommendations for future research found at the end of the article also contribute to refining the search strategy.

14.4.3 Synthesis

The approach to synthesising knowledge in a narrative review is straightforward. Although the reader does not expect an extensive critical discussion, narrative reviews should still be more than a bland list of sources. You must assess each citation to prevent your reader from interpreting it differently.

The annotations may be comparative statements about commonalities or contradictions, inconsistencies, or critical remarks on research gaps found. A simple example of an assessment following a citation is:²³⁸

Levy and Keller discovered a relationship between the maternal behaviour of sheep and neural conditions in the brain.¹² Although their interpretation raised the criticism of several authors,¹³⁻¹⁶ the concept was successfully applied in multiple studies.¹⁷⁻²¹

Since we assume that the quality of the source is already ensured, any further interpretation, such as a judgement of the authors' argumentations, might go beyond the goal of your research. As a rule, a narrative overview does not aim at gaining substantially new insights. Any further critical assessment becomes part of your thesis's results and discussion section.

Don't end each chapter of your narrative review with a summary. A narrative literature review is usually not long enough to necessitate reminding the reader of what they have just read.

14.5 SYSTEMATIC REVIEWS

The term *systematic* refers to a standardised procedure. A systematic review comprises an appraisal and synthesis of literature published in a delimited

²³⁷ Keep in mind: research is a dynamic process.

²³⁸ A comprehensive strategy for a critical analysis is described by (Carnwell & Daly, 2001)

period.²³⁹ The considerable number of sources is the reason for using a pre-determined (and quite rigid) technique.

A systematic review is expected to be comprehensive within its scope. Although we can delimit the scope, we still typically deal with at least hundreds of studies. Without a clearly defined technique, we would be overwhelmed with the decisions we must make to evaluate all contents. That is why systematic reviews are typically the primary research goal of a thesis. In such cases, the research design chapter appears before the systematic review.

14.5.1 Storyline

For a systematic review, we need to determine a series of parameters around the scope, the literature, the sampling, the analysis and synthesis, and the reporting. While we determine these parameters in advance, we must refine them when gaining further insights into the information we collect. This might sound contradictory to the systematic approach, but this kind of dynamics is inherent to any research process.

Figure 14.4 shows an overview of the activities and conditions for a systematic review. Further details are available in the literature.²⁴⁰

14.5.2 Analysis

We conduct a systematic review by focussing on qualitative data, like words, phrases, statements, or themes in particular parts of the publication, such as in the objectives, the methodology, the results, the discussion, or the conclusions. The basic steps of the analysis are:

- *Condensation*: Shortening the transcript while still preserving its core meaning.
- *Coding*: Assigning labels to condensed statements to describe phenomena more exactly.
- *Categorizing*: Creating groups of codes that are similar, different, or provide different aspects of the same phenomenon. A category may address persons, states, times, or locations of a phenomenon.
- *Theming*: Interpreting the underlying meaning (latent content) of categories. A theme is a more descriptive expression of an interpretation and typically addresses the reasoning or action strategy.

²³⁹ An example for a standardized procedures is given in *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA); see (Page, et al., 2021a; Page, et al., 2021b)

²⁴⁰ An extensive guide for narrative systematic reviews is provided by (Popay, et al., 2006)

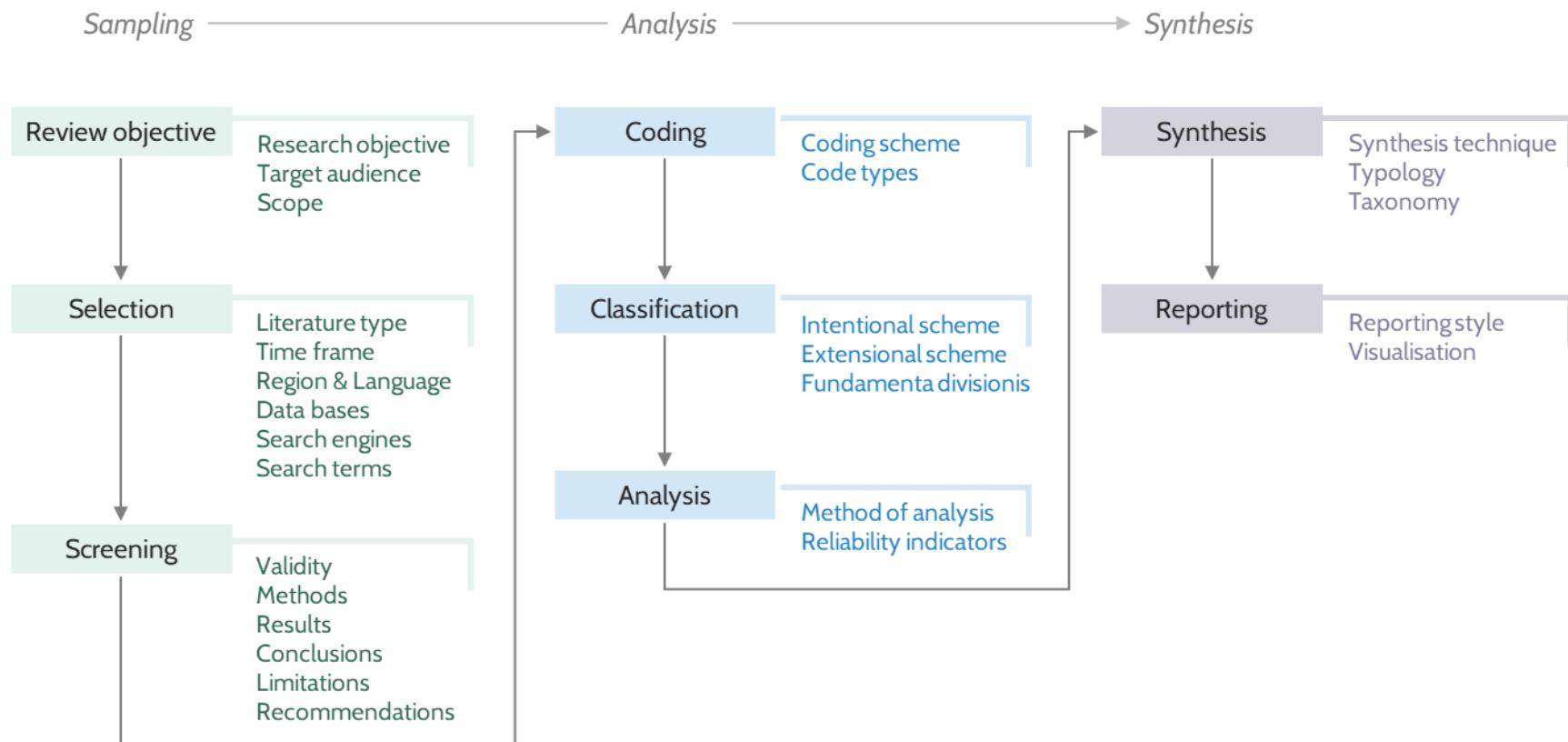


Figure 14.4 Activities and criteria of a systematic review

Another way is to analyse results from multiple narrative studies statistically. That would include quantifying the relevant target information, such as reporting the frequency of research methods used over numerous studies or looking for a correlation between study frequencies and study topics or disciplines.

If the studies under investigation already provide quantitative data, we could use them to perform further calculations or do a statistical analysis of quantitative results. A particular form based on statistical data from studies is called a *meta-analysis*, described in the next chapter.

14.5.3 Synthesis

The synthesis of a systematic review presents a summary of the studies, usually in the form of tables and figures, to summarise the characteristics of the studies and the findings (see Table 14.4). Such textual summaries are particularly valuable for the research community because they provide an overview of multiple studies in a single text.²⁴¹

A discussion section interprets the results in the context of the research questions and other available evidence. This may include implications of the findings for practice, policy, or further research.

14.5.4 Limitations of Systematic Reviews

Although systematic reviews follow a rigid procedure, they have several limitations we need to consider before we decide on this approach.

Methodical variety: The studies included in a systematic review may vary in design, sample size, outcome measures, and other characteristics. This heterogeneity can make it difficult to compare and synthesise the results of the studies.

Limiting objectives: We must be aware that our research objectives delimit the possibility of identifying gaps. This is particularly an issue in social sciences, where a research question or preconceptions can hinder gaining new insights.

Coverage: The demand for comprehensibility cannot be fulfilled since the coverage of databases is often insufficient. The increasing commercialisation of research studies and the lack of free access do not contribute to this.²⁴²

²⁴¹ A systematic review on explainable artificial intelligence (XAI) demonstrates the approach nicely (Schwalbe & Finzel, 2022).

²⁴² For a detailed discussion of this issue in the humanities, see (Schlicht, 2021)

Table 14.4 Excerpt of a summary of a systematic review. The criteria (column headers) may vary according to the research questions. Codes are indicated in boldface.

Author(s)	Year	Source	Short Title	Type	Methods	Results	Limitations	Recommendations
1 Pollanen	2012	Forensic Sci Med Pathol 8, 285–289	Forensic pathology and the miscarriage of justice	Case	Re-interpretation	Misinterpretation of autopsy findings	not given	Peer review of autopsy report; Autopsy practice guidelines
2 Sørensen, Lynnerup	2014	Res Rep Forensic Med Sc 4, 11–17	Fatal outcome after unintended events following medical intervention	Case review	Systematic review	Unintentional incidents after medical intervention	a limited number of cases	Checklist for issuing the death certificate
3 Campobasso et al.	2015	J Forensic Leg Med 34, 67–72	Inaccuracy of cause of death determination without autopsy	Case review	Meta-analysis	Discrepancies between external body examination and forensic autopsy	not given	Standard operating procedures required: unify legislations concerning death certification
4 Giles, Erickson, Márquez-Grant	2022	J Forensic Leg Med 85, 102292	Decomposition variability between scene and autopsy examination	Case review	Systematic review	Decomposition between the scene recovery and subsequent autopsy	insignificant	Use both scene and autopsy photographs for post-mortem interval estimation
5 Papadakis, et al.	2013	Circ Arrhythm Electrophysiol, 6(3), 588–596.	Cardiac death with autopsy findings of uncertain significance	Case review	Systematic review	Erroneous interpretation of sudden cardiac death (SCD) with sudden arrhythmic death syndrome (SADS)	Brugada syndrome as predominant case diagnosis	SCDs with inconclusive autopsy findings should be considered as SADS deaths

Publication bias: Studies with negative or inconclusive results are less likely to be published. Unpublished studies or grey literature may provide information that is not captured by systematic reviews relying just on available sources. This publication bias may lead to overestimating the studies' value or validity.

Interpretative bias: Systematic reviews are as biased as their sources. A systematic review based on sources that use interpretative analysis is only as valuable as the quality of the interpretations it attempts to scrutinise. If the quality of the studies is poor, the systematic review may not provide a valid summary of the available evidence.

14.6 CRITICAL REVIEW

A critical literature review underlies similar principles as narrative and systematic reviews but differs in intention and focus. While a narrative review places emphasis on the synthesis to provide a summary, a critical review focuses on the analysis to identify flaws. A critical review attempts to create new insights into the existing writings and thus expand knowledge in the area under study.

The term *critical* is meant here in its original sense (Greek: *kritikós*, able to judge or discern) to describe an approach to examine texts for their basis of argumentation, consistency, and coherence.²⁴³

Critical reviews are helpful if the research objective addresses an issue whose origins underlie a particular understanding and are subject to misinterpretation or divergent interpretations. Typical fields of investigation are cultural studies, gender studies, organisational theory, leadership and management theories, and research paradigms.²⁴⁴

A key to a critical review is to understand that the methodology authors choose to investigate a phenomenon determines how a model of the phenomenon is constructed. The conceptualization of such constructs becomes the focal point of investigation. If we encounter a claim, we must understand its underlying interpretative process.²⁴⁵

²⁴³ The term *critical* also appears in several methodologies, such as critical discourse analysis (CDA) and critical management studies (CMS), where it refers to the underlying paradigm of critical theory.

²⁴⁴ An excellent review of critical literature reviews is given by (Wright & Michailova, 2022) and a generic strategy is presented in (Carnwell & Daly, 2001).

²⁴⁵ (Van der Walt, 2020, p. 64)

14.6.1 Storyline

A main difference between the narrative review and the critical review is that the former replicates existing knowledge while the latter generates new knowledge. Therefore, the critical review appears after the research design chapter, which includes details on the selection criteria for literature and on methods of text analysis and synthesis.

If the critical review is required to answer a part of the research objectives, it usually precedes the results from other investigations.

If it is the main research project, a narrative literature review may turn up before, informing the reader about existing critical studies, followed by research design and the critical review that replaces the results and discussion section. Table 14.5 exemplifies these variants.

Table 14.5 Different thesis structures for critical reviews

<i>Conventional Structure</i>	<i>Critical Review as partial objective</i>	<i>Critical Review as the main objective</i>
Introduction	Introduction	Introduction
Narrative Review	Research Design	Narrative Review
Research Design	Critical Review	Research Design
Results & Discussion	Results & Discussion	Critical Review
Conclusion	Conclusion	Conclusion

The introductory paragraphs of a critical review state the phenomenon which is under investigation. It also describes the goal of the criticism, what is criticised, and how it is done. Figure 14.5 shows an example.

3 Critical Review of Literature

The following chapters present a critical analysis of business studies on behavioural science and scrutinise their underlying assumptions using models of comparative psychology. The goal is to identify flaws in premises that could lead to an inadequate conceptualisation of business behaviour. The synthesis will present weak spots of established behavioural theories and their impact on the research objectives of this study.

Figure 14.5 Example of an introductory paragraph in a critical literature review

Clear wording is essential to avoid falling into the same traps as the authors of the studies you want to criticise. Avoiding such traps requires an initial

section with definitions for terms that regularly turn up and could be misinterpreted.

We can organise the succeeding subchapters according to different domains, such as:²⁴⁶

- *assumptions*: useful if studies differ in their ontological stance, for instance, idealism and realism.
- *methodologies*: useful if studies differ in their epistemological stance, for instance, if idiographic and nomothetic studies are compared.
- *methodical approaches*: useful if studies differ in their level of abstraction, for instance, if theoretical and empirical studies are compared.
- *models and theories*: useful if different studies underlie different theoretical concepts.
- *disciplines*: useful if the studies stem from different areas of expertise; for instance, if political and economic studies are compared.

The foundations of the chosen domains must be well understood, which poses an extra effort for preparing critical reviews. The domain defines the structure of the analysis and is also reflected in the synthesis.

14.6.2 Analysis

The critical analysis requires generating codes for statements and their relationships to the corresponding domain. Compared to the analysis in the narrative review, this step is more sophisticated and time-consuming.

Each argument or conclusion must match its ontological and epistemological assumptions. The coherence (logical soundness) and the inherent consistency of arguments (being free of contradictions) are two focal criteria.

Similarities of incoherence or inconsistency between studies may also reveal a pattern whose underlying reasons may have the same origin. For instance, a fundamental misunderstanding of the meaning of ontological assumptions for interpreting results (which occurs, for instance, regularly in economic disciplines) may cause misinterpretation in multiple studies.²⁴⁷

As you scrutinise the relevance, objectivity, and logic of interpretation and argumentation, your personal opinion must not matter.

²⁴⁶ These are just examples. The adequate segmentation depends on the chosen *fundamentum divisionis*; the criterion that is characteristic for a division (see chapter 1.5.3).

²⁴⁷ An example is found in a critical study on charismatic-transformational leadership (van Knippenberg & Sitkin, 2013)

Table 14.6 Excerpt of a summary table for a critical review on the topic of leadership styles

Study Type	Approach	Description	Flaws	Consequences	Source(s)
Theoretical	<i>idiographic</i>	<i>Knowledge as a fundament for leadership</i>	<i>Missing criteria for knowledge acquisition; misspecification of servant leadership</i>	<i>Incoherence of the knowledge model; contradicts 8, 11</i>	2, 13
Theoretical	<i>idiographic</i>	<i>Comparative review of leadership styles</i>	<i>Inconsistent set of propositions</i>	<i>Validity of the model questionable</i>	15
Empirical	<i>idiographic</i>	<i>Dependency of leadership traits from recruitment process</i>	<i>Ontology not adhered to</i>	<i>Inadequate comparison of models</i>	11
Empirical	<i>idiographic</i>	<i>Influence of servant leadership and serving culture on individual and unit performance</i>	<i>Interdependency of process and leadership performance ignored</i>	<i>Results interpreted beyond assumptions</i>	5
Empirical	<i>nomothetic</i>	<i>Transformational leadership styles</i>	<i>Authentic and servant leadership styles associated with agile development projects</i>	<i>Not reproducible</i>	14, 19
Empirical	<i>nomothetic</i>	<i>Charismatic and transformational leadership styles</i>	<i>Juxtaposition of result underlying different assumptions; incompatible with cited case studies</i>	<i>Inadequate generalisation; inadequate comparison with 13, 22</i>	33, 34
Semi-empirical	<i>nomothetic</i>	<i>Comparison of statistical approaches to leadership-performance correlation</i>	<i>Inappropriate probabilistic measures of coherence; missing assumptions</i>	<i>Interdependency of process and leadership performance ignored</i>	4, 7, 22
Statistical	<i>nomothetic</i>	<i>Democratic leadership and employee morale</i>	<i>Cross-sectional study design not adhered to</i>	<i>Results inapplicable to compared cases</i>	3

14.6.3 Synthesis

The synthesis of a critical review summarises the findings and their relationships. We present the studies in a table based on their domains and demarcating criteria. Table 14.6 above shows an example. It may be convenient to end the critical review with a short concluding discussion, leading to the results section for any remaining research objectives.

14.7 HERMENEUTICAL REVIEW

The term hermeneutics (Greek: *hermēneúein*,²⁴⁸ construe, interpret) covers the theory of interpretation and a methodology for interpreting texts. As a theory of interpretation, hermeneutics is about the principles of understanding the meaning behind texts.²⁴⁹ It covers the form of examining rational or emotional elements of statements to reconstruct an author's (possibly hidden) intention.

Hermeneutics as a methodology is a systematic approach to interpreting texts. It becomes relevant if a text or transcript is to be interpreted for mental constructs, implicit assumptions, or tacit knowledge. For instance, to understand the intention behind a particular decision-making process that led to an incident.²⁵⁰

The idea of applying hermeneutics to a literature review is that any new information we obtain from sources contributes to understanding other sources. For instance, a new aspect in one study may change the focus and render previously selected sources less relevant. Thus, it reflects a triviality of our natural exploration process: continuous learning and the change in perception.

French philosopher Paul Ricoeur elaborated on the close relationship between hermeneutics and phenomenology. He established an approach to reveal hidden meanings in the apparent meaning and particularly set focus on the literary use of symbols (representative figures), metaphors (comparative

²⁴⁸ The term seems related to the name of the Greek deity Hermes (the messenger) and – although not undisputed – is often referred to as the namesake for hermeneutics. Hermes was more than just a messenger, but an interpreter of the messages of the word of the god Zeus (see also Palmer, 1980).

²⁴⁹ for details on hermeneutics, see (George, 2020); an overview on its application in literature reviews is given by (Boell & Cecez-Kecmanovic, 2014) and a systematic walkthrough in (Boell & Cecez-Kecmanovic, 2010).

²⁵⁰ On the relationship between rhetorical analysis, discourse analysis, and hermeneutics, see (Martin, 2022)

figures), expressive lexis (emotive language) and the narrative (storytelling).²⁵¹

We can investigate various mental phenomena and a series of categories (see Table 14.7). However, we avoid preconceptions about the study object. That is, we identify such code categories ideally after repeated reading to prevent a lack of creativity and innovation when interpreting a text.

Table 14.7 Potential focal categories for hermeneutics

<i>Phenomena</i>	<i>Artefacts</i>	<i>Actions</i>	<i>Context</i>
Perception	Ideas	Social interaction	Historical
Attention	Concepts	Collective action	Social
Awareness	Memory	Daily activity	Cultural
Consciousness	Experiences	Movement	Collective
Self-consciousness	Skills	Gesture	Political
Self-awareness	Knowledge	Posture	National
Self-reflection	Propositions	Speech	Religious
Empathy	Assumptions	Appearance	
Sensitivity	Beliefs		
Meaning	Desires		
Understanding	Values		
Intention	Imaginations		
Will	Emotions		

In a hermeneutical review, we focus on the interpretation of either one or a few carefully selected texts. Our discussion on individual statements is far more detailed than with other reviews, and the number of comparative literature sources is consequently limited. A comprehensive interpretation and discussion usually take up to 80% of a thesis since the introduction and the research design section are comparatively short.

14.7.1 Analysis

A simple example of how reading extends our perception of the context is shown in the following excerpt. Let us assume we read an article about hermeneutic literature reviews.

²⁵¹ He initially termed it the 'hermeneutics of suspicion' but later refrained from using this tautology because of its connotation to omniscience. A treatise on this is found in (Scott-Baumann, 2009).

Not being already familiar with this topic, we encounter the following paragraph:

"Seeing the process of understanding as generally open ended and circular in nature, hermeneutics provides a framework for describing literature reviews. According to this understanding, literature reviews facilitate a deeper understanding not only of the body of relevant literature but also a deeper understanding of individual texts. Literature reviews therefore do not have to start by identifying all potentially relevant texts, [sic] but should proceed from a thorough reading of relevant texts."²⁵²

This paragraph adds a new perspective by arguing for the quality of reading in favour of the quantity of sources. This may lead us to apply certain quality aspects and read the relevant passages more carefully. In turn, it may change our understanding of the text if we read it again from the beginning. While we can achieve such factual results already with content analysis, the fascinating attempt of hermeneutics is the search for hidden meaning.

Understanding is not just a straightforward process of interpretation and intake but becomes a matter of experience with the topic. Hermeneutics considers this by using a so-called *hermeneutic circle*, the continual iteration between understanding text and context. Understanding more about a part of the text leads to new insights about the context, which may refine the understanding of the entire text.

Hermeneutic circle

We demonstrate this with an excerpt from the Nobel Lecture by Barack Obama held in 2009. We recommend you read the following excerpt once before you go ahead:

"We must begin by acknowledging the hard truth: We will not eradicate violent conflict in our lifetimes. There will be times when nations – acting individually or in concert – will find the use of force not only necessary but morally justified. [...] So yes, the instruments of war do have a role to play in preserving the peace. And yet this truth must coexist with another – that no matter how justified, war promises human tragedy. The soldier's courage and sacrifice is [sic] full of glory, expressing devotion to country, to cause, to comrades in arms. But war itself is never glorious, and we must never trumpet it as such.

So part of our challenge is reconciling these two seemingly irreconcilable [sic] truths – that war is sometimes necessary, and war at some level is an expression of human folly."²⁵³

After reading this passage once, you have a first impression of what it is about. Repeated reading and coding reveal logical constructs, contradictions, and linguistic particularities (see Figure 14.6).

²⁵² (Boell & Cecez-Kecmanovic, 2010, p. 133)

²⁵³ (Obama, 2009, paras. 14, 19, 20)

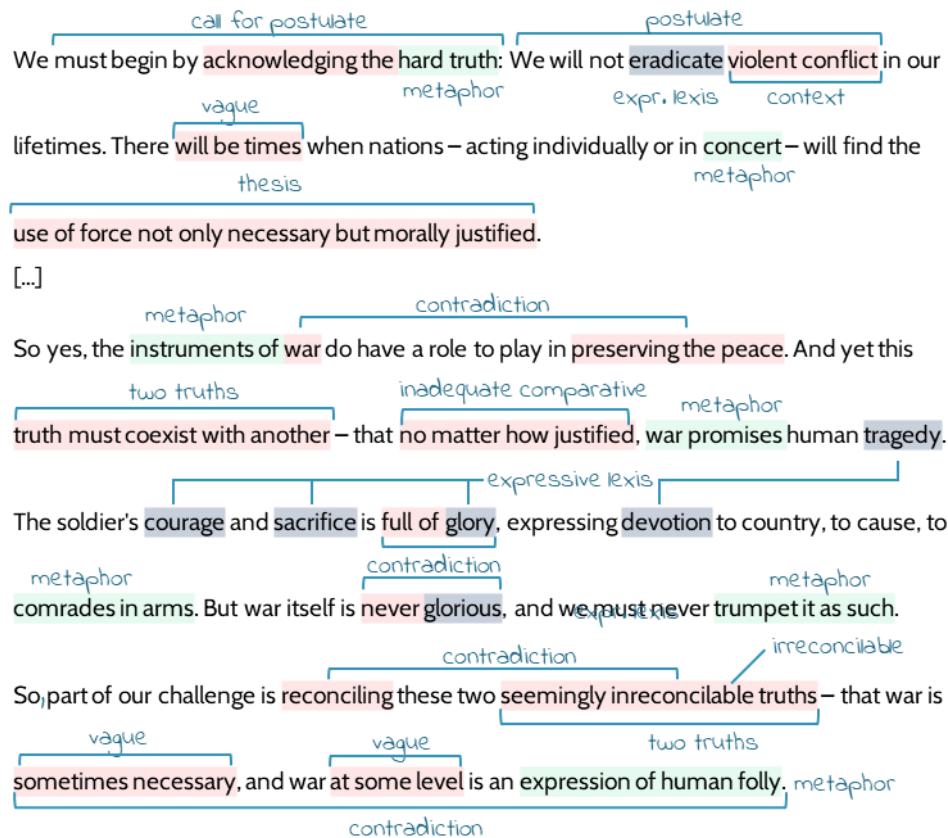


Figure 14.6 Coding example of an excerpt of the Nobel Lecture of Barack Obama, held in 2009. The codes describe the logical and linguistic characteristics of the text.

A closer look at the logical structure reveals an interesting line of argumentation. The excerpt begins with the call to accept the postulate:

“We will not eradicate violent conflict in our lifetimes” (P),

followed by the thesis:

“There will be times when nations ... will find the use of force is not only necessary but morally justified” (T).

We leave out the part of moral justification, which was excluded from the excerpt to shorten the text. For the moment, we concentrate on the remaining text, where we find arguments supporting the thesis:

- “instruments of war play a role in preserving the peace” (T1)
- “courage and sacrifice is [sic] full of glory” (T2)
- “war is sometimes necessary” (T3)

as well as arguments supporting the antitheses:

- “war promises human tragedy” (A1)
- “war is never glorious” (A2)
- “war is an expression of human folly” (A3)

The arguments express four conceptual contradictions, one within the first thesis argument and three from the thesis and antitheses:

- War preserves peace. (T1)
- Preserving peace promises tragic (T1-A1).
- A soldier's duty is glorious, but the cause of it is not (T2-A2).
- War is necessary but foolish (T3-A3).

The latter is addressed as two *seemingly* irreconcilable truths; that is, they are supposed to be reconcilable. The argumentation culminates in the dilemma of unity necessity and nonsense. This interpretation is not representative since it does not consider the entire speech, but it shows the principles of analysis that uncover the basis for the synthesis.

14.7.2 Synthesis

If we reflect on the hidden message, we could interpret it as a strategy that attempts a justification of the postulate through a juxtaposition of theses and antitheses. This strategy anticipates the counterarguments and deliberately weakens their argumentative strength. Vague formulations, metaphors and the declamatory style only seem to disguise the fact that a synthesis between war and peace arguments remains unattainable.

Besides the entire text, hermeneutics also requires considering characteristics of the structure, the genesis, the speech writer, and the historical and political context. Obama's speechwriter, Jon Favreau²⁵⁴, found himself in the dilemma of Obama receiving a Nobel Peace Prize as the leader of one of the most militaristic nations.²⁵⁵ A hermeneutic analysis of the interview with Geir Lundestad, the secretary of the Norwegian Nobel Committee, conducted after the announcement of the prize would be equally interesting.²⁵⁶

Since such interpretations are always subjective, a continual reflection of one's own interpretations is required. Although it is impossible to achieve complete objectivity since each researcher may arrive at a different interpretation, engaging in discourse is necessary to gain a deeper understanding of the meaning of the text.

Continued reflection between text and context is done until a *theoretical saturation* occurs. This metaphor means that new information is either not

Theoretical saturation

²⁵⁴ (Kim, 2013, para 19)

²⁵⁵ According to Alfred Nobel will, the Nobel Peace Prize is given "to the person who has done the most or best to advance fellowship among nations, the abolition or reduction of standing armies, and the establishment and promotion of peace congresses" (Nobel Prize Outreach, 2023, para 16)

²⁵⁶ Try yourself: (The Norwegian Nobel Committee, 2009).

found or does not considerably contribute to understanding. This may happen if we see the same arguments turning up repeatedly, literature repeatedly cites the same sources, or if concepts found in literature become increasingly familiar.

Klein and Myers suggested a valuable set of seven principles for interpretivist studies in information systems research that seems universally applicable.²⁵⁷ Besides the hermeneutic circle, they emphasise understanding a phenomenon within its cultural, historical, and literary context and the abstraction as a principle for the analysis. For the synthesis, they propose confronting preconceptions with actual findings, which in turn must be critically reflected to avoid just accepting the obvious.

14.7.3 Grounded Theory

A standardised approach to hermeneutics is *grounded theory*.²⁵⁸ The coding follows a three-step procedure: open coding, axial coding, and selective coding. We use the excerpt from the Nobel Peace Prize speech presented above as an example.

Open Coding

Open coding refers to searching a text for distinctive phrases relevant to the research objective. Each phrase receives a code and a unique key term:

Phrase	Code
acknowledging the hard truth: We will not eradicate violent conflict in our lifetimes	Inevitability
use of force not only necessary but morally justified	Moral justification
instruments of war do have a role to play in preserving the peace	Peacekeeping
no matter how justified, war promises human tragedy	Suffering
soldier's courage and sacrifice are full of glory	Glory
war itself is never glorious, and we must never trumpet it as such	Lack of glory
reconciling these two seemingly irreconcilable truths	Incompatibility
war is sometimes necessary	Necessity
war at some level is an expression of human folly	Folly

²⁵⁷ (Klein & Myers, 1999).

²⁵⁸ An approach is described by (Wolfswinkel, Furtmueller, & Wilderom, 2013)

Axial Coding

The synthesis begins with *axial coding*,²⁵⁹ subdividing the found codes into categories to establish commonalities between codes. The categories represent broader themes that emerge from the open codes, and the subcategories provide a more detailed understanding of each category:

Category 1. Characteristics of War

Inevitable	Moral justification	Lack of glory
Suffering	Preserves peace	

Category 2. Justification of Force

Inevitable	Moral justification	Peacekeeping
------------	---------------------	--------------

Category 3. Contradictory Truths

Moral justification	Suffering
Glory	Lack of glory
Necessity	Folly

The axial coding helps to establish relationships (axes) between the codes, enabling a deeper analysis of the text and the development of a comprehensive understanding of the perspectives on war and conflict presented in the passage.

Selective Coding

To identify a central category, we use the so-called *selective coding*. This step increases the abstraction level to allow for selecting a central phenomenon that synthesises the results of the entire coding. Based on the axial coding, we can focus on either of three key themes:

Theme 1. Justification of War

Use of force is inevitable, necessary, and morally justified.

Theme 2. Dual Nature of War

War is necessary but leads to suffering.
Soldier's duty is glorious, but its reason is not.
War is necessary but foolish.

Theme 3. Reconciliation

Synthesis of necessity and folly.

²⁵⁹ Some scientist love to disguise their procedures in sophisticated wording.

In selective coding, the focus is on identifying and highlighting the most significant and meaningful codes or themes that capture the essence (or ‘theory’) of the text. After selection, the arguments are re-assessed with this central theme in mind, providing a condensed representation of the key concepts and perspectives presented.

Theory Generation

A ‘theory’ about the text would emerge from an in-depth analysis of the text, where the researcher identifies and connects the various codes, categories, and themes, leading to the development of a theoretical framework that explains the phenomenon being studied. A versatile approach – adapted from one of the original publications²⁶⁰ – is to subdivide categories into:

- *phenomena*: discernible facts, experiences or events described in the text, such as contradictions.
- *causal conditions*: discernible reasons or conditions for the phenomenon’s occurrence, such as the assumptions.
- *strategy*: discernible approaches or actions described to deal with the phenomenon, such as the approach to resolve the contradictions.
- *consequence*: discernible implications of the strategy, such as the contradictions remaining unresolved.

Other subdivisions like assumptions, regional or cultural conditions, or temporal precedence may also be appropriate.

A potential theory that could emerge from the central theme is the *Paradoxical Nature of War and Conflict*. This theory revolves around the idea that war and conflict contain inherent contradictions and dualities that are difficult to reconcile. The theory would cover:

- *Assumptions*: War is unfortunate but unavoidable. It is deemed necessary and morally justified.
- *Causal conditions*: the contradiction between necessity and consequence.
- *Strategy*: Juxtaposition of contradictions.
- *Consequence*: Acknowledgment of war’s necessity while acknowledging it as the expression of human folly.

The consequence in our example suggests the inherent tension between the need for force and the negative consequences it entails cannot be reconciled.

²⁶⁰ (Corbin & Strauss, 2015)

Comparison with Literature

After the theory is established, we perform a comparative assessment with literature and other evidence. We can extend our arguments in the following categories.

Cause of the Phenomenon: The cause of the paradoxical nature of war and conflict can be attributed to the complex interplay of political, social, and moral factors. Factors such as geopolitical tensions, ideological differences, power struggles, and the inherent fallibility of human decision-making contribute to the emergence of this phenomenon.

Strategy to Deal with the Phenomenon: A potential strategy to address the paradoxical nature of war and conflict could be the pursuit of diplomatic and peaceful means to prevent or resolve conflicts whenever possible. This strategy may involve fostering international cooperation, promoting dialogue, negotiation, and mediation, and striving for diplomatic resolutions to minimise the resort to force.

Consequences of the Strategy: The consequences of adopting a strategy that prioritises peaceful means to address the paradoxical nature of war and conflict can include reduced human suffering, preservation of life and resources, enhanced international relationships, and the promotion of stability and security. The ultimate approach would be finding non-violent alternatives.

In grounded theory, the specific central phenomenon, cause, strategy, and consequences would emerge from the analysis of empirical data rather than being imposed from external sources. That is, the comparative review follows the interpretation.

14.7.4 Remarks on Grounded Theory

From a formal point of view, the procedure of grounded theory uses both *extensional* and *intensional* classification. Extensional classes are formed by open coding using the empirical evidence associated with a concept or category. It uses the actual instances (the extension) and forms the class by grouping specific instances that share common observable characteristics (code categories).

Intensional and extensional classification

Intensional classes are formed with axial coding by identifying the focal categories and their *fundamenta divisionis* of meaning (or intension) in advance, such as phenomena, causes, strategies, and consequences.

Several application areas take advantage of the grounded theory procedure, such as ontology engineering in information sciences, research on decision-making in healthcare and business, or the development of study programs

in educational sciences. However, there are some misconceptions about grounded theory we like to address.²⁶¹

A misleading name

Firstly, the name *grounded theory* may be misleading to the inexperienced researcher. In contrast to the meaning of *theory* as an explanatory model of a natural domain, the term is used here in the sense of principles and a procedure backed up, or *grounded*, by data stemming from the statements of social actors and the researcher's interpretation.

Subjective or objective?

A second origin of misconception is the apparent inconsistency between interpretation and modelling. In other words, mental phenomena that usually elude a normative inspection are assessed through systematic subjective interpretation to achieve a universally valid understanding. The grounded theory, therefore, requires a consensus between the idiographic and the nomothetic epistemologies. This issue has further consequences.

Biased but targeted

While an actor's subjectivism is an unavoidable part of the social setting, the key to addressing the (undesired) researcher's subjectivism is to approach the topic under investigation without preconceived ideas. To avoid bias in interpretation, researchers refrain from any prejudice towards the text. However, a clear research objective, rules for the systematic procedure, and a comparison with the literature – at least after model building – are still required and delimit the interpretational freedom.²⁶²

Explorative but systematic

While the procedure is necessarily systematic, it should not conceal that grounded theory is of *explorative* nature. The creativity of the researcher may change at any time with the data collected, the identified categories, and the interpretation of patterns and relationships. As a result, the procedure does not end at a predefined stage but continues until theoretical saturation.

Ongoing but ending

The concept of theoretical saturation deprives any regularity. While redundancy of interpretations might be a criterion for a coherent model, it might also indicate the researcher's ineptitude of ongoing abductive reasoning.

Abductive rather than inductive

Although grounded theory is often described as an inductive approach, we have already shown that it relies on abductive reasoning (see Chapter 3.1). The misconception stems from relating hypothesis (or theory) generation only to induction and forgetting about the role of abductive reasoning. However, the principle of demarcation between the two is probability and possibility and not the fact that they generate hypotheses.

²⁶¹ A nice summary of misconceptions is given by (Suddaby, 2006)

²⁶² There is an ongoing discussion about whether the literature review shall be performed before or after the modelling (see, for instance, McGhee, Marland, & Atkinson, 2007). We don't see value in engaging in this debate since the researchers' subjectivity is an inevitable part of the interpretivist's epistemology.

Systematic procedures like grounded theory are inevitable in research, and the freedom demanded by idiographic researchers is consequently delimited. To use grounded theory appropriately, we need to understand our assumptions, or as Ghezeljeh & Emami formulated:

"Credible grounded theory research should begin by clearly articulating the underpinning epistemology & methodology."²⁶³

But we should also refrain from dogmatism concerning any of the scientific paradigms. Otherwise, we run the risk of misapplying it.

14.8 META-STUDY

The prefix *meta* (Greek: above, beyond, transcending) expresses a higher level of abstraction going beyond a subject's level.²⁶⁴ A meta-study can be understood as a study that goes beyond the knowledge provided by individual studies.

The goal of abstraction is to transform a subject into a more general (and often simplified) form that represents common and unique characteristics. For example, we may abstract results from individual studies to establish universal normative principles.

Any entities found in studies can be abstracted. We can derive knowledge from commonalities between underlying theories (meta-theoretical), methods (meta-methodical), forms of analysis (meta-analytical), and results and implications (meta-interpretative).²⁶⁵

Since meta-studies are time-consuming, the number of sources is usually delimited. They, therefore, do not aim for comprehensiveness, and the sampling is delimited by purpose and convenience.

14.8.1 Storyline

Although a meta-study could be part of a larger research project, it is typically a stand-alone project due to the time-consuming interpretation.

²⁶³ (Ghezeljeh & Emami, 2009, p. 23)

²⁶⁴ The prefix is found in words like metaphysics (subjects transcending physical objects; although the discipline meanwhile covers much more.) or metadata (data on a higher abstraction level). It is often used in the sense of 'about' (like metadata = data about data) even though this preposition does not adequately cover the essence of abstraction.

²⁶⁵ An extensive description of meta-methods is found in (Paterson, Thorne, Canam, & Jillings, 2001); an example methodical approach is given by (Barnett-Page & Thomas, 2009)

Consequently, the thesis's introduction will cover the meta-reviews objectives and the rationale for using this approach.

Whether a narrative literature review should turn up before is debatable. A narrative literature review could precede to inform the reader about existing meta-studies, and the actual meta-study would replace the results and discussion section. However, if the interpretative approach assumes a value-free assessment, the logical structure would be to present a comparison with the literature after the meta-study (Table 14.8).

Table 14.8 Different thesis structures for meta-studies

<i>Meta-study with narrative review</i>	<i>Meta-study with literature comparison</i>
Introduction	Introduction
Narrative Review	Research Design
Research Design	Meta-study
Meta-study	Literature Comparison
Conclusion	Conclusion

The research design clearly outlines the review method, ideally referring to a standardised approach and using a flow diagram. This includes the initial process of exploratory scoping of literature, the search processes (databases, search terms, period), the selection and appraisal of documents (criteria and justification for inclusion and exclusion), the number of documents selected, the analysis and the synthesis procedure (for details, see chapter 14.5).

14.8.2 Analysis

The question of which parts of a text are relevant is derived from the research objectives, which may focus on theory, method, analysis, or interpretation.

Meta-theoretical analysis aims to compare the theoretical bases of studies and scrutinises them for commonalities and differences. It pays attention to ontological and epistemological assumptions and their consequences on the chosen methodology.

An analysis on the *meta-methodical* level focuses on the comparison of chosen methods. It must assume comparable research goals and the same ontological and epistemological assumptions.

The *meta-analytical* approach looks at how data are analysed and aims at deriving new knowledge from a comparative assessment. The meta-analytical approach to *qualitative data* is tricky since it involves any interpretable text,

like themes, statements, opinions, or arguments. Here we approach the slippery domain of interpretative research. It is helpful to familiarise yourself with concepts of meta-interpretation,²⁶⁶ although studies covering such concepts are often ideal subjects for critical reviews.

If we deal with quantitative data, we achieve abstraction through mathematical (mostly statistical) evaluation, which follows strict methodological principles (see also the *meta-analysis* described in chapter 0).

A *meta-interpretative* analysis focuses on the assessment of results interpretation; we could say we interpret interpretations to provide insights going beyond the original ones. Such an approach requires a purposive and iterative sampling of studies for synthesis, focuses on meaning in a context, and uses interpretations as the raw data for synthesis.

14.8.3 Synthesis

The synthesis of a meta-study is conceptual rather than descriptive. The goal lies in interpreting commonalities and differences in the chosen meta-domain and their implications for the results presented in the studies.

We present the synthesis in a summary table, showing the key findings in narrative form, accompanied by paragraphs discussing the key findings. A comparison with existing literature (for example, other meta-studies) on the same topic appears afterwards.

A synthesis approach to *meta-interpretation* was published in 1988 by Noblit & Hare under the name *meta-ethnography*.²⁶⁷ During an ethnographic study, a researcher lives and interacts with the members of a culture for a longer period. They report their insights in ethnographies, describing their experiences and interpretations when immersed in the cultural system. A *meta-ethnography* is consequently a meta-interpretation of ethnographies.

Meta-ethnography

The goal is to find analogies between studies having the same implication on conclusions. The synthesis should then allow for drawing cross-case conclusions. The originators state:

“meta-ethnography sees synthesis as involving translation—the translation of the whole interpretations (we like to think of these as storylines) of each study (not the individual themes, concepts, or elements) into one another.”²⁶⁸

²⁶⁶ An overview of meta interpretation is given in (Weed, 2005)

²⁶⁷ (Noblit & Hare, 1988). Although developed in educational sociology, it surprisingly gained faster popularity in health care than in its original discipline – let alone social and cultural anthropology, where the term ethnography was borrowed from.

²⁶⁸ (Noblit G. , 2018, p. 36)

Describing the seven phases of a meta-ethnography would go beyond the purpose of this book, and we refer to the literature.²⁶⁹

Meta-ethnography seems still in its infancy, as critical reviews suggest,²⁷⁰ a central issue being the consensus on a unique terminology being used throughout the scientific community.²⁷¹ However, it might be helpful if the research objective is to focus on meta-interpretation, which could be advantageous in discourse analysis in ethics, history, political sciences, and policy development.

14.9 META-ANALYSIS

The term *meta-analysis* is the short form of what should be called *statistical meta-analysis of effect estimates*. It should not be confused with the meta-study described in chapter 14.8, which focuses on qualitative data. Meta-analyses originated in medical studies and were later adopted by other disciplines.²⁷²

In a meta-analysis, researchers use a standardised statistical methodology to collect and analyse statistical data from multiple studies to pool the results of these studies and calculate an overall effect size. This effect size represents the magnitude and direction of the relationship between the variables under investigation across all the studies included in the analysis.

Meta-analyses are commonly used in medicine, psychology, and education to synthesise and evaluate extensive empirical studies. They are considered even more rigorous in evidence synthesis than systematic reviews. However, they require careful attention to the quality of the individual studies included in the analysis and issues such as publication bias and heterogeneity across studies.

There are different opinions about the number of studies to be involved. Valentine, Pigott, and Rothstein argue that a fixed-effects meta-analysis requires only two studies to improve the estimates of the individual studies.²⁷³ Davey

²⁶⁹ An example of a comprehensive meta-ethnographic description is found in (Franzel, Schwiegershausen, Heusser, & Berger, 2013). For a review on meta-ethnographies addressing the analytical issues, see (France, et al., 2019)

²⁷⁰ An extensive critical review on meta-ethnography was provided by (France, et al., 2014); a recent review can be found in (Soundy, 2022).

²⁷¹ For instance, there seems to be still a discussion about so-called *first*, *second*, and *third order* constructs, and key concepts, and the originators didn't contribute to clarification when using terms like *reciprocal* and *refutational translation* or the *line of argument* metaphor.

²⁷² You may recognize that several articles cited in this chapter stem from medical journals, since this discipline is particularly interested in systematic approaches for literature reviews. See, for instance, (Glass, 1977; Smith & Glass, 1977)

²⁷³ see also (Valentine, Pigott, & Rothstein, 2010)

et al. found the median number of studies used in clinical meta-analysis to be three.²⁷⁴

In general, a higher number of studies increases the bias. Therefore, the sample size of the individual studies is more relevant than the number of compared studies. Meta-analysis considers studies that are similar in population address the same substantive issue and use the same statistical procedure.

14.9.1 Storyline

The storyline resembles the one of a systematic review but is delimited to a statistical assessment and even more rigid regarding the selection and validation of sources. Figure 14.7 gives an overview of the activities and conditions for a meta-analysis. The literature reveals further details on standardised procedures.²⁷⁵

The literature search is typically conducted in relevant electronic databases, such as PubMed, PsycINFO, and Web of Science, and first identifies all relevant studies to the research question. The research design section should describe a systematic, transparent, reproducible search procedure.

The studies identified in the literature search are then screened for eligibility according to predefined inclusion and exclusion criteria. These criteria are based on the research question and may include factors such as study design, sample size, and outcome measures.

Once the studies were selected, data are extracted from each study using a standardised data extraction form. This involves recording information on study design, sample size, intervention or exposure, outcome measures, and statistical results.

14.9.2 Analysis

The statistical analysis of the data involves calculating effect sizes and their associated confidence intervals for each study. These effect sizes are combined using statistical techniques to produce an overall effect size estimate and confidence interval.

²⁷⁴ (Davey, Turner, Clarke, & Higgins, 2011)

²⁷⁵ Standardized procedures for clinical studies can be found in the *Cochrane Handbook for Systematic Reviews of Interventions* (The Cochrane Collaboration, 2022) and the CRD's *guidance for undertaking reviews in health care* (Centre for Reviews and Dissemination, 2009) and the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (Page, et al., 2021a; Page, et al., 2021b).

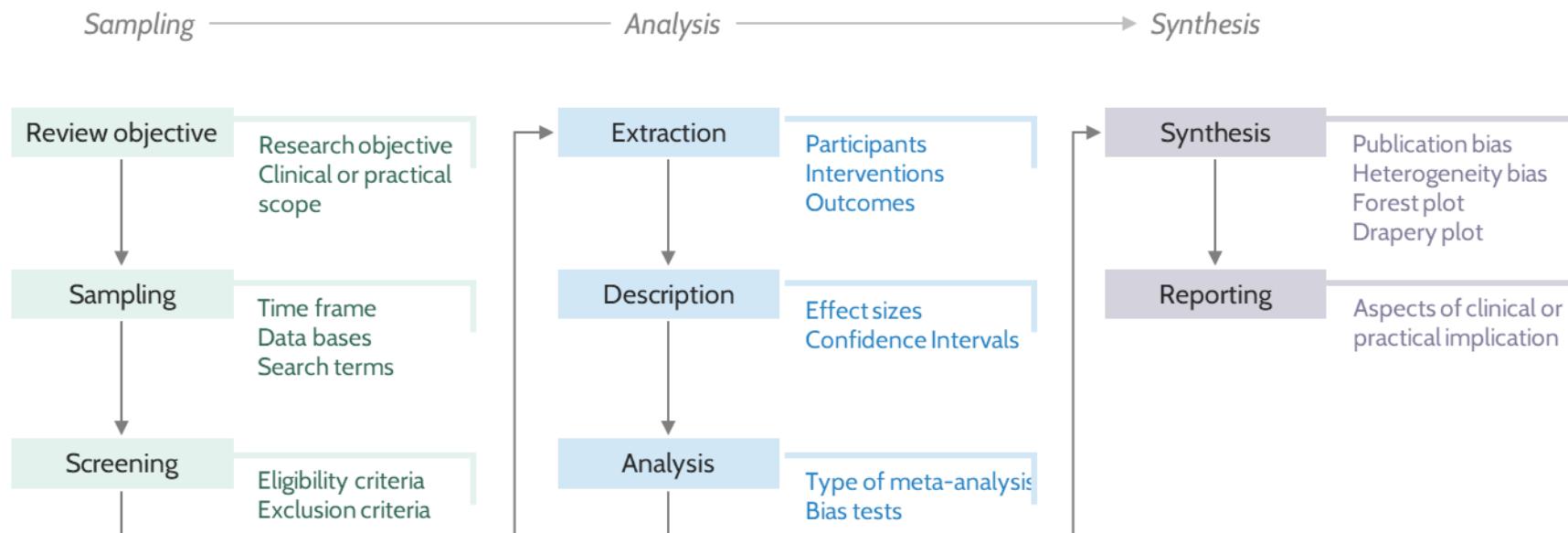


Figure 14.7 Activities and criteria of a meta-analysis

The meta-analysis is conducted by calculating descriptive statistics (such as a difference between means) as an estimate for an observed effect for each study. Subsequently, a combined effect estimate is calculated as a weighted average of the individual effect estimates.

Part of the analysis assesses the heterogeneity of effect sizes: the degree of variation across studies. Heterogeneity determines whether the studies are sufficiently equivalent to be combined in the meta-analysis.

A criterion of analysis is publication bias: the tendency for studies with significant findings to be published more frequently than studies with nonsignificant findings. It is essential to assess for publication bias using statistical methods to identify its impact on validity and generalisation.²⁷⁶ For further details on the challenges of interpretations and conclusions, we refer to the relevant literature.²⁷⁷

Heterogeneity

Publication bias

14.9.3 Synthesis

The results are usually synthesised in a forest plot (Figure 14.8).²⁷⁸ The visualisation is best performed with statistical software.²⁷⁹

Forest plot

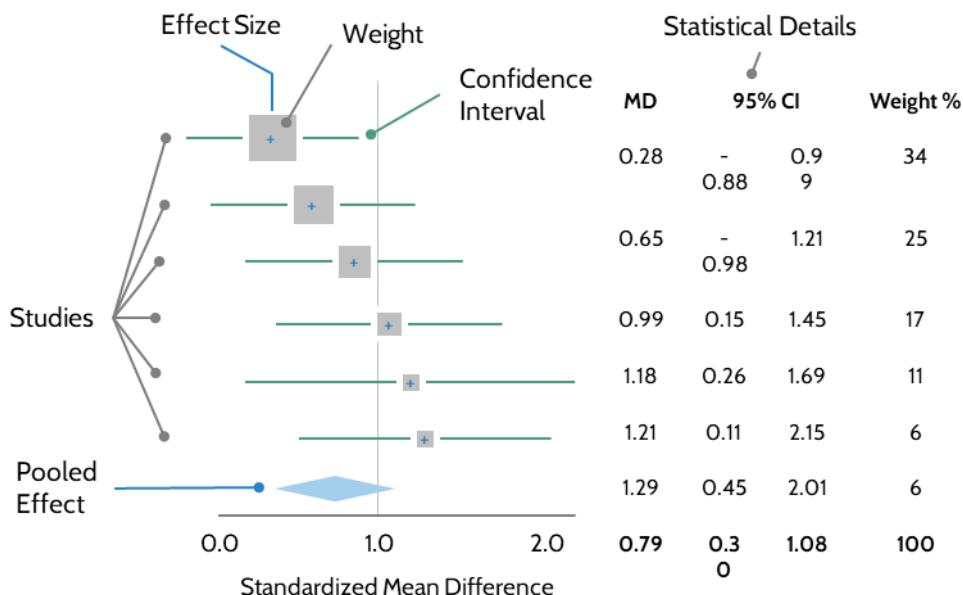


Figure 14.8 Elements of a forest plot

²⁷⁶ For details on quantification of publication bias, see (Lin & Chu, 2018)

²⁷⁷ (Schünemann, et al., 2022)

²⁷⁸ about forest plots and heterogeneity, see (Dettori, Norvell, & Chapman, 2021)

²⁷⁹ A comprehensive book on using the statistical package R for meta-analysis was published by (Harrer, Cuijpers, Furukawa, & Ebert, 2021a); see also the online version.

The forest plot provides a visual summary of the results of a meta-analysis, highlighting any significant effects and the variability of effect sizes across individual studies.

It includes a vertical line that represents the null effect, meaning that there is no effect of the intervention or exposure being studied. The squares or circles on either side of the vertical line represent the effect size estimate of each individual study. The size of the square or circle corresponds to the weight assigned to the study, which is typically proportional to its sample size.

The horizontal line extending from each square or circle represents the confidence interval of the effect size estimate. If the confidence interval crosses the vertical line, it indicates that the effect size is not statistically significant.

The diamond at the bottom of the plot represents the summary effect size of the meta-analysis, which is a weighted average of the effect sizes of the individual studies. The width of the diamond shows the confidence interval of the summary effect size estimate. If the diamond falls to the left of the vertical line, it indicates a significant effect in favour of the intervention or exposure being studied. If it falls to the right, it indicates a significant effect against the intervention or exposure.

Drapery plot

Forest plots are complemented by the recently introduced drapery plot.²⁸⁰ The drapery plot resembles the forest plot in that it is used to display the results of a meta-analysis, but it provides additional information about the heterogeneity of the effect sizes across studies. It shows the distribution of the effect sizes and their weights in each study, using overlapping functions that resemble drapes or curtains (Figure 14.9).

A drapery plot shows the p-value functions of primary studies, with study weights from the random effects model represented on a grayscale from high to low precision. The peaks of the functions indicate the point estimates of the studies.

The emphasised main curve shows the pooled estimate either from a random effect model (assuming the true study means were drawn from a random normal distribution) or a fixed effect model (assuming the true study means are measured without error). The peak of the main curve indicates the pooled average. A shaded curve shows the range of prediction and indicates the heterogeneity of the studies. Horizontal dashed lines may be added to identify confidence intervals for common alpha levels. The drapery plot is implemented in the R package *meta*.²⁸¹

²⁸⁰ The drapery plot was introduced by (Rücker & Schwarzer, 2021)

²⁸¹ (Balduzzi, Rücker, & Schwarzer, 2019)

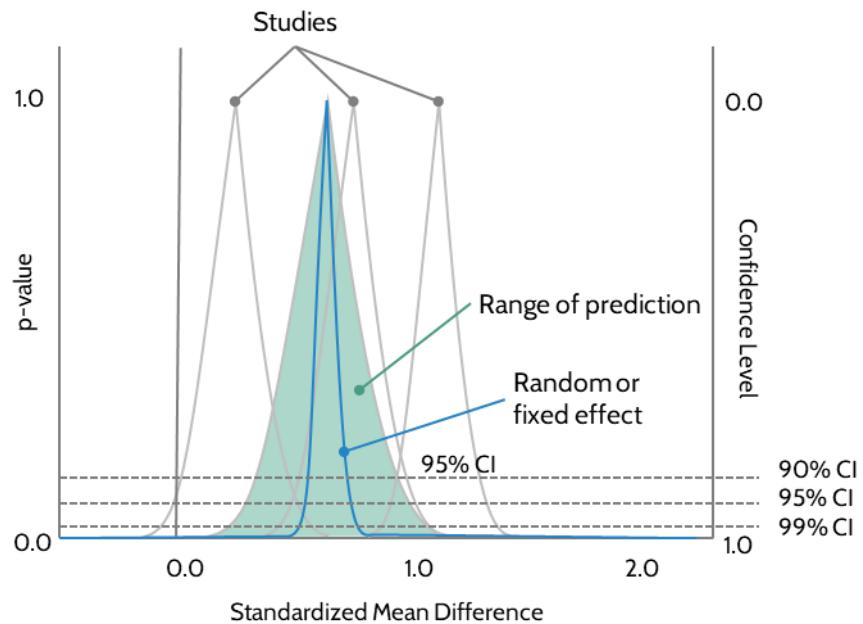


Figure 14.9 Elements of a drapery plot showing the p-value functions

The final step in a meta-analysis is to interpret the results based on forest and drapery plots, considering the quality of the individual studies, the magnitude and direction of the effect size, and the clinical or practical implications of the findings.

14.10 THE WORST PRACTICE

Literature reviews resemble fairy tales in many aspects. In both, the protagonist embarks on a quest for knowledge, seeking artefacts of wisdom or magic, facing academic wizards and witches that cannot always be relied on, and entering a land where citations grow on trees and are used like breadcrumbs marking the trail to hidden treasures of truths. The problem is that "Once upon a time ..." at the beginning of the literature review has gained rather little acceptance in the scientific community. How to get around this is described below.

A Fair Scientific Fairy Tale

Beginning your literature review is easier than you would think. First, you could explain to the unexperienced reader what a literature review is, why it is important, and address the scope of the review, without forgetting to explain special terminology and to introduce the structure of the remaining chapter:

A literature review is a very important part of any credible research project. Literature is basically what people write. As the name implies, a literature review thoroughly reviews literature to inform the reader about other writings. The term 'literature' is here meant in a sense of academic literature; that is, the review does not cover non-academic writings, like fiction, graphic novels, and shopping lists. In the following, we will and lay out the literature that was used to understand the this study. In what follows, we lay out the literature that was used to understand this study. We begin with general literature and then move step by step to more specific literature.

The following subchapters can be easily organised into ancient texts, newspapers and magazines, contemporary blog posts, and comic books. You will need to create several subchapters (such as 2.1.1.1.1.3 Blog-posts and Conspiracy Theories about Conspiracy Theories), each followed by a sentence or two.

Rather than using established theories, you can come up with your own, like ethnocalinalisation (the study of culture and wastewater), chromohydrokinetics (about colouring easter eggs), or the neuropragmatic angular aperture (describing the ability to look around the corner).

Cite exclusively from journals with impressive scientific names, such as *Transactions on Serious and Significant Sciences*, the *International Journal of Metaphysical Metabolism*, or the popular magazine *Christ & Canalisation*.

Refrain from using other (potentially credible) scholarly articles, books, and equally complicated texts. Make sure to include an assortment of random websites, Wikipedia pages, and your favourite influencer's blog post.

When citing, extensively use the indirect citation ('as cited in') and don't forget to add for any own contribution the meaningful remark 'source: own illustration'. Using these techniques when defining special terminology looks like:

Water (noun, from Proto-Germanic, *watōr*): a colourless, odourless, tasteless liquid found in rivers, lakes, seas, rain, toilets, the water tap, and at the bottom, if the glass fell (source: own definition based on Goderman-Ecclesfield & Lu-XinJaingwi, n.d., as cited in Overmiller jr., Mc-Gonagall & van Alsterwasser, 1794, pp. 1023-1658; see also weather.com)

It is not necessary to read the sources as long as the title fits. However, whenever you copy and paste entire chapters, don't forget to surround them by double quotation marks to exclude the passages from plagiarism checks.

If you refer to web sources, either cite the short form:

www.aa.com

or provide a long citation, preferably using (n.d.), and ensuring that the full URL provides your access history in the reference:

Miller (n.d.). Navigation in Space and Surrounding Localities. *International Studies on Astrology and Aspirin*, 2(3), 1-2. <http://www.aa.com/114.pdf?request-date=080623&origin=www.twitter.com/userprofile=Miller&password=password&visited-before=Netflix&film=game-of-thrones&episode=winter-is-coming-despite-climate-change&user-fell-asleep=0230>

Whenever you cite something, you should include a critical assessment:

Miller (n.d.) claims that ..., however, Garner opines ..., and I am confused.

Feel free to repeatedly cite the same source to reduce the list of references to less than ten entries. If you cite from company websites – which is the ultimate source for credible product information – make sure you use the correct writing, like Astra-Seneca, Mercedes-Benz AG, and Kentucky Dried Chicken, LLC.

Finish your literature review with a summary in the form:

As we have seen in the literature review on the study of [insert your topic here], the literature review provided considerable insights into the existing knowledge on [insert your topic here]. The next chapter will follow the literature review, beginning with short reminder on the synopsis of the literature.

15 THE RESEARCH DESIGN

Equating methodology with method is like putting the cookbook in the pan.

In academic theses, the research process appears either in chapters titled *Methodology* (in the social sciences) or *Methods and Materials* (in the natural sciences), or it is considered so self-evident that it doesn't even deserve a chapter (as in mathematics or philosophy).

We will deviate from the established and call this chapter *Research Design*. We use the word *design* because this chapter lays out the blueprint to achieve our research objectives. It covers more than just a methodology or a method. It provides a comprehensive overview of the ideas and assumptions that lead to the procedure underlying our research. Additionally, we strongly recommend you write an explicit research design chapter to prevent ending up in the ivory tower of your discipline.

Breaking a rule again

The research design chapter has two aims: it allows the reader to *reproduce* the research and *assess the validity* of your results.²⁸² This is only possible if we state the assumptions underlying our research and describe the methodical process.

If we use established methods, our research design describes their *implementation* rather than the methods themselves. We can assume that anyone reading this chapter is proficient in research; otherwise, our readers would simply skip it. Instead of explaining established research methods or terminology, we describe why we have chosen a method and how we applied it.

Describe the implementation, not the method.

²⁸² Your supervisor uses it also to assess your proficiency in research. However, your supervisor is just part of your target audience.

A further description is only necessary if we deviate from established methodologies, methods, or terminology.

15.1 THE STORYLINE OF THE RESEARCH DESIGN

A comprehensive account of the knowledge generation process requires describing a series of elementary aspects of our research design. Table 15.1 shows the aspects to consider.

Table 15.1 Aspects of a research design

<i>Aspect</i>	<i>Description</i>	<i>Examples</i>
Assumptions	Basic premises	Ontology, epistemology, axioms, postulates, definitions
Methodology	Research principles	Logical, experimental, empirical, interpretative, dialectic
Methods	Procedure to conduct the research	Formal logic, laboratory or field experiment, observation, content analysis, hermeneutics
Instruments	Technology, tools, or materials used	Sampling equipment, probes, analytical instruments, chemicals, tissues, software, field notes, transcripts, questionnaire
Acquisition	Procedure to acquire units of analysis	Sampling, probing, data mining, participant selection, literature selection
Analysis	Procedure to identify characteristics	Coding, classification, typology, taxonomy, descriptive statistics
Synthesis	Procedure to conflate results	Grounded theory, inferential statistics, statistical modelling, theory generation
Validation	Procedure to ensure credible results	Reliability, validity, accuracy, precision, repeatability, reproducibility
Constraints	Limitations of the selected research approach	Measurement limits, limits of interpretation or generalisation, treatment of confidential or sensitive information, protection of participant privacy, ethical considerations

The *assumptions* cover all premises we take for granted or no longer question. Examples are ontology, epistemology, theories, models, definitions, propositions, axioms, or postulates. Without clearly stating the premises, our argumentation for other aspects of the research procedure lacks a foundation.

The *methodology* covers the principles of the research procedure, which we derive from our chosen epistemology. Based on these principles, adequate methods are selected.

The *methods* describe the concrete procedure to conduct an investigation. Methods derive from their underlying methodology but are not necessarily exclusive to it. For instance, experimentation and empirical research both use the method of observation.

Research *instruments* cover any means that support the execution of the method. It includes technical instrumentation, tools, software, materials, or specific procedures. They are often independent of method or methodology.

Acquisition refers to the selection process for the primary source of data or information of interest. It may address the sampling procedure for raw data, probing of material, or the selection of text and other artefacts.

The *analysis* describes parameters and variables and how they are analysed, such as statistics, content analysis, coding, classification, or interpretation. The methodology often determines the analysis.

The *synthesis* defines the procedure to combine the results of the analysis, bringing them to a higher level of abstraction. The methodology and the analysis often determine the synthesis.

Validation addresses the means or procedures employed to ensure the results are dependable and trustworthy. The focus of validity differs in the methodologies.

Constraints cover the known limitations of the selected methodologies, methods, instruments, analysis, and synthesis and how they affect the validity or the applicability of the results. This includes ethical considerations.

Research activities underlie certain *ethical principles* in terms of reliability, honesty, respect, and accountability.²⁸³ While it is taken for granted that we adhere to good research practises our research or its outcomes may conflict with ethical norms, for instance, if we use confidential or sensitive information or compromise the protection of participant privacy. Therefore, we describe how we ensure alignment with ethical norms to minimise harm.

Although the terminology for these generic aspects may differ in the scientific disciplines, we consider all of them relevant for a comprehensive research design. They distinguish their starting point and expected outcome.

²⁸³ Examples are the *Code of Ethics* of the World Economic Forum (World Economic Forum, 2018) and *The European Code of Conduct for Research Integrity. The European Code of Conduct for Research Integrity* (European Federation of Academies of Sciences and Humanities, 2017).

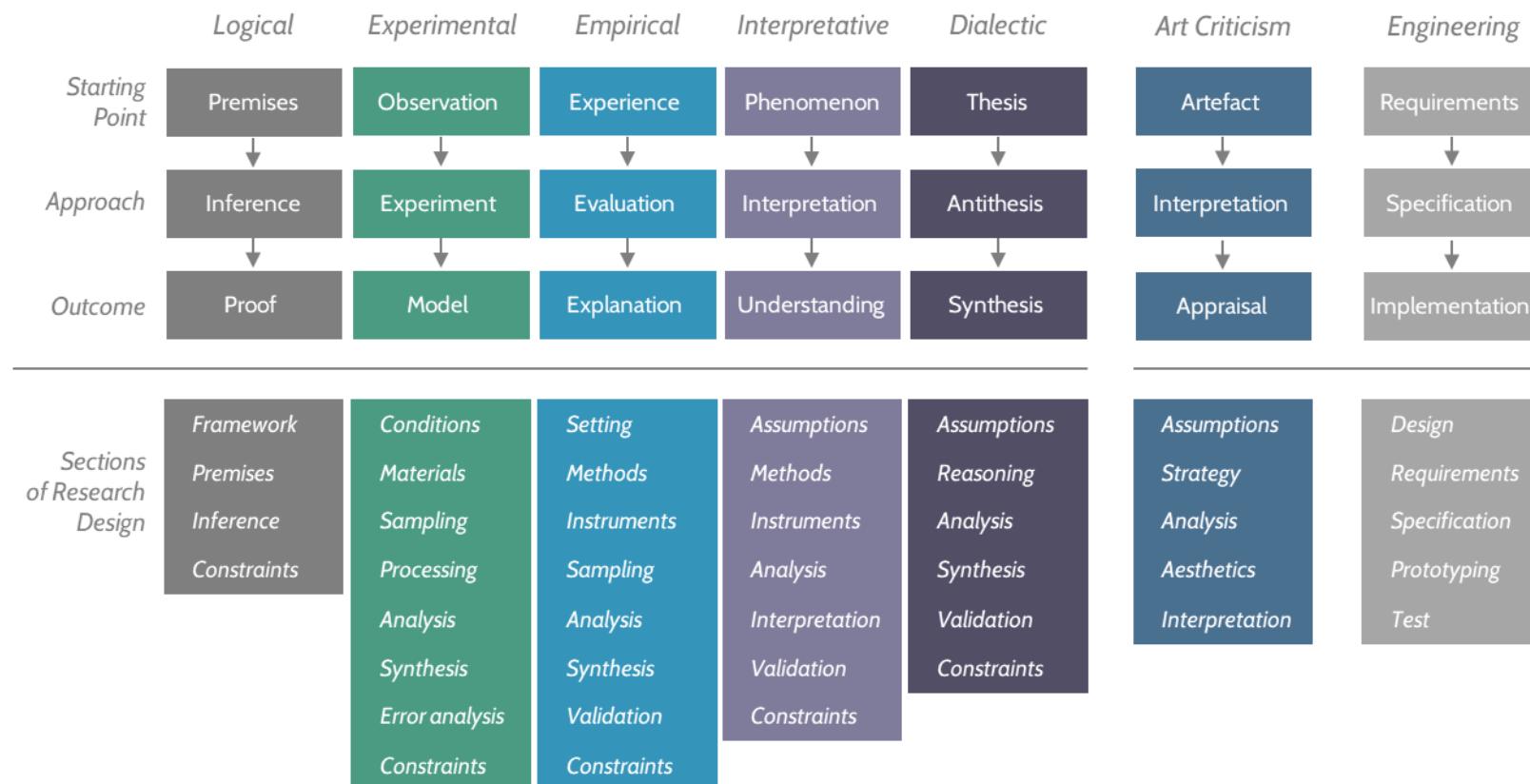


Figure 15.1 Typical research designs and their fundamental steps

<i>Formal Sciences</i>	<i>Natural Sciences</i>	<i>Life Sciences</i>	<i>Cognitive Sciences</i>	<i>Applied Sciences (Examples)</i>			<i>Social Sciences</i>	<i>Humanities</i>
Philosophy of Science								
Formal Logic	Astronomy	Astrobiology		Space Science	Physical Geography	Agriculture	Human Geography	Philosophy
Mathematics	Geosciences	Paleontology	Cognitive Ethology	Environmental Sciences	Ecology	Cultural Studies	Archaeology	History
Systems Theory	Biology	Physiology	Psychology	Social Psychology	Ethical Studies	Religious Studies	Anthropology	Languages
Information Theory	Physics	Genetics	Cognitive Linguistics	Learning Theory	Pedagogy	Education	Linguistics	Literature
Theoretical Computer Science	Chemistry	Biochemistry	Neuroscience	Toxicology	Pharmacology	Medical Sciences	Sociology	Literary Arts
		Bioinformatics	Artificial Intelligence	Applied Artificial Intelligence	Information Technology	Engineering		Performing Arts
	Logical			Architecture	Design	Digital Media		Visual Arts
	Experimental			Public Administration	Healthcare	International Relations	Political Science	
	Empirical			Civil Law	Criminal Law	International Law	Law	
	Interpretative			Business Administration	National Economy	International Economy	Economics	
	Dialectical							
	Art Interpretation							
	Engineering							

Figure 15.2 Categories (vertical) and commonalities (horizontal) of scientific disciplines. The colours represent the typical (although not exclusively used) research design.

15.2 SELECTING THE RESEARCH DESIGN

To decide on a research design, we distinguish the starting point, the approach, and the outcome. Figure 15.1 shows the designs, their fundamental steps and the typical chapter structure. Figure 15.2 shows how these designs apply to exemplary science disciplines.

The following chapters describe:

- *Logical design*: We assume an abstract logical system and want to prove logical relationships.
- *Experimental design*: We observe a natural phenomenon by instrumental measurement and want to explain its underlying mechanisms.
- *Empirical design*: We experience behavioural phenomena and want to explain their underlying regularities.
- *Interpretative design*: We encounter a social phenomenon and want to understand how it affects mental constructs.
- *Dialectic design*: We take a position and want to find arguments for and against it to reach a consensus.

Two approaches that do not fit the above types deserve a separate chapter:

- *Interpretation of Artwork*: We view artwork and want to interpret its meaning and implications. This is an interpretative task based on aesthetics without explicit validation.
- *System Development Design*: We want to implement a technical solution based on demands and requirements. Although not a research project in the traditional sense (since we don't generate new knowledge), it is a typical task of applied sciences.

Although a single design is usually chosen, multiple aspects of designs may apply to different research objectives. The following subchapters will address such overlap. A final checklist is found at the end of the chapter.

15.3 FORMAL LOGIC DESIGN

The idea of logical argumentation is not to find *truth* in a metaphysical sense but to identify a state of the undeniable in a formal system. The research process in a logical approach is, compared to other research, straightforward and the research design chapter, therefore, usually short.

Theses in formal sciences rarely contain an explicit research design section since the procedures are taken for granted and a description deemed unnecessary. However, this delimits the audience to the experts in the field, and the result ends up in a disciplinary ivory tower, which cannot be the goal of science. Therefore, we recommend clearly stating the assumptions and the process of inference and validation (Figure 15.3).

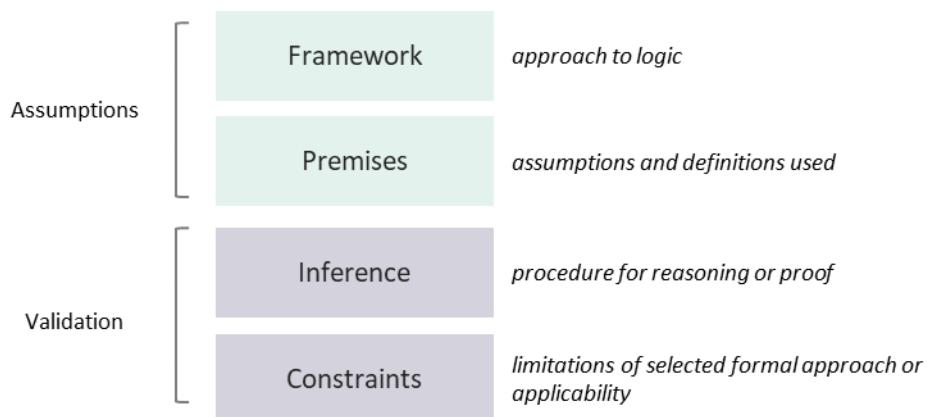


Figure 15.3 Sections of a logical research design

The *framework* identifies the logical approach, such as propositional logic, predicate logic, or axiomatic system.

The *premises* state the assumptions or mathematical preliminaries. Mathematical preliminaries might be definitions, axioms, postulates, or theorems. For any other assumptions, such as propositions, hypotheses, or assumed probability distributions, we must provide evidence.

The *inference* presents any procedures used for reasoning, such as deduction, mathematical induction, or non-deductive forms, like enumerative induction, eliminative induction, analogical induction, or abduction. If the inference is performed under an assumed model, that model should correctly specify the true mechanism generating the data, allowing the reader to draw a clear connection to the conclusion.

The *constraints* address any limitation in terms of the applicability of the chosen approach, the definitions, and the selected inference procedure. It also addresses the applicability or validity of the conclusion.

15.4 EXPERIMENTAL DESIGN

The experimental research design is typical for natural sciences and related disciplines. Traditional natural sciences cover astronomy, geosciences, physics, chemistry, and biology. Two new categories of the life sciences and

cognitive sciences emerged in the last century. They both represent an overlap of disciplines that address the same domain (life or cognition).

People associate natural sciences often with the so-called *scientific method*. However, calling it a *method* is at least confusing in the contemporary understanding of this term. It is more of a *methodical approach*, relying on principles that are mostly uncontroversial among scientists. Furthermore, the term covers an evolution of sciences of over 3500 years rather than a particular method and continually underlies adaptation.²⁸⁴

Although we could talk about a *contemporary scientific method*, which is subject to change with fundamental paradigm shifts (such as relativity or quantum theory), there is no contrasting program. The research principles underlie a realist ontology and experimental epistemology. That is why natural scientists call this chapter simply *Methods & Materials* since the assumptions and the methodology underlying the same fundamental principles.

15.4.1 Principles

There are several principles to adhere to, the most important being clear *terminology*: natural sciences would be unsuccessful if there is no consensus about the meaning of words. That is one of the reasons why natural scientists prefer formal logic and mathematics as supporting disciplines.

The tendency to create *classifications* becomes apparent in the chemist's periodic system of the elements, the physicist's electromagnetic spectrum, the biologist's taxonomy of organisms, the astronomer's Hertzsprung-Russel diagram of stellar classification, and the geoscientist's geologic time scale.

The aim to *generalise* emphasises the normative character of the scientific research design. Therefore, the *reproducibility* of experiments and argumentation is an indicator of the *accuracy* (approaching a true result).²⁸⁵

The goal is to create *models* that represent natural phenomena on a more abstract level. A *theory* is understood as a generic model (or a set of models) describing natural scenarios, but a model is not necessarily a theory.²⁸⁶ Natural sciences consider *natural laws* as part of their theories.

²⁸⁴ One of the oldest records of a scientific methodology is a medical papyrus from Egypt, written around 1600 BCE (Sanchez & Meltzer, 2014)

²⁸⁵ However, reproducibility is neither a necessary nor a sufficient indicator of accuracy since accurate results are not always reproducible, whereas inaccurate results might be reproducible (see Devezer, Navarro, Vandekerckhove, & Ozge Buzbas, 2021).

²⁸⁶ In informal conversations, *theoretical* often means *speculative* or expresses a contrast to *practical*. If we say *theoretically*, we usually mean *hypothetically*.

The principle of *parsimony* states that models with fewer variables and assumptions are preferred. That does not mean deliberately limiting the complexity of a system but preferring simpler alternatives.

Natural scientists seek to *falsify* hypotheses rather than test them positively. For example, the statement that an electron has a negative charge is a postulate that encompasses a series of experimentally observable phenomena. If we encounter a negative charge, we could state the hypothesis that it is an electron. However, testing the phenomenon for a negative charge does not prove it is an electron; it could be, for instance, a muon. However, testing for a positive charge does prove it is *not* an electron.

Figure 15.4 shows typical sections in the experimental research design.

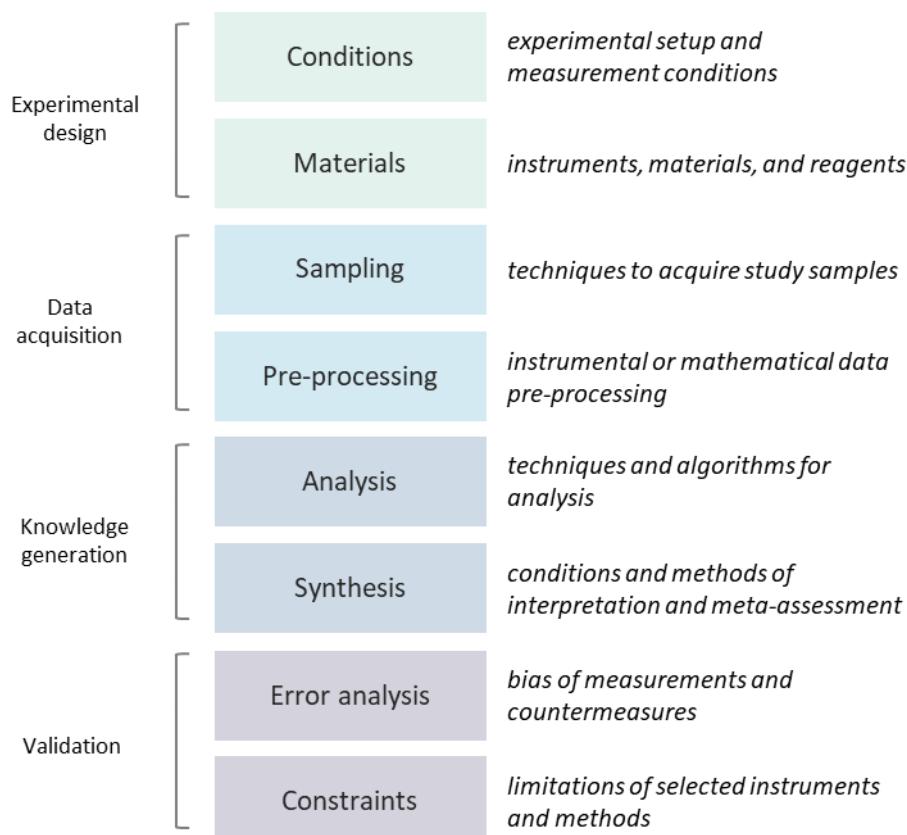


Figure 15.4 Research design of experimental research

15.4.2 Conditions and Materials

The *conditions* describe the laboratory and the measurement instruments. Any techniques comprehensively published elsewhere are just referred to, whereas deviations from a published procedure are clearly described. New experimental methods require a complete protocol of the experimental procedure.

For laboratory experiments, we specify the laboratory conditions, such as equipment and physical parameters (like temperature or moisture). In field experiments, we specify the location, size, and physical and geographical characteristics and provide site maps.

Instrumental conditions cover measurement instruments (including brand name and model), detectors, relevant physical parameters (like wavelength and signal output), calibration, and measurement techniques (such as sensing or counting).

A *materials* section lists any physical (like containers, media, carriers), chemical (like reagents, solvents, solutions) or biological materials (like cell lines, tissues, culture media). This includes supplier information (brand name, charge), concentrations, and quantities. In case we study organisms, we provide their scientific names, numbers, size, sex, and other relevant characteristics.

15.4.3 Sampling and Pre-processing

The *sampling* section incorporates sampling techniques, sample preparation, and sample treatment. In human studies, we specify the number of study subjects, how, when, and where the subjects were recruited, the criteria subjects had to meet to be included in the study, and the appropriate informed consent conditions. This includes applicable experimental controls or comparators and the conditions under which they are applied.

Data processing covers the procedures to pre-process the raw data before they go into the analysis to achieve the primary data. This includes, for instance, any instrumental processing (such as automated calibration), procedures for outlier exclusion, training and test set selection, feature reduction, integral transformations, or the conversion of qualitative data to frequencies.

15.4.4 Analysis and Synthesis

The *analysis* section describes the procedure to generate interpretable new data or information from the primary data. It includes any formulas, algorithms, calculations, program libraries, or clustering and classification techniques used. Typical examples are:

- *descriptive statistics*: describing data in terms of their central tendency, dispersion, and distribution.
- *inferential statistics*: approaches to hypothesis testing and generalisation, such as regression, correlation, cross-correlation, autocorrelation, convolution, and temporal evolution.

- *modelling*: discovering relationships between data, using principal component analysis, structural equation modelling, Markov models, or artificial neural networks.

Again, established algorithms are not explained; we just describe how we applied them. New algorithms are explained in such detail that they can be reproduced.

The *synthesis* section covers the methods used to interpret the data or information generated in the analysis. Examples are identifying cause-effect relationships using statistical significance tests, null hypothesis rejection, Bayesian inference, and effect size estimation. The synthesis may conclude with an applicable generative or discriminative model, a structural equation model, or a taxonomy.

15.4.5 Error Analysis and Constraints

The validity of an experimental result relies on the accuracy, precision, repeatability, and reproducibility of the measurements (see Table 15.2). It includes an *error analysis* to quantify the bias. Common measures are the mean absolute error (MAE), mean absolute percentage error (MAPE), mean squared error (MSE), and root mean squared error (RMSE). The error analysis is supported by the (adjusted) coefficient of determination (R^2) and may include measures for the performance of a model or prediction system, such as recall score and F-score or a confusion matrix.

Table 15.2 Measures of experimental validation

<i>Measure</i>	<i>Description</i>
Precision	Measure of variation in repeated measurements, typically affected by random errors. Precision can be easily assessed with statistical methods.
Accuracy	Closeness of a measured value to its true value; typically affected by systematic errors. Accuracy can only be approximated by comparing with measurements taken under different conditions.
Repeatability	Measure of variation of experiments repeated under the same conditions using the same methods. It is a necessary (but not sufficient) condition for reproducibility.
Reproducibility	Measure of variation of experiments repeated under different conditions, using different methods, and performed by different researchers.

Methodical *constraints* describe any known limitations of the experimental setup, the measurement instrument, and methods. The constraints also

address methodical assumptions and limitations in terms of applicability, availability, precision, accuracy, quality, and risks affecting the interpretation of the results.

15.5 EMPIRICAL DESIGN

We distinguish the empirical research design from the experimental design in that the data are acquired by the researcher immediately through observation and perception rather than measured with an analytical instrument. Examples are observations in natural surroundings in behavioural biology and nomothetic research in social and cognitive sciences.

The assumptions in empirical sciences are found in the ontology of realism using an empiricist epistemology. We assume an objective reality that can be investigated by observation of phenomena in a particular setting. The goal of the research is a generalisation. Figure 15.5 presents the typical sections of an empirical research design.²⁸⁷

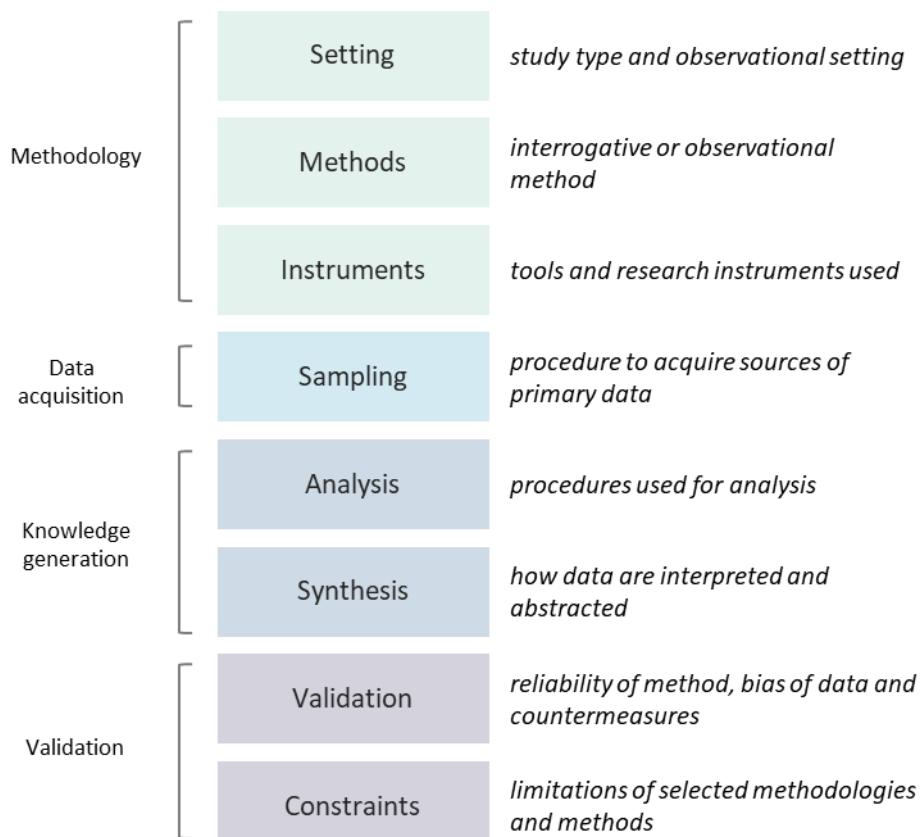


Figure 15.5 Research design for empirical research

²⁸⁷ An overview on social science research methods is given by (Sheppard, 2020)

15.5.1 Setting, Methods, and Instruments

Empirical research offers several methodologies (examples are shown in Table 15.3). The key differences lie in the environmental settings under which the researcher's observations take place.

Table 15.3. Typical methodologies used in empirical studies

<i>Methodology</i>	<i>Description</i>
Laboratory Study	A systematic observation in a controlled artificial setting
Field Study	A systematic observation in a real-life setting
Case Study	A systematic observation in a particular application scenario

Laboratory studies take place in a controlled environment, which we describe together with the environmental conditions. An example is a study on memory recall taking place in a sleep laboratory.

Field studies take place in natural surroundings. An example is a psychological study of children during school lessons. While the classroom serves as the *field laboratory*, keeping the conditions comparable for all participants, the setting is a natural one that underlies limited control. Therefore, the focus in describing field studies lies on distinguishing between controllable and uncontrollable parameters, which delimit or expand the range of potential extraneous variables.

The *case study* investigates one or more units of study (cases). Units might be events, communities, or organisations in a real-world context. An example is a case study of decision-making in selected European start-ups. The difference to a field study lies in the lack of control: the settings are comparable only in terms of the application scenario. Case studies require, therefore, a comprehensive description of the scenario, focussing on commonalities and differences between the cases.

Distinguishing factors among these studies lie in the settings where the research occurs, the level of control over variables, and the depth of analysis applied to the subject matter. Each method offers distinct advantages and limitations in exploring and understanding different aspects of the world, providing researchers with various tools to investigate their subjects from different perspectives.

The *methods* section describes the procedure to perform the investigation. Typical methods in empirical studies are given in Table 15.4.

Table 15.4. Examples of methods of empirical studies

<i>Methodology</i>	<i>Description</i>	<i>Type</i>
Concealed observation	Observation without the researcher being recognised by the subjects under investigation.	<i>Observational</i> Based on observing people or natural systems
Non-participant observation	Observation without the researcher becoming involved in the situation being observed.	
Participant observation	Observation with a researcher becoming a participant in the situation being observed.	
Focus group	Investigation with a selected group of people who are asked about their attitudes and opinions of a subject. The researcher moderates, asks questions, listens, and observes.	<i>Dialogic</i>
Survey research ²⁸⁸	Verbal or written responses to questions or statements from a selected population	Based on the question and response
Interviewing	Two-way purposeful conversation to obtain information that is relevant to the research objective. Used to obtain primary data or to validate the interpretation of results.	

The underlying methodology defines the conditions to implement the method, but the method is not necessarily delimited to a single methodology, and methods may be combined. For instance, a focus group observation in a product showroom is a laboratory study that pays particular attention to constant experimental settings (for example, room, time of day, way of product presentation).

Focus groups are complemented with interviews to obtain deeper insights into consumers' perceptions. A customer interview in the supermarket is a field study, where conditions are less controllable but still underlie certain constant conditions, like the location and the questions asked.

When we describe the setting, we address constant conditions and those that are considered dynamic and may influence extraneous variables. Changes in the setting and the results of observations are documented in field notes.

Finally, we specify any research instruments or tools, such as a questionnaire, an interview guide, or video and audio recorders, and describe the procedures of taking and organising field notes.

²⁸⁸ Although surveys are often found in the category of methodologies since they underlie certain principles, they basically belong to the field of research methods.

15.5.2 Sampling

The sampling section defines the selected population (such as participant group, research site, country, and habitat) and their estimated size, as well as the samples (subjects, documents, artefacts) and the sample size. It describes the sampling method, including details of sampling, such as the type of probability sampling (random, clustered, stratified, systematic) or non-probability sampling (quota, convenience, purposive, snowball).

15.5.3 Analysis and Synthesis

The *analysis* section describes the procedure to generate interpretable information from the primary data. Like in the experimental design, it may take advantage of parametric statistics for quantitative or transformed qualitative data.

A focus lies on *causality*: the relationship between a cause and an effect. Causality implies temporal precedence: the effect must occur after the cause. The corresponding variables require a correlation; however, a correlation does not necessarily indicate a cause-and-effect relationship.

Non-parametric models gain precedence if the distribution parameters of the population are unknown. Examples are non-parametric statistics, k-nearest neighbours, decision trees, support vector machines, or Markov models.

The *synthesis* section covers the methods used to interpret the data or information generated in the analysis. It uses the same approaches as the experimental studies (for example, hypothesis tests, Bayesian inference) but begins with estimating effect sizes and their variability.

A main difference is the more complicated validation of quantitative data in terms of their relationship to the constructs being measured.

15.5.4 Validation and Constraints

The validation section addresses how we ensure the *reliability* and *validity* of results.²⁸⁹ *Reliability* in empirical research refers to the likelihood of obtaining similar results when a study is repeated. Reliability is achieved if multiple results are consistent with previous findings and is a condition for validity.²⁹⁰

²⁸⁹ The term reliability in empirical designs is equivalent to *reproducibility* in experimental designs. Similarly, the empirical *validity* resembles the experimental *accuracy*. Don't ask us why there is no consensus on terminology between the disciplines.

²⁹⁰ As mentioned before, reliability (or reproducibility) is neither a necessary nor a sufficient indicator of validity (accuracy) since valid results are not always reproducible.

Table 15.5 shows typical reliability measures in empirical designs.

Table 15.5 Types of reliability in empirical research

Type of Reliability	Description
Split half reliability	Correlation between two halves of a randomly divided test measuring the same construct.
Inter-item reliability	Consistency of scores of individual items measuring the same construct.
Test-retest reliability	Consistency of test scores over time (repeatability).
Inter-method reliability	Consistency of test scores obtained simultaneously time with different methods.
Inter-rater reliability	Consistency of ratings of two experts or observers on the same method.

To explain this, let us look at how we assess the reliability of a written exam:

- *Split-half reliability* is achieved if we randomly split the students into two halves and obtain the same distribution of grades.
- *Inter-item reliability* is achieved if the scores for each exam question addressing the same concept correlate with each other.
- *Test-retest reliability* is achieved if the same students writing the same exam later obtain the same grade.
- *Inter-method reliability* is achieved if an oral exam provides the same grade for a student as a written exam.
- *Inter-rater reliability* is achieved if different professors grade the exam similarly.

While reliability is necessary to ensure exams consistently measure the same construct (the knowledge) under different conditions, it does not assure the results are valid.

Validity addresses the closeness to a real state. Since we can only estimate a real state, we compare our results to studies that address the same subject using different methods, models, or theories.²⁹¹ Table 15.6 shows the types of validity distinguished in empirical research.

²⁹¹ Sometimes called ‘triangulation’; a case in point for the misuse of a scientifically unambiguous term to lend a touch of scientific dignity to a triviality. Triangulation stems from trigonometry and is used in geodetics to determine the distance of an object by measuring angles from two reference points forming a virtual triangle.

Table 15.6 Types of validity in empirical research

<i>Methodology</i>	<i>Description</i>	<i>Type</i>
Face validity	Judgment on the operationalization of a construct, typically judged by non-experts (e.g., respondents); weakest form of assessment	
Content validity	Judgement on whether the measures fully represent the domain (coherence), typically judged by experts; the domain is ambiguous; no consensus on assessment	<i>General</i> Based on judgement
Internal validity	Relates to the causality between a measure and its construct. Requires at least temporal cause-effect relationship, the correlation between cause and effect, and lack of alternative explanations.	
External validity	Is achieved if results can be generalised to other individuals in the same domain	<i>Construct validity</i> Based on a measure of the construct
Convergent validity	This is achieved if different methods provide the same (convergent) findings	
Discriminant validity	It is achieved if a method provides different findings for conceptually different constructs in the same domain	
Concurrent validity	It is achieved if the results of a measure correlate with a simultaneously measured criterion	<i>Criterion-related validity</i>
Predictive validity	Is achieved if the method predicts a criterion in the future	Based on correlation

Let us again use an example of an exam written after the lecture on research methods to explain the types of validity. The construct of interest is the student's knowledge in the domain of advanced research:

- *Face validity* is achieved if students agree that a written exam is a valid measure of knowledge in the field of advanced research.
- *Content validity* is achieved if professors agree that all dimensions of the knowledge domain are represented in the exam.
- *Internal validity* is achieved if students who understand methodologies (preceding cause) can select appropriate methods (succeeding effect), assuming we can exclude alternative explanations.
- *External validity* is achieved if the written exam gives comparable results in future semesters (can be generalised).
- *Convergent validity* is achieved if oral exams lead to the same results as written exams for all students (cf. inter-method reliability).

- *Discriminant validity* is achieved if the knowledge of students (construct to be measured) is not related to their intelligence (different construct in the same domain).
- *Concurrent validity* is achieved if the results of the current exam correlate well with those of a standardised written exam (criterion) taken at the same time with a different group of students.
- *Predictive validity* is achieved if the average grades of all examinations of a student predict the grading (criterion) of a graduation thesis.

Although the validity of results can describe the closeness to a real state, such results cannot always be generalised. The reason is that each methodology has its limitations, either because of its assumptions or due to the procedure we apply. That is, even valid results have limited applicability.

To finalise our assessment of validity, we address those *constraints* of our research design that are known in advance and that might impact the reliability, validity, or applicability of our results. At that point, it is not a critical reflection of our results (which is addressed later in the thesis), but it explains our awareness of the limitations of the chosen research design.

15.6 INTERPRETATIVE DESIGN

Research that primarily relies on the interpretation of perceptions, meanings, attitudes, consciousness, and other human artefacts deals with mental constructs: those unmeasurable aspects of the human mind that only express themselves in personal and social behaviour. Naturally, the interpretation of such aspects requires a higher degree of freedom and eludes a rigid formal approach, although the investigation follows a systematic procedure.

The sample is delimited to a few or even single artefacts, individuals, or phenomena, which is described in the introduction or as part of the research objectives. For example, psychotherapeutic sessions work with one individual, and a hermeneutical interpretation might just use a single text. A population is not of interest since a generalisation is not intended.

Interpretative studies are typically idiographic, although the results might support generalisation at a later stage. The results are inevitably an amalgamation of the interpretations of the researcher, the subject, and society. Therefore, assumptions play a more important role than in other research designs. Figure 15.6 provides an overview of the research design in interpretative studies.

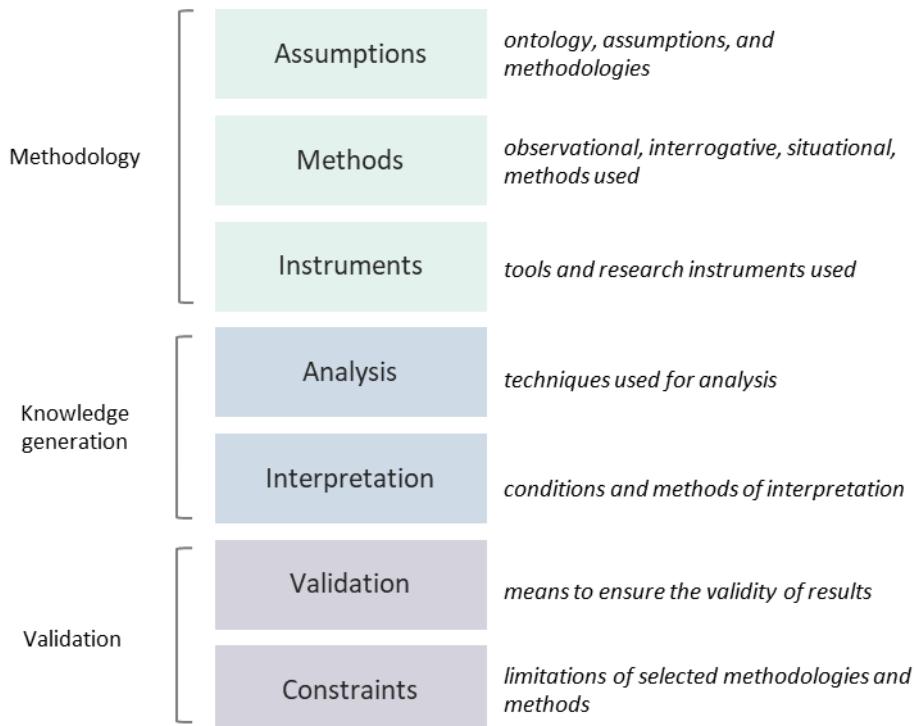


Figure 15.6 Research design of interpretative studies

15.6.1 Methodology

The assumptions in interpretative studies may rest on the ontology of idealism or realism, where the latter admits behavioural laws independent of the subject at least partially existing. You may assume different ontologies for answering different research questions, but you must *adhere to their assumptions*.

That is, you may use a result from one approach to support one that underlies another, but you cannot contrast results if they rely on incompatible assumptions. For instance, you cannot argue with an idiographic interview result against a result of a nomothetic survey, but multiple interviews may reveal patterns that support nomothetic findings.²⁹²

Interpretative sciences offer a wide range of methodologies (see Table 15.3). The key differences lie again in the assumptions rather than the methods.

It is advised to state ontology, epistemology, assumptions, and the methodology used for each research question in a consistency matrix (see also Table 11.2 in the previous chapter).

²⁹² Idiographic research focuses on individuals or limited scenarios, whereas nomothetic research tries to find patterns that allow for generalization.

Table 15.7. Typical methodologies used in interpretative studies

<i>Methodology</i>	<i>Description</i>	<i>Typical focus</i>
Phenomenology	Interpretation of meanings evolving for participants during interaction with phenomena	
Ethnography	Science of behaviour and relation to cultural settings in cultural anthropology	
Ethnomethodology	Science of forms of action and consensus to uncover norms in societies in everyday life	dialogue, appraisal, and hermeneutics
Hermeneutics	Theory of understanding and interpretation of linguistic and non-linguistic expressions in their historical context	
Discourse analysis	Study of how written and spoken language contributes to meaning in a discourse.	
Ideology Critique	Approach to reveal dominant and hidden ideologies that maintain the status quo and contribute to oppression and inequality	
Critical Ethnography	Science of behaviour and culture in relation to ideological settings	dialectics, change, and improvement
Critical hermeneutics	Theory of ideological deformation and systemic distortion by use of language	
Critical discourse analysis	Study on written and spoken language to uncover underlying meaning and social implications.	

15.6.2 Methods and Instruments

The *method* section describes the procedure to perform the investigation. The underlying methodology defines the conditions to implement the method, but the method is not necessarily delimited to a single methodology.

For instance, interviews may help to uncover reasons behind team conflicts. This could be based on phenomenology since attention is paid to the meaning and interpretation of statements. If the focus lies on the influence of cultural differences on the conflict, it could follow ethnomethodological principles. Typical methods in interpretative science are given in Table 15.4.

Use specific research textbooks rather than generic ones.

A general remark: If you want to use specific techniques, such as discourse analysis, critical incident technique, or action research, we recommend you not just rely on generic research textbooks. Use multiple textbooks that cover the method exclusively.²⁹³

²⁹³ Ask your supervisor for a recommendation.

Table 15.8. Examples of methods of social science research

<i>Methodology</i>	<i>Description</i>	<i>Typical focus</i>
Interview	Two-way purposeful conversation to obtain information that is relevant to the research objective.	
Expert Interview	Two-way purposeful conversation with a domain expert to validate information or obtain results.	<i>Inquiry</i> Based on the question and response
Focus group Interview	Conversation with a pre-selected group of people focussing on their attitudes and opinions towards a subject or phenomenon.	
Participant observation	Observation with a researcher becoming a participant in the context being observed.	
Concealed observation	Observation without the researcher being known to the subjects under investigation; requires ethical assessment.	<i>Observational</i> Based on observing people with all senses
Symbolic Interaction	Research focusing on behaviour, expression, and the use of language	
Role-play	Investigation of an emotional response to a simulated scenario	
Stage act	Investigation and discussion of an acted play resembling a real-world scenario	
Critical Incident Technique (CIT) ²⁹⁴	Observation of human behaviour in critical situations to facilitate its potential usefulness in solving practical problem	<i>Situational</i> Based on simulated or real-world scenarios
Action research	Approach of assisting actors in real-world situations in improving their actions	
Content review	Systematic approach to identify information within the text to collect primary data.	
Narrative review	The interpretation of a chronologically told story, exploring how various elements are sequenced	<i>Hermeneutical</i> Based on media and communicative artefacts
Grounded Theory	The interpretation of underlying meanings and implications in transcribed communicative artefacts.	

Any research *instruments* or tools, such as a questionnaire, interview guides, narrative, logs, tests, or software, are also specified. These instruments vary in their purpose, the type of data they collect, and the methodology used to obtain information.

²⁹⁴ The term *critical* in ‘Critical Incident Technique’ refers to a *critical incident* rather than a critical theory approach.

15.6.3 Analysis and Interpretation

The *analysis* strongly depends on methodological assumptions and on the selected method. It uses recordings, transcripts, and field notes as primary sources of information.

Table 15.9 Type of analysis in interpretative studies

Type of analysis	Description
Content analysis	Analysing the content of a text to identify patterns, trends, and themes. It is a common method of qualitative data analysis in the social sciences.
Discourse analysis	Investigation of ongoing flows of communication (particularly with audio recordings) to find patterns of interaction and argumentation.
Semiotic Analysis	Investigating symbols, signs, and metaphors used in a text to explore the meaning behind them.
Hermeneutic Analysis	Exploring the meanings of verbal expressions and their implications on knowledge generation.
Critical Analysis	Analysing a text from a critical perspective to uncover hidden meanings or messages.

The *interpretation* section addresses the conditions and methods used to find meaning behind texts, such as axial coding, and uses logical approaches to interpretation. The interpretation is related to the cultural, historical, or literary context of the phenomena and is confronted with preconceptions. The results lead to an abstraction rather than a generalisation.

Keep in mind that methods may complement each other. For instance, *Interpretative Phenomenological Analysis* (IPA) integrates phenomenology and hermeneutical analysis in idiographic research.

15.6.4 Validation and Constraints

There are several constraints inherent to the interpretative study we need to address since they delimit the validity of our results.

Due to the idiographic nature of the studies, the researcher's interpretation is necessarily subjective and depends on the researcher's own values, opinions, and experience, leading to disagreement among researchers.

Personal information may be difficult to obtain when participants are unwilling or unable to share information, making it hard to assess the honesty and reliability of answers.

Furthermore, the procedure of interpretivist research is not easily replicated and is barely reproducible, making it difficult to argue with reproducibility as a factor contributing to the validity of results.

An assessment of validity can be argued for in terms of consistency and coherence. *Consistency* refers to a system without contradiction between its entities. It is a minimal requirement for coherence. *Coherence* refers to a comprehensive explanation of all facts and their relationships.

While the model or theory which most effectively reconciles all facts may be considered most likely to be true, the main limitation lies in the human inability to acquire all facts of an experience.

Additionally, coherence is difficult to dispute as a criterion of truth. Coherence primarily deals with internal consistency within a particular system or framework of ideas and is barely applicable to generic settings.

15.7 DIALECTICAL DESIGN

The dialectical methodology uses a dynamic and iterative process in which arguments and perspectives are continually questioned, challenged, and refined, leading to a deeper and more comprehensive understanding of the subject at hand.²⁹⁵

A dialectical discourse is often found in philosophy, history, social sciences, law, linguistics, literature studies, and religious studies.²⁹⁶ It plays a significant role in research adopting the critical theory paradigm for investigating the social status quo, imbalances, and inequalities. The word dialectic (Greek: *dialektiké*, argumentation) is derived from the word dialogue (Greek: *diálogos*, conversation), and both describe forms of communication. The main difference is in the goal:

- *Dialogical* communication seeks to understand different points of view by exchanging perceptions and understanding the opinions of others. It usually takes place in the exploratory phase of research.
- *Dialectical* communication evaluates multiple conflicting concepts or positions. It is primarily concerned with evaluating arguments of opposing sides to approach a synthesis, therefore incorporating characteristics of explanatory and normative research phases.

²⁹⁵ For details of dialectal reasoning, see (Popper K. R., What is dialectic?, 1940)

²⁹⁶ For further details on research methods in the humanities, see (Van Peer, Hakemulder, & Zyngier, 2012)

Dialogic reasoning is often a predecessor of dialectics (although educational scientists still debate this).²⁹⁷ However, dialectical argumentation exhibits a larger variety of arguments, often analogic (drawing more or less appropriate comparisons), rhetorical (using persuasion) or apodictic (delimiting the assumptions to attain an undeniable state).

Unfortunately, academic theses written in the humanities often neglect the value of an explicit research design chapter since their methods are deemed established, well-understood, or predetermined in the scientific discipline. This often leads to confusion, creates unnecessary debates about assumptions, prevents comparability, debate, or consensus, and lacks the contribution to collective understanding.

Figure 15.7 shows components of a dialectic research design.

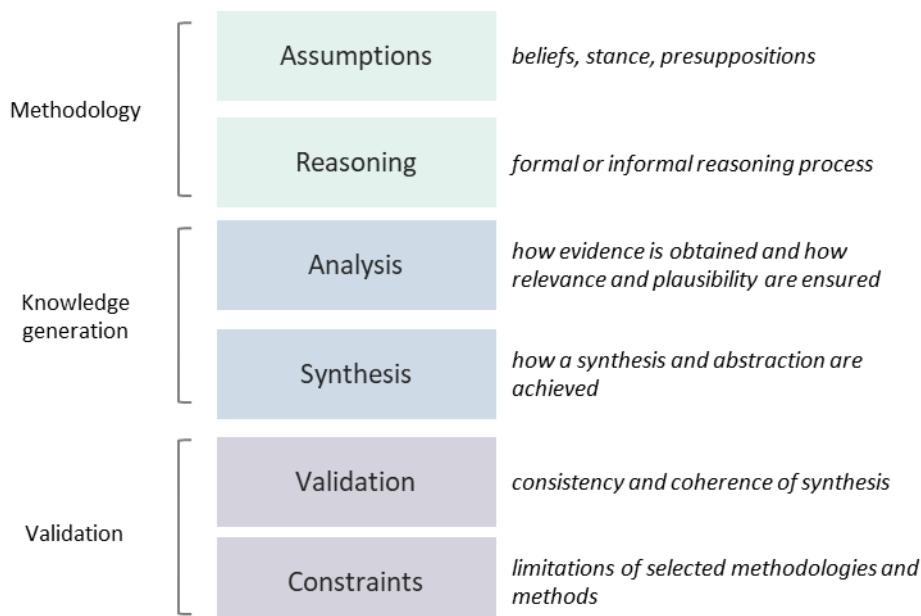


Figure 15.7 Structure of a dialectical research design

15.7.1 Methodology

Besides ontological and epistemological stances, we clearly state any logical *assumptions* (axioms, postulates), beliefs, and values we consider desirable, such as moral principles, ethical values, or normative demands. Again, definitions play a crucial role in preventing misunderstandings.

We also describe the form of logical *reasoning* that serves as a foundation for the arguments provided. Typical forms are syllogism, including inductive,

²⁹⁷ An example is the debate around Vygotsky's psychological and Bakhtin's philosophical model of language; see (Matusov, 2011) and a critical reply from (Cornejo, 2012)

deductive, and abductive reasoning, as well as analogical and causal reasoning.

15.7.2 Analysis and Synthesis

Dialectical research designs may take advantage of a variety of concepts for analysis and synthesis, each of which relies on unique assumptions. We usually begin with conceptual analysis, breaking down concepts into key concepts based on linguistic aspects, an approach which is closely related to hermeneutical methods, like grounded theory.

The probably most commonly used method is the dialectic triad of thesis, antithesis, and synthesis. It involves the following entities:

- Thesis: A position or claim²⁹⁸
- Antithesis: An opposing position or claim to emerge from the thesis
- Synthesis: A reconciliation of the two opposing positions to achieve a consensus on a higher level of abstraction.

Figure 15.8 shows the structure of a dialectic triad.

Beginning with fundamental *beliefs*, *values*, and *definitions*, we formulate a thesis and its antithesis, which emerges as a response to the thesis.

The actual controversy takes place between the *thesis* and its *antithesis*, which must underlie the same assumptions. If fundamental assumptions differ, the procedure is simply inapplicable.²⁹⁹

We can achieve a sound argumentation for a thesis only if we fully understand the arguments for the antithesis. This requires initially a dialogic approach to the antithesis: an open and respectful exchange of ideas and perspectives aimed at arriving at a deeper understanding through questioning, challenging, and refining. Afterwards, we can scrutinise the antithesis for weaknesses in argumentation.

Both thesis and antithesis must be supported by *relevant* and *plausible evidence*. Relevance refers to evidence that is necessary, sufficient, and meaningful in the context. We achieve plausibility if the evidence is accepted as likely to be true. While arguments might stem from empirical or rational evidence, they must be, in any case, logical to arrive at a credible synthesis.

²⁹⁸ That's where the name *thesis* for the academic thesis originates from. A traditional academic thesis was a monograph outlining one or more thesis statements and their argumentation.

²⁹⁹ For instance, a meaningful dialectic debate about the existence of god between a theist and an atheist is infeasible, since the fundamental postulates differ. A dialogic approach is required in such case.

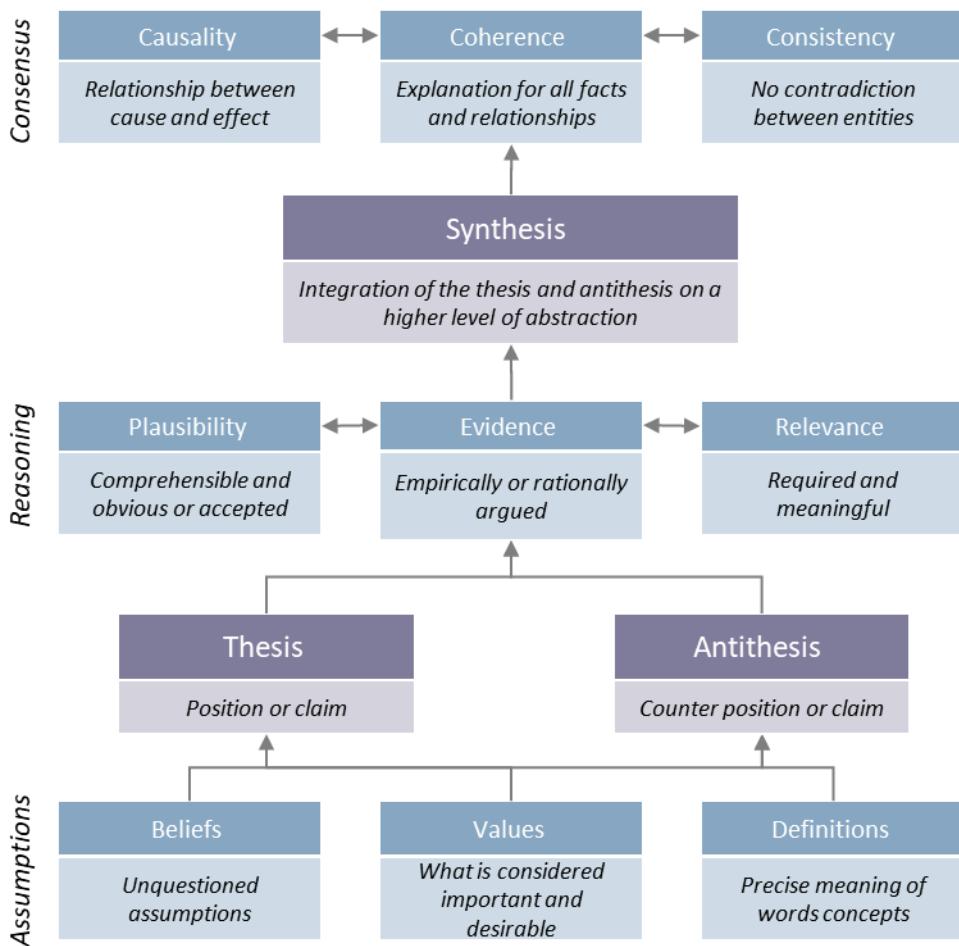


Figure 15.8 Structure of inference using a dialectic triad

The thesis and antithesis, as well as its underlying assumptions, must be particularly well-defined and comprehensive, even if the formulation may become complicated. Any misinterpretation takes the process of dialectics *ad absurdum*.

The goal of dialectic argumentation is to arrive at the most defendable state for a thesis and its antithesis through a process of questioning, challenging, and refining the two perspectives. The synthesis is the integration of the evidence of the thesis and antithesis into a claim of higher abstraction.

Arriving at a synthesis requires critical thinking, abductive creativity, and the ability to see connections and relationships between seemingly disparate elements. The goal is to arrive at a more comprehensive and accurate understanding that transcends the limitations of individual perspectives.

While the synthesis leads to a consensus between the opposing arguments, it may serve as a thesis for further dialectic discourse.

15.7.3 Validation and Constraints

The synthesis must be scrutinised in terms of its *causality*, be *consistent* to prevent contradiction, and be *coherent* to explain all facts and relationships. Such an approach relies on arguments which are either *valid* (deductively true), *sound* (being valid and all its premises are true), or *persuasive* (being sound and either axiomatic or plausible and accepted). We describe any measures taken to ensure the validation of the synthesis as well as limitations of abstraction due to assumptions.

15.8 ART CRITICISM DESIGN

Interpretation in the arts is a systematic procedure to understand why and how an artwork was created and what it means to the artist, the viewer, or society in its historical and cultural context. It may also help to uncover the hidden meanings and stories within an artwork.

Art is typically assigned to the humanities; its close relationship to anthropology, history, literature, and cognitive sciences is obvious. But it also resembles aspects of engineering when we consider the creation of artefacts. The link between philosophy and the arts lies in the field of aesthetics.

The main difference from other interpretative studies is that its analytic procedure involves an aesthetic judgement.³⁰⁰ The goal of the interpretation is not finding a truth or an undeniable state. It rather attempts to elaborate the nature and rules of the concept of *beauty*, involving perception, judgement, and value of aesthetic elements in artistic artefacts.³⁰¹

Interpreting artwork has a variety of aspects we can address. The aspect of *beauty* emphasises the subjective visual appeal, harmony, balance, and emotional impact of an artwork. An objective approach focuses on the intrinsic qualities of the artwork, independent of its subject matter or context.

It could be argued that the goal of the visual interpretation of the artwork is deliberately subjective, and therefore the interpretation should not be constrained by a rigid analytical procedure. However, this does not exclude the need for a systematic approach to convincingly convey the results of such an interpretation to the audience. Looking at the proposed research design (Figure 15.9) it becomes obvious that the synthesis ends with the interpretation and that validation, which turns up in every other research design, is missing. The reason is simple: we can barely validate a synthesis based on

³⁰⁰ For an extensive discussion on aesthetics and criticism, see (Becker, 2008, pp. 131-164)

³⁰¹ A detailed approach to the empirical study on the response to art is given by (Pelowski, Markey, Forster, Gerger, & Leder, 2017)

aesthetic judgements since they evade normative grounds. Art is eventually in the eye of the beholder.

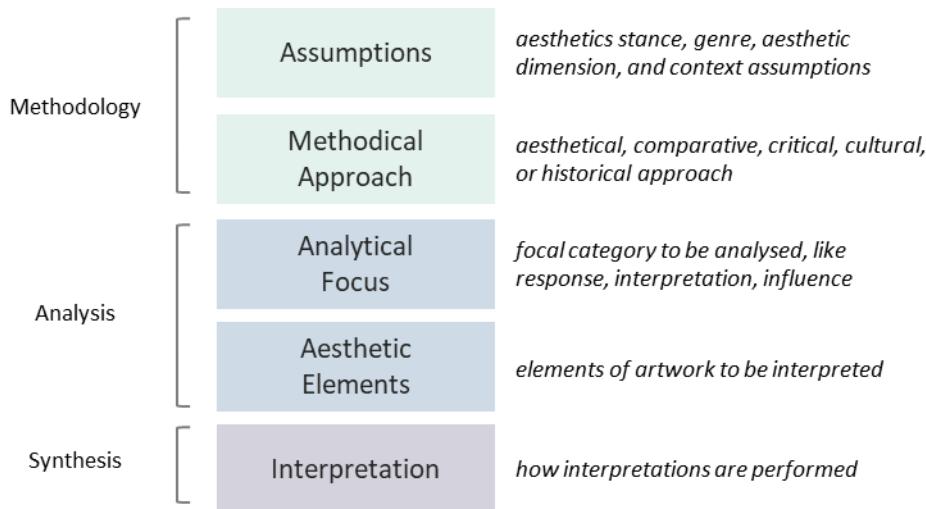


Figure 15.9 Research design of interpretative studies in the arts

15.8.1 Assumptions

Assumptions include the aesthetics stance, such as aesthetic realism, formalism, expressionism, pragmatism, or cultural relativism. If we don't accept rigid or objective standards of aesthetic judgment, we can follow a *postmodern stance*, challenging traditional aesthetic assumptions and emphasizing multiple subjective or contradictory readings of the artwork. Other assumptions include the focus on a genre, a cultural or historical context, or utilising a particular interpretational technique, such as iconography or semiotic analysis.

15.8.2 Deriving a Research Design

To derive a meaningful research design in art criticism is more complicated compared to conventional research. We present a decision tree in Figure 15.10 and explain the categories in the following.

15.8.3 Target Group

We propose beginning with a target group consisting of three focal categories: artist, audience, and society. Focussing on the *artist* may elaborate on the historical context in which the artwork was created or the creative process and the artist's intended message or meaning (if any).

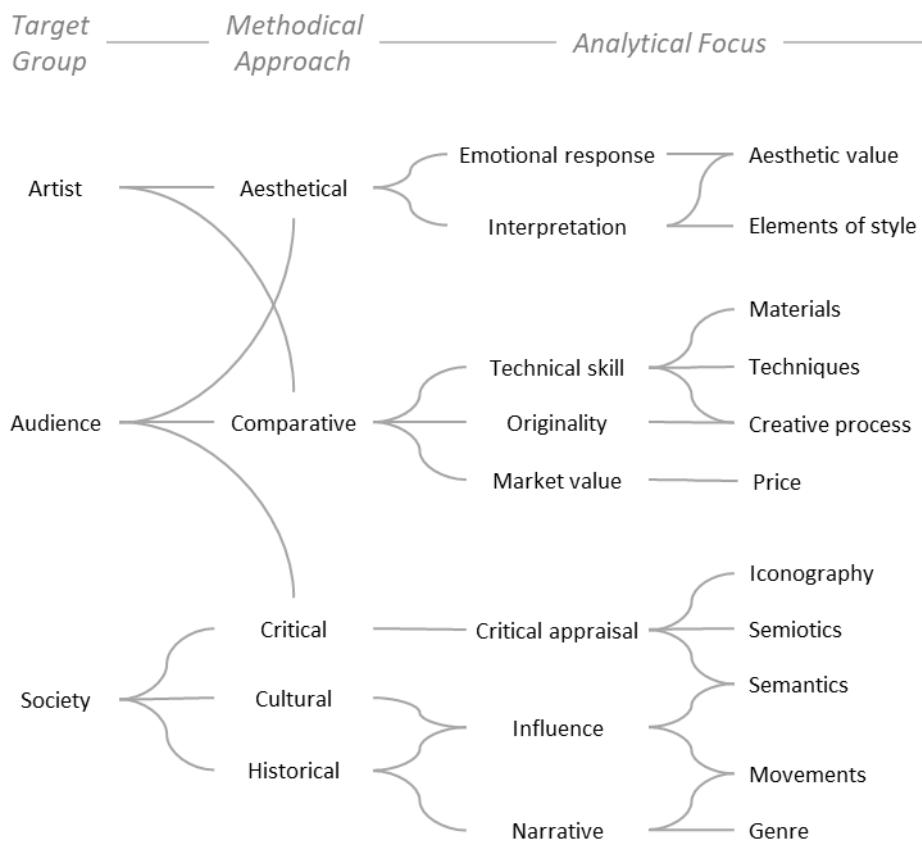


Figure 15.10 Decision tree for art criticism

Another focus is the response of the *audience*. This might involve looking at how different audiences interpret the artwork in terms of its creative components or its impact on observers and society.

We finally can choose to concentrate on the implications of artwork and its aesthetic value on *society*. Artworks can be used as a form of political activism to raise awareness about social issues and advocate for social change. It can also reflect and shape cultural identity, serve as a means of cultural expression and representation, and foster a sense of community. Finally, artwork can also serve as a means of education and social commentary. It can teach us about history, culture, and social issues and encourage critical thinking and reflection.

15.8.4 The Role of the Receptive Audience

In the analysis of art, the importance of the reception audience is contingent on various factors, including the goals of the analysis, the type of art under scrutiny, and the context in which the art is situated. Traditionally, art criticism has been bifurcated into two broad categories: artist-centric and audience-centric models.

Artist-Centric Approach

In this model, the primary audience is often the artist themselves or a select group of connoisseurs or critics. We can distinguish two groups of audiences:

- Artist: For art as a medium of the artist's self-expression, the artist is the primary audience. The importance lies in the individual's journey through art creation.
- Art critics: Within specific genres and historical periods, the views of a small group of educated critics may be. Their interpretations can influence the broader societal perception of the art.

The artist-centric model can uphold high art standards and may promote innovation and mastery. However, it can be exclusionary and may marginalize divergent interpretations.

The unique role of peer artists

In the artist-centric approach to art evaluation, incorporating peer artists as a reception audience introduces a layer of complexity and nuance deserving of focused scholarly attention. Peer artists operate within the same artistic milieu, sharing technical knowledge, creative inspirations, and often, the struggle for recognition and financial support. They can offer critiques that are both technically informed and contextually sensitive:

- Technical Evaluation: Peer artists are likely to have specialized training or experience in the same medium, which equips them to offer insightful critiques of technique and execution.
- Creative Sounding Board: Peer artists can serve as collaborators or mentors, offering new perspectives or inspiring creative explorations. The peer group can act as a space for brainstorming and sharing original ideas.
- Quality Control: Given their understanding of the medium and artistic intent, peer artists are often equipped to discern nuances in the artwork that general audiences might miss. They can identify subtleties in execution, concept, and innovation.
- Contextual Understanding: Being a part of the same artistic landscape, peer artists bring an understanding of the societal, historical, and cultural contexts in which the artwork is created and exhibited.

Peers serve not simply as passive evaluators but also as active agents in circling and adapting artistic ideas. They can influence artistic understanding in multiple ways:

- Technical Mastery: An artwork displaying exceptional skill can be a benchmark or even a tutorial for peers. Such works can encourage peer artists to refine their techniques.

- Innovation and Originality: Groundbreaking works often challenge established norms and provoke peers to rethink their artistic practices.
- Conceptual Depth: Conceptually layered Art can inspire peers to engage with themes or questions more intricately.
- Stylistic Impact: A unique style can lead to a ripple effect among peer artists, influencing the stylistic choices of an entire artistic community.
- Social and Political Influence: Artworks addressing sociopolitical issues can encourage peers to engage more actively with these topics in their own works.

Audience-Centric Approach

The audience-centric approach is more democratic. It allows for a broader range of interpretive strategies for different audiences:

- Public: For art designed to be accessible and appreciated by a broad audience, the general public's reception is critical. This is often the case for public artworks, street art, performances, and popular media.
- Target Demographics: Some art is produced for specific social, ethnic, or age groups. The interpretation by these targeted audiences can be central to the art's intended impact.
- Institutional Gatekeepers: In some contexts, curators, museum visitors, and academics can serve as an influential audience. Their perceptions can affect how the art is exhibited, studied, and archived.
- Market Audiences: In a commercial context, collectors, galleries, and auction houses serve significant reception audiences. Their valuations can significantly impact the market value of art.

A risk of diluting artistic quality for mass appeal may be an outcome that is susceptible to market forces.

Societal Approach

An artwork's meaning is closely tied to its *historical, social, and political context*, emphasizing the external factors surrounding the creation of the artwork, such as the artist's biography, societal influences, or art movements. An artwork's aesthetic value is also influenced by the *cultural context* in which it was created; different cultures may have distinct aesthetic standards, symbolism, and meaning systems.

Multidimensional Approach

A more nuanced understanding recognizes that these audiences are not mutually exclusive. Art can serve multiple audiences simultaneously. For instance, it may be appreciated at one level by the public while providing deeper layers of meaning to experts in the field. Additionally, the importance of the audience can change over time. What may have initially been received poorly could be reevaluated by future generations.

15.8.5 Methodical Approach

The methodical section details the focus and determines the principles we follow in interpreting the artwork. Examples are historical, comparative, critical, and ethnographic methodologies.

In a *historical* methodology, we concentrate on how a piece of art was shaped by the period in which it was created. This includes the artist's personal setting, the political, social, and cultural events happening at the time, as well as the evolution of the artwork during the lifetime of the artist.

A *comparative* methodology concentrates on different artists, genres, or origination, highlighting similarities and differences and explaining why these comparisons are relevant to the interpretation.

A *critical* reflection of artwork focuses on its expression and impact in a historical or political context, in particular in terms of social power relationships and inequalities. It, therefore, resembles the dialectic research design.

The *cultural* methodology focuses on the aesthetic value of the artwork for shaping and transforming culture and thus takes advantage of ethnographic and ethnomethodological principles.

15.8.6 Analytical Focus

The interpretation of art involves both subjective and objective criteria. Personal emotional response and interpretation often provide a subjective yardstick, while technical skill, innovation, contextual relevance, market value, and critical acclaim serve as more objective measures. A subjective approach may focus on:

Subjective perspective

- Personal emotional response: One of the most prevalent criteria is the art's emotional impact on the viewer. Art that evokes strong positive or negative feelings is often labelled as impactful or 'good.'
- Personal interpretation: The meaning an individual derives from the artwork also plays a significant role. In this view, good art is often seen as open to multiple interpretations and rich in symbolic meanings.

While the subjective perspective enables a personalized, emotional connection with the Art, it can lead to a narrow, solipsistic view of Art, susceptible to emotional biases.

Objective criteria provide a more standardized framework for evaluation and include diverse viewpoints through expert opinions and societal standards:

Objective perspective

- Technical skill: Mastery over medium and technique is traditionally one of the key indicators of art. The skill level can often be assessed through formal elements depending on the art form, such as line, colour, texture, shape, composition, choreography, musicality, etc.
- Innovation and originality: These criteria examine whether the Art pushes boundaries or presents ideas novel ideas. Originality can elevate a work from being merely competent to exceptional.
- Contextual relevance: Art does not exist in a vacuum. Its societal, historical, or cultural context can add layers of meaning and impact, thus contributing to its value.
- Market value: Although not a purely artistic criterion, the market value of Art often serves as a shorthand for its quality. Generally, the willingness of the audience to pay for the presented Art reflects importance and perception.
- Critical appraisal: Art critics, scholars, and experts often shape public opinion. Their assessment can serve as a more 'objective' measure, though it is not without its own biases.

Such criteria can be exclusionary or elitist and may overlook niche or emerging art forms.

A pluralistic approach incorporating multiple criteria can offer a more nuanced and comprehensive evaluation.³⁰² A more contemporary perspective accepts that the criteria for 'good' Art can be multifaceted and that different criteria may be more or less relevant depending on the context. In this view, multiple criteria are often employed simultaneously to evaluate an artwork.

A pluralistic approach is useful.

We might focus on an art *movement* or a *genre* in historical and comparative analysis or use *stylistic elements* of artwork, such as composition, shape, or space. *Materials and techniques* play a role in the physical properties of artwork, such as colour, line, texture, medium, tools, and the procedure for creating the artwork. The *creative process* describes the creation from

³⁰² For a detailed assessment of criteria, see (Carroll, 2009)

conceptualization to the final artwork. This may include the use of sketches, prototypes, and other preparatory materials.

Critical studies may concentrate on *iconography*, the study of images and symbols used in the artwork and what they represent, and *semiotics*, how the signs and symbols communicate meaning. Even *psychoanalytical* aspects might be helpful in exploring an artwork's unconscious meanings.

A central role in cultural analysis is the aesthetic dimension,³⁰³ like judgement, attitude, experience, and value, and their individual descriptive elements.³⁰⁴

15.8.7 Artistic Domains and Aesthetic Elements

Different artistic domains require considering different aesthetic elements of interpretation (see Figure 15.11), each of which can take advantage of methodologies and methods of other research designs.

<i>Artistic Domain</i>	<i>Aesthetic Elements</i>
Visual Arts	Photography, Drawing, Painting, Sculpture Visual elements, composition, colours, textures, size, space, proportions, brushstroke, material, function, site, light, façade, and other visual and material attributes
	Conceptual Art Conceptual idea, expression, symbols, metaphors, meaning, implications
	Digital Art Digital technique, vector art, 3D modelling or sculpting, photomanipulation, matte painting, pixel art, 2D or 3D animation
Performing Arts	Interactive Art Character shape and animation, environmental shape, acting pathways, storylines, hardware, game mechanics
	Performance Art, Theatre, Film, Dance Method of acting, choreography, scripting, direction, music, singing, set design, sound, lighting, costumes, makeup
Music	Instrumental, Electronic, Singing Duration, dynamics, harmony, melody, structure, texture, notes, timbre, harmony, rhythm, sequence, repetition, variation, ostinato, inversion
Literature	Fiction, Drama, Poetry, Prose Plot, character, setting, point of view, symbolism, imagery, theme, tone, structure, style

Figure 15.11 Aesthetic elements for different artistic domains

³⁰³ Examples of aesthetic dimensions in art interpretation are found in (Innis, 2022).

³⁰⁴ A taxonomy of descriptive elements is found in (Christensen, Cardillo, & Chatterjee, 2023).

In *visual arts*, including sculpture, painting, and comic art (for example, manga), the impression and emotional reaction is an important subjective part of the analysis. In this sense, it is related to interpretative design in cognitive sciences and may take advantage of its methodology. Similarly, *interactive art* (for example, video games) may focus on participation, event performance, instruments, game genre, interaction devices, and digital support.

Digital visual arts require technologies to generate artwork, including concept art, illustration, character artistry, environmental artistry, and 2D and 3D animation. It includes technical aspects playing a role in the creation and relates to the development design.

Conceptual art focuses on the idea behind the work rather than the finished object. Compared to other types of art, it emphasises the planning and decisions made to produce the artistic artefact. Conceptual artwork may use any artefact, from painting, installation, or performance to linguistic expression.

Performing art includes theatre studies, film, anime, dance, music, opera, theatre, musical theatre, magic, illusion, mime, puppetry, circus arts, and performance art. The analysis can take advantage of methodologies of empirical or interpretative studies and literary criticism.

Musicology relies on music theory, has an artistic and aesthetic account, and includes a procedure to create sounds. Interpretation requires active listening, for instance, by concentrating on particular musical elements at a time (such as harmony, rhythm, melody, and form) as well as compositional devices (such as sequence and repetition).

Literary art covers the analysis of intention, structure, speech, and textual comparison. It relies on narrative analysis, including semiotics (such as analogy, allegory, metonymy, and metaphor) and symbolism in the case of visual signs (such as hieroglyphs). It takes particular advantage of hermeneutics and grounded theory.

15.8.8 Synthesis

The synthesis section finally describes how interpretations are systematically performed. The results must be seen in the context of the chosen interpretative goal, methodology and analytical categories.

For instance, a historical synthesis reflects the artist's intentions in the broader cultural, social, or historical context, whereas a comparative synthesis focuses on other relevant artworks, artists, or art movements and discusses similarities, differences, influences, or any notable connections that shed light on the artwork's significance. A critical synthesis emphasises the

relationships and connections between artwork and its broader implications on society.

Since the interpretation of artwork and the judgement of aesthetics are purely subjective, validation cannot be achieved and is not intended. Any attempts to draw substantive conclusions would require a dialectical design, an approach to achieve a consensus to prevent ending up in unconstructive criticism.

15.9 ENGINEERING DESIGN

Technology, engineering, construction, architecture, design, and information technology are typical examples of applied sciences that employ the development of technical systems. While they typically follow principles of the natural sciences in their research, their development approach usually begins with a demand.

The goal is to invent rather than to discover; for instance, to develop a conceptual design, a technical design, a system specification, prototypes, or construction models. The focus lies on the process of requirements engineering, which is the crucial factor for the applicability of a technical solution. Consequently, the methodology differs from other research designs in that we derive its assumptions from an initial demand and a series of requirements.

Figure 15.12 shows the proposed structure of the design chapter.

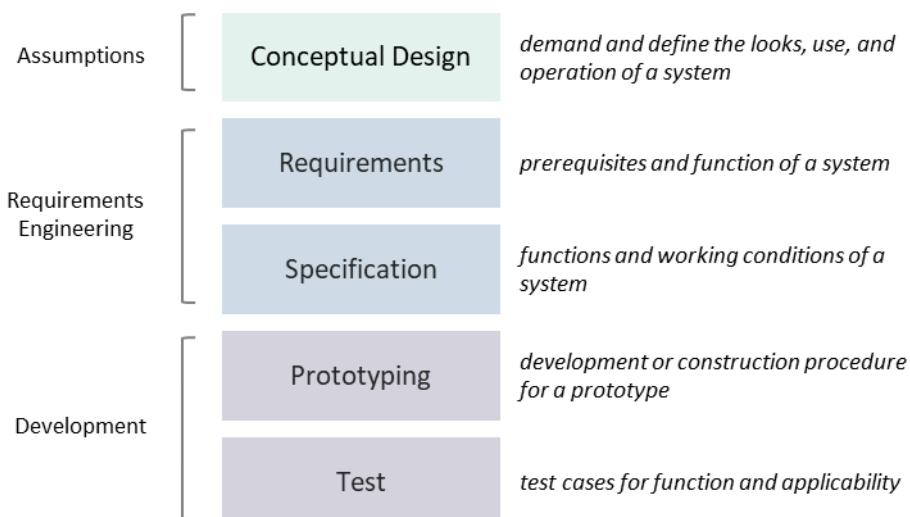


Figure 15.12 Research design in system development and engineering

15.9.1 Conceptual Design

A conceptual design is the initial phase of the design process, where the idea for a product, system, or structure is explored and developed. It begins with stating the demand for which a system is developed, describing the requesting party, the reasons for the development, and the utilisation of the system.

The scenario could be a business use case focusing on business operations and business goals to achieve. Typical components of the design would then be strategic value, financial benefits, and a risk assessment. A use case in information technology focuses on the workflow, the operating conditions, and the system boundary. A user story is often helpful in describing the benefits and results of the operation and in covering acceptance criteria.

The further process involves researching possible solutions to a given problem by brainstorming, creating sketches, diagrams, construction plans, and prototyping. The aim of this stage is to create a basic design concept that can be used to guide further development, determine boundary conditions, and elaborate requirements.

15.9.2 Requirements Engineering

Requirements engineering describes the procedure to comprehensively identify requirements and verify them against the stakeholders' expectations. Consequently, this includes a description of how stakeholders were identified and their expectations collected and assessed. The requirements of engineering may be part of the research objectives.

You also may apply instruments used in social sciences, such as interviews or questionnaires, to obtain the requirements; however, these should provide facts rather than interpretable statements, and their interview transcripts should be condensed.

The *requirements* may be part of the research objective and enumerate the functional, non-functional, and technical requirements. They are usually presented in a table, divided into functional (such as a user interface function), non-functional (such as performance, maintenance, or acceptance criteria), and technical or environmental requirements (such as operating temperature).

We validate each requirement to ensure it is valuable for the solution, clearly described, its implementation is assessable, and its compliance with relevant norms is ensured (see Table 15.10).

Table 15.10 Criteria to validate system requirements

<i>Criterion</i>	<i>Description</i>	<i>Category</i>
Comprehensible	for stakeholders and developers	
Relevant	for the intended solution	Value
Achievable	with the available resources and qualifications	
Specific	unique and unambiguous in its description	
Discrete	distinct from other requirements	
Independent	of uncontrollable parameters	Clarity
Open	without reference to a solution	
Measurable	in terms of successful implementation	
Traceable	using a standardised coding	
Prioritised	according to a standardised ranking	Assessment
Terminated	with a date of complete implementation	
Legal	according to legal regulations	
Ecological	according to good environmental practices	Compliance
Ethical	according to culturally accepted norms	

The *specification* derives from the requirements and provides a coherent and unique system definition. Depending on the focus, we can distinguish:

- Design Specification: contains design elements and layout.
- Functional Specification: lists software functions.
- System Specification: describes the entire system, including design elements and performance parameters.
- Technical Specification: describes technical considerations for the development of individual components.

The specification may also include the technical equipment and tools, such as hardware, software, programming languages, construction material, or applicable industry standards. Each of these requires an argumentation for its fitness for use.

15.9.3 Development

The development section covers the procedure to create a prototype of a system or construction. The outcome might be a technical design describing the configuration of a system, a CAD visualisation or animation, a source code, software, or a physical model.

This is best visualised in a work breakdown structure (WBS) that categorises activities according to different fundamental divisions. For example, software development projects typically use objects (for example, user interface, search engine, database), functions (for example, authentication, administration, data management), or phases (for example, design, development, test). Each tier is categorised consistently according to one of the fundamental, although sub-tiers may use different ones (see Figure 15.13).

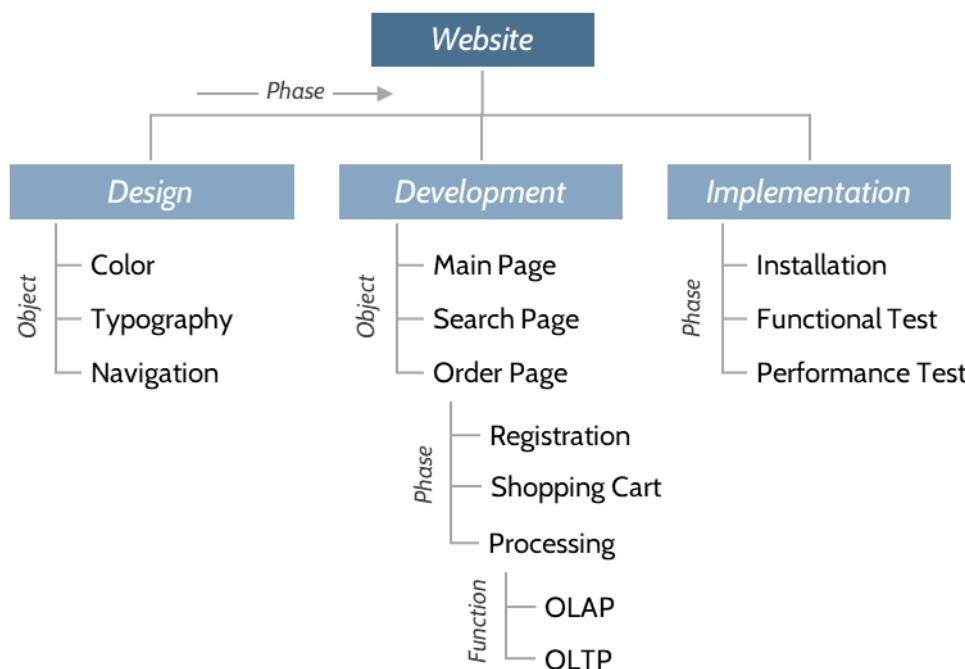


Figure 15.13 Excerpt of a work breakdown structure for website development with object-, phase-, and function-oriented categories. OLAP: online analytical processing; OLTP: online transaction processing.

The lowest levels of a WBS are the work packages, which describe activities of a limited effort which are not further divided.

The *test* phase covers the alignment of the requirements with the actual use. This might include the implementation of a physical system, the proof of concept of a technical design or a software test. It is a good idea to establish a clear process for each of these steps and document it.

Further recommendations for implementation and use might be derived from the test results. If applicable, conditions for maintenance and decommissioning of the system are included.

15.10 A RESEARCH DESIGN CHECKLIST

The checklist in

Table 15.11 will help to comprehensively describe the research design.

Table 15.11 Checklist for the research design

<i>Category</i>	<i>Criterion</i>	
Assumptions	Ontology and epistemology stated	<input type="checkbox"/>
	Postulates, propositions, and axioms stated	<input type="checkbox"/>
	Selection of definitions argued	<input type="checkbox"/>
Methodology	Established methodologies cited	<input type="checkbox"/>
	Deviation from established methodology described	<input type="checkbox"/>
Methods	Established methods cited	<input type="checkbox"/>
	Deviation from established methods described	<input type="checkbox"/>
Instruments	Analytical or observational instruments described	<input type="checkbox"/>
	Experimental or empirical settings described	<input type="checkbox"/>
	Tools and software described and cited	<input type="checkbox"/>
Data Acquisition	Sampling procedure described	<input type="checkbox"/>
	Population and sample described	<input type="checkbox"/>
Analysis	Analysis procedure described	<input type="checkbox"/>
	Analysis techniques and algorithms cited	<input type="checkbox"/>
Synthesis	Synthesis procedure described	<input type="checkbox"/>
	Modelling or theory generation described	<input type="checkbox"/>
Validation	Reliability measures addressed	<input type="checkbox"/>
	Precision, accuracy, repeatability, reproducibility addressed	<input type="checkbox"/>
	Reference for validation cited	<input type="checkbox"/>
Constraints	Methodological, methodical, and analytical constraints addressed	<input type="checkbox"/>
	Ethical implications of the study procedure addressed	<input type="checkbox"/>
	Ethical implications of study outcomes addressed	<input type="checkbox"/>
Comprehensibility	Workflow easy to follow	<input type="checkbox"/>
	Workflow replicable	<input type="checkbox"/>
	Terminology is limited to the necessary	<input type="checkbox"/>

Apart from the checklist, ensure you:

- do not explain research terminology or established and well-documented research procedures.
- do not address paradigms if only one exists.
- do not mix up analysis – the dissection of results into categories and their relationships – and synthesis – the combination of results to reach conclusions.
- describe whether generalisation is intended or not.
- Be aware of that validation is only achieved by comparison with alternative methods, approaches, and researchers.

With the research design chapter, you finalise the theoretical foundations of your thesis. The next step is to approach the presentation of results.

15.11 THE WORST PRACTICE

In the research design section, you can lay out to your reader how you actually work. On second thought, why would you disclose it to a reader who has not made the slightest effort to assist you in this complicated endeavour? Isn't what you do at home a matter of privacy and protected by the General Data Protection Regulation? With this in mind, let's start over again.

The Mystical Research Design Guide

In the research design section, you can leave your reader in the dark. If you describe your research in a way that is comprehensive and replicable, you just run the risk that any guy can repeat it and find out about your fake data.

But how to begin? Since your readers do not have the profound knowledge of sciences that you achieved during your studies, you may begin by explaining the fundamentals of research:

Good research relies on a profound methodology. Methodology is important because it ensures a credible study, which is the foundation of good science. To understand the value of good science, I first explain what science is ...

From now on, you can take advantage of colourful scientific terminology. You begin by stating your personal metaphysical stance as a critical progressive pragmatist or as a post-constructional hacktivist (use the famous research onions if you need further ideas). Alternatively, you can use the terms qualitative and quantitative in combination with other famous scientific terms.

This research uses a qualitative induction to triangulate the quantitative qualities of quantum physics.

What follows is the description of methods or methodologies (they are essentially the same, but the latter sounds more impressive). To not run into argumentative issues, use the 'anything goes' approach of pragmatism and mixed-methods research, meaning you are allowed to use qualitative, quantitative, and mystic data.

You then describe analysis, synthesis, hypothesis, parenthesis, and prosthesis, which are again the same but impressively contribute to the colourful and enigmatic scientific vocabulary.

Finally, you discuss the validity by raising some critical questions, for instance:

The study does not address whether the reliability replicates an accurate precision. It rather verifies its sound credibility by confirming the correctness of its validity.

Don't forget to state your ethical considerations at the end, such as the moral implications of someone expecting students to understand all these terms.

16 THE RESULTS & DISCUSSION

Having no idea could be a valuable null hypothesis.

The results we obtain by applying our research design extend the knowledge presented in the literature review. To generate new insights, we need to interpret our results, giving them meaning that contributes to achieving our research objectives.

Interpretation, however, is always subjective. Any decision we made before already delimits our interpretation. We state research questions that delimit the scope of the investigation. We decide on a methodology and limit our analysis and synthesis procedure. We read literature that shapes our preconceptions. We decide on a chart type and again delimit our interpretational freedom. Finally, we cannot avoid our experience influencing the way we understand results.

To at least approximate objectivity, it might be helpful to approach our results without preconceptions. To begin with, the generic null hypothesis is that we don't know anything about the subject matter. Therefore, we take a step back and ask what a result shows before we engage in interpretation.

In this chapter, we describe general principles for presenting and interpreting results; the following main chapter covers the discussion separately.

16.1 OUTLINE OF THE RESULTS SECTION

As with every main chapter of your thesis, the results section begins with a brief introduction to the structure and the selected sequence of subchapters.

Objectives as guiding principle

In any case, it is helpful to consider arranging subchapters according to research questions. Figure 16.1 illustrates an example.



Figure 16.1 Research questions as guiding principles for the structure of the results chapter.

Other criteria for structuring the results section are the result type (for example, a categorization into raw data and derived data), the priority (for example, novel findings before less significant findings), and whether a discussion (for example, inferences and links to secondary data) should either follow the interpretation or in a separate chapter immediately.

16.2 EXPLAINING AND INTERPRETING RESULTS

The focus of the results chapter lies on presenting information rather than data. We already learned that we transform data into information by representing them in a different form, such as text, table, equation, or graphics. However, a piece of information is of no value if we fail to explain and interpret it.

The interpretation is twofold: the meaning of the information itself and the meaning it has in the context of our research. We will distinguish here

between the explanation (for example, what a chart shows) and the interpretation (what is its message).

Why is it necessary to explain what a quotation, chart, or table shows? Should the message not be obvious? The issue is that if we don't provide the reader with *our* understanding of the information, we leave the interpretation to the reader. This bears the risk of discrepancies in assessment and inference of author and reader, as the following excursus shows.

Why explain the obvious?

Excursus: The mysterious offset quotation

There is a trend in books and articles to begin a chapter with an offset quotation, a statement of deep thought of a well-known author that should emphasise the intellectual depth of the upcoming chapter. We find students regularly adopting this in theses. The issue is that the quotation is often stated without being addressed in the text. The message seems so obvious that further explanation is deemed unnecessary. However, the message is often not obvious.

Suppose we take a quotation from Mark Twain at the beginning of a chapter:

"Truth is stranger than fiction, but it is because fiction is obliged to stick to possibilities; Truth isn't."³⁰⁵

Without explaining what this statement means to us, the reader can interpret it in multiple ways:

- Truth is strange because it does not underlie possibilities.
- Truth must not stick to possibilities.
- Fiction must make sense.
- Fiction must be possible, truth not.
- Truth has a higher degree of freedom than fiction.
- Truth is factual, whereas fiction underlies possibilities.

What Mark Twain probably intended to emphasise – given the context of the quote – is that the credibility of a fictional story depends on whether the reader could accept it as being real, whereas truth (or reality) appears to be sometimes unbelievable or strange.

We might want to use this quotation to talk about the basis of reality a fictional story requires, but our reader might expect us to talk about truth being interpretable, truth being not necessarily true, or truth being sometimes impossible.

Without explaining the meaning of such a quotation in its own context and relating it to the context of our writing, our reader will most probably perceive it differently. We run the risk of setting false expectations, leading to a

³⁰⁵ In the source, the statement is attributed to *Pudd'nhead Wilson's New Calendar*, whose author is a fictional character created by Mark Twain (Twain, 1898, p. 156).

discrepancy between our readers' line of thinking and our own argumentation. That is, we have a high chance of disappointing our readers, and that is the last thing we want to do.

Confine the freedom of interpretation.

A golden rule is to confine the reader's freedom of interpretation. Convince readers of *your* understanding of the presented information. Even though they have their own opinion and may interpret things differently, we must direct their attention to *our* line of reasoning to make *our* arguments transparent.

The A-P-E-I-D approach

We recommend distinguishing between explanation and interpretation and follow a generic sequence for presenting results:

1. *Announce* the upcoming result in your text.
2. *Present* the result as a paraphrase, quotation, figure, table, or equation.
3. *Explain* the key message of the result, such as the key concept in a statement, the focal area in a figure, a pattern in a table, or the crucial elements of an equation.
4. *Interpret* the key message to derive its meaning in the research context. If appropriate, compare the result to other findings of your own or the literature.

Then, either go ahead with the next result or immediately:

5. *Discuss* the implications of the meaning of the results and how they contribute to answering the research objectives.

While a result presented always requires an explanation and interpretation, the discussion may occur in a separate subchapter.

Separate discussion

We prefer a discussion in a separate subchapter if the results are initially independent and only their combined interpretations give rise to a discussion. This often applies to results presented in charts, diagrams, or tables (see Figure 16.2).

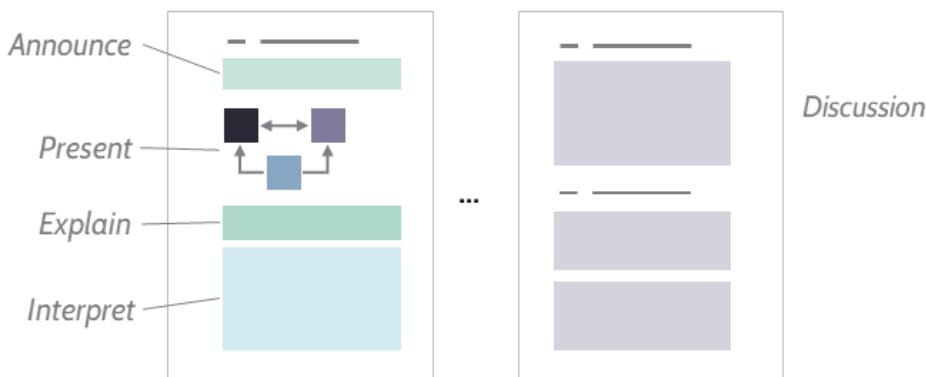


Figure 16.2 Sequence of results presentation with separate discussion.

We discuss a result immediately after the interpretation if our results are interdependent or must be answered sequentially, for instance, if the discussion of a preceding result contributes to the discussion of succeeding results. This often applies to quotations or other texts. In this case, an overall synthesis may appear in a separate chapter (see Figure 16.3).

Immediate discussion



Figure 16.3 Sequence of results presentation with intermediate discussion.

In the following, we present examples for the interpretation of four typical types of information: charts, statistics, narratives, and technical designs.

16.2.1 Presentation of Charts

In contrast to a common belief amongst students, there is no need to always use sophisticated statistical methods to interpret quantitative data. For instance, if we investigate an entire population rather than a sample or do not aim for generalisation, a deeper statistical analysis does not make sense.

As an example, Figure 16.4 shows responses to a survey question about the frequency of cybersecurity incidents occurring at a company site. The underlying research objective is to improve critical incident management at the site.³⁰⁶ Since the population (the company site) is covered completely, an analysis of analyse the central tendency, dispersion, or distribution of the data with statistics is not required. A simple frequency analysis with percentages suffices to describe the situation in question.

Announce

Present

Explain

Interpret

5.3.1 Responses Concerning Critical Incidents

We defined critical incidents for the respondents as events or situations occurring in the company that have the potential to cause emotional, psychological, or physical harm to individuals or groups. The responses to the occurrence of critical incidents in 2022 are shown in Figure 35.

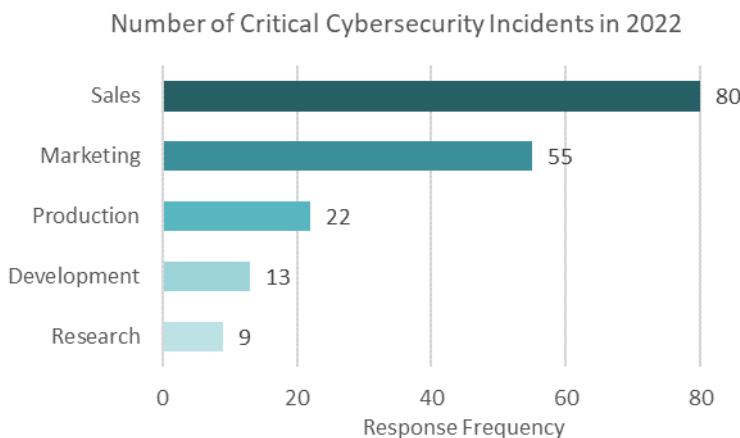


Figure 35. Frequency of responses to the occurrence of critical incidents in 2022 (n=188).

The responses show frequently occurring critical incidents in sales and marketing departments, making up about 75% of all critical incidents.

The smaller number of incidents in production, development, and research might be related to higher security measures and more strict compliance requirements previously described. This is consistent with findings from the expert interviews and aligns with the national trend in the same industry sector.⁸⁴

Figure 16.4 Excerpt of an interpretation of responses to the occurrence of critical incidents.

³⁰⁶ Critical Incident Management refers to the strategic approach and coordinated processes used to effectively respond to, manage, and mitigate the impact of critical incidents. Critical incidents are events that pose a significant risk to individuals, organizations, or communities and require an urgent and organized response.

16.2.2 Presentation of Statistical Data

If we want to generalise our findings or compare them with secondary data, we need a statistical assessment. Statistical data are presented as text, tables, or charts, each containing the statistic and its parameters. Figure 16.5 shows an example of a multiple linear regression table.

In sentences, the test statistic is presented with the relevant parameters in parentheses, such as the degrees of freedom, the p-value, the confidence interval, or a correlation coefficient.³⁰⁷

5.3.3 Perception and Prediction

The impact of the perceived probabilities of occurrence, detection, and risk severity on the prediction error of critical incidents is shown in Table 15.

Announce

Table 15. Multiple linear regression for prediction error of critical incidents; $r(7) = 0.98$, $p = .014$

	β	SE	t	P-Value	Confidence Interval	
					95%	
(intercept)	0.15	0.11	1.34	0.25	-0.16	0.47
Occurrence	0.99	0.16	6.19	0.00	0.54	1.43
Detection	-0.27	0.11	-2.45	0.07	-0.58	0.04
Severity	0.22	0.23	0.96	0.39	-0.42	0.86

β standardised coefficient; SE Standard error; t test statistic.

The regression model shows a strong impact of the perceived probability of occurrence on the error of predicting a critical incident and an expected negative (and less significant) impact on the perceived detection probability. The perceived severity cannot be identified as a significant contributor; subsequent analysis of the second team reproduced this result.

Explain

The results indicate that if critical incidents are anticipated, the accuracy of prediction suffers, which might result from a lack of experience or the use of an inadequate assessment scale. The perceived severity underlies a series of extraneous variables, such as experience and personality, and therefore only increases the bias of the model. This is consistent with findings from other studies, which identified inadequate assessment of critical incidents as the main reason for inaccurate predictions.⁹⁸⁻¹⁰¹

Interpret

Figure 16.5 Example of an interpretation of tabulated statistical data, including explanation and interpretation.

³⁰⁷ An overview on statistical data presentation with more examples is given by (In & Lee, 2017).

The explanation involves assessing the significance of the independent variables by repetition. The interpretation emphasises the validity of results assessed by comparison with other studies.

A graphical representation of statistical results conveys a different message (see Figure 16.6). The scatterplot requires both the x-axis and y-axis labels to indicate what each variable represents, and the units of measurement are indicated. Consider the appropriate scaling for the axes. Linear or logarithmic scales might be necessary based on the nature of the data. Ensure that the plot captures the entire range of the data for both axes. This prevents distortion and provides a comprehensive view of the relationship.

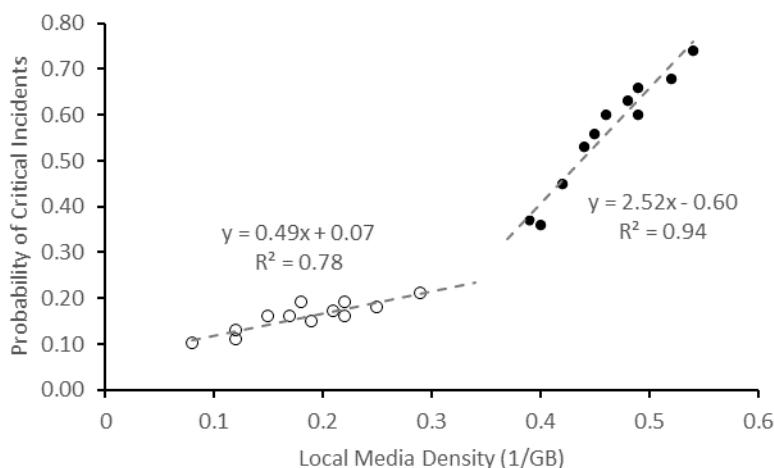
A brief explanation in the figure caption helps to clarify the interpretation. However, keep the plot simple and easy to understand and avoid cluttering the plot with unnecessary information that might distract from the focus.

Announce

5.3.3 Impact of Media Density

Critical incidents are influenced by the density of media used during data processing. However, a regression analysis revealed that two categories of media density exhibited a different strength of impact on the probability of critical incidents (Figure 21).

Present



Explain

Figure 21. Correlation between local media density and the probability of critical incidents. Two regions can be distinguished with densities less than 0.3, $r(10) = 0.97$, $p = 0.003$, and values above 0.4 media per gigabyte, indicating a stronger impact, $r(9) = 0.88$, $p = 0.009$.

Interpret

The higher impact found with media densities of more than 0.3 per gigabyte of processed data is consistent with an increase in critical incidents found in systems with multiple interfaces.

This suggests that media density is a contributing factor, particularly with high media densities. A potential reason for the smaller correlation with lower densities might be related to the impact of exogenous variables,

such as the smaller number of data processors. Further analysis is shown in the next chapter.

Figure 16.6 Excerpt of an interpretation of a regression chart.

The focus of the explanation lies on the different slopes of the regression lines that give rise to a classification. The interpretation states a potential hypothesis and leads to further analysis.

16.2.3 Presentation of Narratives

Narratives can come from any text, such as quotations or paraphrases from publications, responses to open-ended questionnaire items, excerpts from interview transcripts, or field notes.

We quote the narrative either as an indented block quote (for longer statements or multiple sentences) or as inline quotations (for single or partial sentences). If it stems from a publication, we cite it with a page number. If we want to refer to a complete or condensed transcript in the appendix, we cite the appendix and the line number. In the case of electronic recordings, we refer to the file name and the time stamp.

Figure 16.7 shows an example of a content analysis, where we search for factual statements and interpret their meaning in our research context.

6.1.3 Affective Patterns in Incident Management

Patterns of emotional responses have been found in multiple instances. A typical example was a response of a member of the CIMT, expressing her opinion about communication gaps occurring in video conferences:

*"Managers at [REDACTED] often believe it's enough to have a video conference to manage any incident. I wish they would more often attend and see, how hard it is to understand the criticality of a situation, and how people feel being left alone."*⁵⁷

Announce

Present

Explain

Interpret

The respondent was not convinced that video conference is appropriate to prevent misunderstandings from evolving into incidents. She expressed the feeling that decision-makers are unaware of the challenges of a realistic setting.

A similar concern was alleged by a team lead who was notably worried if managers "do not have an idea about the consequences of an incident".⁵⁸ This is consistent with concerns previously evolving in the statistical analysis of the survey data and supports the relevance of affection-attitude patterns in case of incident management dissent.

⁵⁷ Appendix C-2, line 17

⁵⁸ Recording CIMT-2, 12:50

Figure 16.7 Factual interpretation of an excerpt of an interview transcript. Part of the quotation is blackened to conceal sensitive information. The example shows two footnotes referring to a line number in the appendix and the time stamp of an audio recording.

In this case, the explanation simply restates the facts, and the interpretation is limited to a hypothesis supported by other results.

Interpretative analysis

In interpretative approaches, we investigate the text more thoroughly in terms of the situational context, verbal expression (wording), semiotics (non-verbal cues, such as enthusiasm, reluctance, insecurity, and gesture), semantics (meaning), relationships between statements, and action strategies and their consequences (see also chapters 14.8 and 14.6.3).

We present an excerpt of a full transcript (including semiotic artefacts), explain and clarify the meaning of the statement from the respondents' point of view, present our understanding, and address the consequences of our interpretation of the research objectives.

6.1.3 Patient Complaints

Announce

The second part of the interviews addressed complaints from patients about the careless behaviour of nursing personnel. Responses to such questions were found in three categories: evasive, antagonistic, and mediating responses. An example of an evasive response taken from the interview of candidate 2 is:

Interviewer: "What steps have you taken to address the complaints about the rude behaviour of nursing personnel?"

Present

Nurse: "Well, the patient's well-being is really important to me, and I'm always looking for ways to improve the patient's mood. However, our daily workload does not allow us to have extensive conversations, and patients are not willing to understand that. (sighs deeply) I address this regularly with the hospital management, but I feel like talking to a brick wall."

Explain

The respondent expresses the patient's well-being as a personal motivational factor. He emphasises the conflict between the patient's conversational demand and the limited time and beliefs that the hospital management is not willing to resolve this issue.

Interpret

The respondent begins with the self-defensive statement that the patient's well-being is "really" important to him, thus defending himself against an anticipated prejudice of the interviewer. Rather than addressing the question for concrete steps taken, he states that he is "always" looking for improvement, underlining his defensive position as well as showing his inability (or unwillingness) to provide a concrete answer.

It is remarkable that the person's view changes from "I" to "we" when talking about the daily workload, an issue that obviously relates to the

candidate's colleagues, too. Switching back to the "I" perspective after a deep sigh turns to the candidate's perspective again. The use of the brick wall metaphor emphasises the helplessness of the respondent when attempting to shift the responsibility to the hospital management.

Such patterns occur consistently in other interview⁵⁸ and are in line with findings towards responsibility shift described in the literature.⁵⁹

⁵⁷ Recording A2, 10:31

⁵⁸ cf. recordings A2, 21:15; A4, 18:12; and transcript B9, line 98

⁵⁹ cf. Hartwood (2019, p. 421) and Geller et al. (2020, p. 124)

Figure 16.8 Excerpt of an interpretative approach to an interview response.

This is just a short example. Interpretative text analysis can cover more than a page or even chapters, for instance, when using grounded theory. In any case, we interpret the text more critically and compare the results with secondary findings before we engage in a self-reflective discussion.

16.2.4 Presentation of Technical Results

Presenting a technical system does not require an interpretation and reduces to explaining the system's components or principles. In contrast to other scientific disciplines, the research questions are replaced by requirements, which were assessed for consistency and coherence. The results section describes how the development of the system was (or will be) achieved and how the design is validated. An example of a technical design step is shown in Figure 16.9.

Announce

Present

Explain

5.3 Design of the Coding Process

The transmission of two classical bits using one part of an entangled qubit takes advantage of quantum teleportation (the transmission of one qubit using two classical bits; see Figure 15).

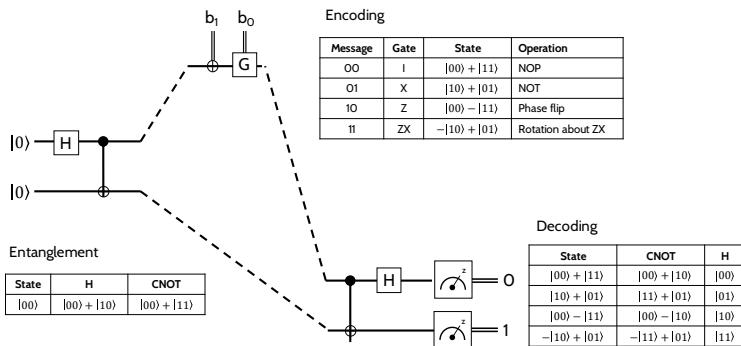


Figure 15. Technical layout of the system for superdense coding (H Hadamard gate; G encoding gate). The normalization factor of the states is left out.

The entanglement is achieved by a third party splitting the entangled qubits between sender and receiver. The sender encodes her message using encoding gates (G), whose outcome is decoded by the receiver using the inverse gate operations. This principle ensures secure quantum coding since it eliminates the possibility of eavesdroppers intercepting messages. Any attempt to measure either the sender's or receiver's qubit would collapse the quantum state, which will be recognised.

Figure 16.9 Excerpt of an explanation of a technical solution. The text explains the figure and describes its value for secure data transmission.

16.3 DISCUSSING RESULTS

The discussion uses the interpretations to reach individual conclusions. It explores alternative interpretations, highlights different perspectives, and addresses potential limitations of interpretation or criticism.

If you decide on a separate discussion section, you may consider summarising the main interpretations of the findings in tabular or graphical form and presenting the details in the same sequence in individual subchapters. In the same sense, new insights from non-narrative literature reviews become part of the summary.

Besides reasoning with your own results, you again engage with the secondary sources. You use previously cited sources or introduce new ones that weren't relevant to a narrative literature review. Discuss how your findings compare with previous research in the field, highlighting similarities and differences and any implications for the research objective.

These sources ideally exhibit a different perspective on the topic to enrich the context and support the discussion while presenting multiple viewpoints. Figure 16.10 shows an example of including a supportive statement from literature.

The surveys and interviews indicated that the research taught in the economic study program emphasises mathematics and statistics as primary tools. This is puzzling, considering that economics is part of the social sciences.

John Davis mentions a phenomenon that contributes to this discrepancy. In a paper on neoclassical dominance in economic education, Davis found that economists regularly notice anomalies in the transition from economics research to economics instruction. He identified:

"...contents that persist in instruction, despite changes in the content of research, uneven transmission across levels of instruction [and] appearance of instructional contents unrelated to changes in research"³⁰⁸

His findings that content does not reflect changes in research seem to exhibit a significant gap in the scientific education in economics study programs. The disparity of education content and the state of knowledge may have one origin in the pronounced conservatism that often accompanies the economics fields.

Figure 16.10 Excerpt of a discussion supported by literature.

In any case, you critically reflect on your own results as well as the literature by questioning assumptions, countering arguments, or challenging established views. To achieve this, it is helpful to distinguish between different forms of argumentation.

16.4 IDENTIFYING FORMS OF ARGUMENTATION

An important part of the discussion is the comparative approach to literature. We can distinguish four main types of arguments (Table 16.1) to assess the value of a statement to support our arguments or identify a conflict.

Table 16.1 Example of linguistic forms of argumentation

Type of argument	Description and example
dialogic Latin: <i>diálogos</i> conversation	Open argumentation to explore multiple perspectives:

³⁰⁸ (Davis, 2006, p. 5)

	<i>Legalizing cannabis can eliminate the illegal market or reduce its influence.</i>
dialectical Greek: <i>dialektikē</i> argumentation	Argumentation with opposing positions: <i>Case studies show that cannabis consumers are more likely to commit crime than non-consumers.</i>
rhetorical Greek: <i>rhētorikē</i> art of speech	Using persuasive language and emotional appeals to influence an audience's belief: <i>Liberal pot culture in Amsterdam has spawned social problems from robbery to prostitution and hard drug use.</i>
apodictic Greek: <i>apodeiktikos</i> demonstrable	Argument based on a self-evident truth with logical certainty: <i>If no one would produce drugs, we would have no drug addicts.</i>

Dialectic and dialogic argumentation are both approaches that involve critical thinking and the exploration of different perspectives. However, they differ in their focus and their goals.³⁰⁹

Dialogical argumentation involves a process of open and collaborative communication that seeks to explore and understand different perspectives. The goal of dialogic argumentation is not necessarily to arrive at a conclusion but to engage in a respectful and constructive exchange of ideas. We use this approach in settings with diverse perspectives or stakeholders, such as community discussions or policy debates. It is essentially used in the descriptive phase of the research cycle.

Dialectical argumentation involves a process of critical thinking that seeks to identify contradictions or tensions within a particular perspective or position. Dialectic argumentation aims to synthesise these different perspectives into a more comprehensive understanding of the topic. We use this approach in academic settings, examining different theories or perspectives to arrive at a more nuanced or thorough understanding of a particular topic.

Rhetorical argumentation is a persuasive approach that employs emotional appeals, vivid language, and rhetorical devices to influence an audience's attitudes. It focuses on crafting compelling arguments without necessarily relying solely on logical reasoning or evidence.

Apodictic argumentation presents claims with absolute certainty and indisputable evidence, leaving no room for doubt or counterarguments. It relies on self-evident truths, logical deductions, or well-established facts.

³⁰⁹ For further reading on the difference between dialogic and dialectic argumentation, see (Dafermos, 2018)

The following shows examples and describes how the forms of argumentation may be recognised.

16.4.1 The Dialogical Argument

Dialogical reasoning, in the most general sense, refers to a conversation to explore different perspectives. It contrasts the monologue, a form of speech where an individual presents their perspective without engaging in dialogue or considering opposing viewpoints. Let us look at some arguments for and against hydraulic fracturing (fracking):

Hydraulic fracturing has reduced our dependency on foreign energy sources and created new jobs in the energy sector. The revenue generated has contributed to economic growth, leading to improved infrastructure and public services.

On the other hand, fracturing poses environmental risks as it contaminates groundwater with harmful chemicals and thus risks the health of nearby communities. It also puts a strain on local water supplies and contributes to greenhouse gas emissions, exacerbating climate change.

The individual arguments in both positions do not necessarily contradict each other. They are just a collection of thoughts and ideas around the topic.

Dialogic refers just to a verbal exchange of opinions. It does not necessarily attempt a resolution. The goal is to identify all arguments for and against the positions to achieve a comprehensive description of the issue.

A characteristic is the careful choice of words highlighting tendencies and possibilities rather than rash assertions or value statements. Another characteristic that clearly identifies good dialogical arguments is that you will not be able to identify the personal stance of the author. Although contrasting the arguments may be part of the dialogic argumentation:

While hydraulic fracturing supports economic growth, it poses environmental risks.

taking a concrete stance would leave the dialogical argumentation and turn into a dialectical form.

16.4.2 The Dialectical Argument

Dialectical argumentation prefers a position and provides weighted statements against the counter position, ideally anticipating counterarguments:

Fracking allows us to access previously untapped reserves of natural gas, which emits fewer greenhouse gases than coal when burned for electricity.

In dialectic argumentation, the opposing position is scrutinised to find an element that weakens it:

Even though natural gas burns cleaner than coal, methane leaks during the extraction and distribution process can offset those benefits.

Ideally, we find an argument that outweighs the counter position, for instance, by abstracting the issue:

Fracking is only a temporary solution that distracts us from investing in renewable energy sources and more sustainable practices.

The goal to be achieved with dialectical argumentation is the consensus on a synthesis:

While accepting fracking as a temporary solution, we should prioritise and invest considerably in alternative renewable energy sources.

16.4.3 The Apodictic Argument

Apodictic arguments do not leave room for interpretation; they are uncontested. To generate such arguments, we need to reduce the topic of hydraulic fracturing (a complex system) to a single aspect or phenomenon (a complicated system).

Hydraulic fracturing is the currently most efficient method for accessing natural gas reserves.

Considering the economic evidence, this statement is true, although it ignores the complexity of the issue and is, therefore, barely adequate in isolation. Usually, we can easily contradict an apodictic argument by changing the perspective to another detail of the debate:

If hydraulic fracturing is the currently most efficient method, then because we didn't search for a more efficient one.

Again, this argument can barely be contradicted, but it ignores the complex context.

16.4.4 The Rhetorical Argument

Rhetorical arguments are often used to support a point of view rather than arguing for it. An example is:

Fracking opens a bright future to energy production, revolutionizing our energy landscape and creating thousands of new and secure jobs.

The rhetorical devices are adjectives like *bright future*, *revolutionizing*, and *securing* create a positive sense of progress and play with the positive connotation of security, appealing to the audience's emotions and aspirations.

Emotional appeals

Such arguments often stem from abductive reasoning or speculation and can easily be dissected by extracting the emotional connotations and reducing the statement to its factual meaning:

Fracking is a new form of energy production that creates other job opportunities.

Since the counterarguments are risk-related, it is even easier to generate a rhetorical argument against hydraulic fracturing:

No reasonably intelligent chemist would have the idea to pump chemicals, such as strong acids, bases, complex alcohols, or carcinogenic organic toxins, into the ground just to gain access to cheap energy.

The argument appeals to *intelligence* and uses words with negative connotations, like *chemicals*, *acids* and *carcinogens*, to evoke fear and concern about the utility of fracking. Dissecting this argument leads to:

We should not take environmental risks to just gain access to cheap energy.

Interestingly, both dissections lead to apodictic statements, which cannot be countered but ignore the complexity of the issue of hydraulic fracturing.

A typical indicator for rhetorical argumentation is euphemism (Greek: *eúphēmos*, good speech): a way of conveying a potentially unpleasant message in a more indirect, mild, or socially acceptable manner:

Euphemism

Hydraulic fracturing, also known as 'energy liberation,' unlocks the hidden potential of our natural resources, paving the way for a prosperous future."

The use of the euphemism *energy liberation* softens the impact of hydraulic fracturing and presents it as a positive endeavour. The phrase *unlocks the hidden potential* and evokes a sense of untapped possibilities, while a *prosperous future* plays on aspirations for economic growth and success. A counterargument may be identified by looking at a single euphemism:

What is the value of energy liberation if its technologies threaten our lives?

Questioning a single euphemism might be enough to turn the reader's attitude towards the counterargument.

16.5 CRITICAL ASSESSMENT

When we look at the meaning of our own results and determine the type of argumentation in the literature, we can phrase critical questions. We addressed in Chapter 3.1 that the conditions for justification rely on the exclusion of alternatives, falsification, causality, and consistency, which ultimately leads to a coherent system of argumentation, providing a comprehensive explanation for all phenomena and relationships. The following sections present further details we should consider for our own interpretation as well as the literature.

16.5.1 Relevance

Arguments and conclusions are relevant if they contribute to the research objectives. If our goal is to test the effectiveness of vaccines and we state:

The clinical trials showed that mRNA-based COVID-19 vaccines were effective in preventing symptomatic infections and severe disease. Moreover, it was found that wearing masks in public settings significantly reduces the transmission of the virus.

then the second argument addresses virus transmission, which is irrelevant to the vaccination.

Relevance vs significance

At this point, we need to distinguish between relevance and significance. Significance refers to confidence in research findings. For instance, statistical significance expresses the confidence we have in an observed effect or relationship. That a result is (statistically) significant does not mean it is relevant to the research objective.

16.5.2 Exclusion of Alternatives

By excluding alternative explanations, we adopt the remaining explanation as the most possible one. If we make generic claims in isolation, like:

Increased atmospheric carbon dioxide levels are caused by human activities, primarily through the burning of fossil fuels.

the argument fails to exclude alternative sources of increased atmospheric carbon dioxide levels, such as volcanic eruptions, wildfires, and natural decay processes.

When we review results, we consider plausible alternative reasons for findings and discuss how they impact the conclusions:

A typical discussion amongst practitioners is whether the lecture about research should be at the beginning or the end of the studies. Placing it at the beginning

would emphasise its foundational nature. The counterargument is that students forget everything when they approach thesis writing at the end of their studies. However, the latter argument seems not a striking one. If they forgot everything, then because there was no need to use it in forthcoming lectures. However, the goal should be to encourage students to use research throughout their studies and apply it to the continuous and final examinations of other lectures.

The critical assessment in the second paragraph emphasises a flaw in the assumptions of the first two arguments.

16.5.3 Causality

If we assume a cause-effect relationship, we also need to find the temporal precedence of cause and effect and a correlation. However, correlation does not indicate causality:

The strong correlation between the number of books in the student's homes and their academic performance emphasises the value of access to literature for academic success.

Assuming that more books at home causes better academic performance is a logical fallacy. The correlation between the two variables does not necessarily indicate a causal relationship.

16.5.4 Missing Evidence

Sometimes arguments simply miss evidence:

A strong argument of the advocates of de facto standards is the increased competitiveness in global markets.³¹⁰ While this sounds plausible, we did not find any reliable studies that validate the use of standards as a primary reason for a company's success and increased revenue.

The absence of crucial information that is necessary to draw a complete and accurate conclusion invalidates the argument.

16.5.5 Consistency

Inconsistency in statements refers to situations where two or more statements or beliefs contradict each other or cannot coexist logically. Justification in the context of reasoning and argumentation relies on the principle of logical coherence and internal consistency.

*Inconsistent statements
cannot be justified.*

³¹⁰ see, for instance, (Yamada & Kurokawa, 2005)

When a set of statements is inconsistent, it becomes impossible to logically or rationally justify or support the truth of all the statements simultaneously. Justification typically involves providing reasons or evidence to demonstrate the validity or truthfulness of a claim. However, in the case of inconsistent statements, attempting to justify them would result in a logical paradox or an incoherent argument. For instance, we cannot argue:

All birds can fly.
 Penguins cannot fly.
 Therefore, penguins are birds.

Since the minor premises already contradict the conclusion. Consequently, none of the explanations within a system – whether related or not – are allowed to contradict another:

Although no evidence of dark matter has been found yet, the presence of dark matter would explain the observed gravitational effects within galaxy clusters.

In this example, the hypothesis and the observation are inconsistent. The hypothesis states that dark matter would explain the gravitational effects, but the observation contradicts this by showing no evidence of dark matter. Although dark matter is a valid hypothetical concept that accounts for gravitational phenomena that can only be explained with the existence of additional (yet undetected) matter, it remains an unverified hypothesis.³¹¹ In a recent study, Sipols & Pavlovich investigated the rotation of 214 galaxies and found only evidence for visible mass. They ended their article with a nice analogy:

"Perhaps dark matter is like Confucius' black cat—hard to find in a dark room, especially if there is no cat."³¹²

16.5.6 Falsification

If we can find reliable, contradicting evidence, we can safely reject the explanation. If arguments cannot be falsified, they defy deductive or inductive argumentation. For instance:

The multiverse theory suggests the existence of an infinite number of parallel universes, each with its unique set of physical laws and constants.³¹³

The concept of the multiverse theory is an intriguing idea proposed to explain certain phenomena in the universe. However, it (currently) lacks empirical evidence to confirm or refute its existence. As a result, the multiverse

³¹¹ For an alternative discussion, see (Mannheim, 2019)

³¹² (Sipols & Pavlovich, 2020)

³¹³ (Friederich, 2021, p. 3)

theory remains in the realm of a hypothesis, making it currently beyond the scope of falsifiability through standard scientific methods. Nevertheless, it may still be subject to refinement or falsifiability in the future as technology and observational capabilities advance.

16.5.7 Logical Invalidation

Argumentative fallacies occur more often than you would think. Milton Friedman brought up a popular argument against ethics education in business in 1964. Hooker summarised it as follows:

“The ethical duty of business people [sic] is to maximize profit. This means they should study marketing, finance, and operations and should not waste time studying ethics.”³¹⁴

You will find that Friedman presents a seemingly striking argument for his position: he claims that corporate executives are not qualified to do anything other than maximise profit. However, the assertion that corporate executives are only qualified for maximizing profit ends up being a circular reasoning:



Such weak arguments can easily be taken down from a logical point of view; without even engaging in the ethical debate, which is far more controversial.

16.5.8 Questioning Assumptions

Assumptions are the basis for argumentation. We can easily refute arguments if their assumptions are flawed. Suppose we find the following:

Shareholder primacy theory states that shareholders' interests always take priority and other parties' benefits are very much secondary or derivative.

While this argument seems reasonable, it assumes that shareholders are a uniform interest group. In practice, shareholders' interests are pretty diverse.

³¹⁴ (Hooker, 2004, pp. 75-76)

Their interests depend on their financial share, institutional characteristics, and investment in related or competing industries.

We expect that assumptions or premises are clearly stated and relevant to the conclusion, i.e., they need to support the likelihood of the conclusion either positively or negatively.

16.5.9 Challenging Experts

Although experts are experienced in their respective fields, their statements should not be taken as absolute facts without further investigation. Ultimately, the views and opinions of experts are solely their own and may be subject to error or oversight. Simply referring to an authority's claim is not enough. For instance, the fact that:

Paul Feyerabend, who significantly contributed to the philosophy of science, believes that a universal scientific method does not exist.³¹⁵

does not justify his claim. From a logical perspective, the only thing this sentence justifies is the fact that he claimed something.

Although Feyerabend is an expert in the philosophy of science, you may find a flaw in this position, and your task as a scientist is to challenge it:

Paul Feyerabend's concept of epistemological anarchism states that a universal scientific method does not exist and argues that there is no justification for valuing scientific claims over claims by other ideologies like religion, astrology, or complementary medicine.

However, comparing science with cultural traditions such as religion appears not valid. While religion assumes a dogmatic or at least invariant concept, a scientific theory that conflicts with new observations will not survive over time.

Of course, such an argument requires to understand the original statement fully in its context. But criticizing established views is how science evolves.

The matter of clarity However, sometimes we find that an expert's conclusion is so badly argued that its meaning gets lost:

"In the general process of disciplinarianisation, two contrasted types can be schematically distinguished depending on the fact that the constitution of established professional fields follows or precedes the process of disciplinarianisation. In the first case, a process of secondary professionalisation, in the second place one of secondary disciplinarianisation takes place. Like medicine, sciences of education belong to the second category which groups disciplines or disciplinary fields

³¹⁵ (Feyerabend, 1993, p. 214)

where strongly organised professional fields pre-existed whose professional knowledge was one basis on which the disciplinary field was established."³¹⁶

What the authors term *disciplinarisation* (an artificial word not found in common dictionaries) is the question of how a research field (or discipline) evolves. In their conception, a discipline emerges when a research practice specialises, differentiates itself from other disciplines, and becomes established. The message behind this paragraph can be summarised as follows:

Scientific disciplines are either created independently or evolve from scientific practice. Examples of the latter are medical and educational practices that led to the emergence of the disciplines of medicine and education.

It is astonishing that we find such unnecessarily convoluted sentences excessively often in contributions from the educational sciences, which should actually be able to do better.

16.5.10 Challenging Authorities

Suppose we find the following (fictional) statement:

The left-bundled electrode chronoquibulum is more sensitive to radiation.

Since nobody knows what a *left-bundled electrode chronoquibulum* is (presupposed it has not been defined before), we cannot argue for or against it. An argumentation always requires definitions.

However, even organisations that are assumed to be authorities for definitions are not without fault. As an example, the quality management standard ISO 9000 defines *quality* as the

"degree to which a set of inherent characteristics of an object fulfils requirements"³¹⁷

and subsequently extends it with definitions for *characteristic*: "inherent distinguishing feature"; *object*: "anything perceivable or conceivable"; and *requirement*: "need or expectation that is stated, generally implied or obligatory". If we extend the definition accordingly, we obtain:

Quality is the degree to which a set of inherent distinguishing features of anything perceivable or conceivable fulfils a need or expectation that is stated, generally implied, or obligatory.

³¹⁶ (Hofstetter & Schneuwly, 1999, p. 18)

³¹⁷ (International Organization for Standardization, 2015, chap. 3)

While at first sight, ISO's definitions seem carefully elaborated, a closer look reveals surprising deficits.

- A *degree* implies measurability. Consequently, anything not measurable would not account for a quality criterion.
- The *inherent distinguishing feature* excludes extrinsic features such as colour, which would account for a quality criterion.
- Equating *anything perceptible or conceivable* with a term like an object seems inappropriate. We could also ask: Is there anything out there that is neither perceptible nor conceivable? Can quality then also be applied to any other conceivable concept, such as poverty? Could we talk about 'high-quality poverty'?
- Finally, are needs or expectations always stated or implied? There was neither a need nor expectations when the first energy drink was devised for the market. It was implied by the industry, not by the consumer.

If ISO simply defined:

Quality describes a system's fitness for use.

they would have circumvented these pitfalls: *fitness* does neither imply measurability, nor is it restricted to inherent characteristics; the *system* would extend the term object to processes, but not to arbitrary concepts; and finally, *use* would determine the needs or expectations.

16.5.11 Ethical Considerations

Adhering to ethical standards in sciences is not just a moral imperative but also a key element of conducting reliable scientific research. This includes considering the impact of conclusions on nature and society.

French cognitive psychologist Nicolas Guéguen found a correlation between tattoos/piercings and alcohol consumption among young people in France.³¹⁸ In an article published by the *American Association for the Advancement of Science* (AAAS), he was quoted as follows:

"We found that pierced and/or tattooed individuals had consumed more alcohol in bars on a Saturday night than patrons in the same bars who were non pierced[sic] and non tattooed[sic],' said Guéguen. 'This is the first time that we found a relation among tattoos, piercings, and alcohol consumption in France.' He suggested that educators, parents and physicians consider tattoos and

³¹⁸ compare (Guéguen, 2012)

piercings as potential 'markers' of drinking, using them to begin a conversation about alcohol consumption as well as other risky behaviors."³¹⁹

Whether Guéguen really suggested educators, parents, and medical professionals consider tattoos and piercings as indicators of potential alcohol consumption or whether it was an interpretation of the unnamed author of the AAAS article is not clear.

Guéguen results are based on a serious study, but such a suggestion would barely be ethically justified. As a social scientist, he knows that the relationship he found indicates a correlation merely. But the extent to which there is a potential cause-effect relationship is not confirmed. If he really made this suggestion, Guéguen would walk a fine line, given the discriminatory nature of such advice.

In the same sense, we refrain from using dogmata, doxas, or ideological doctrines, all of which refer to fixed beliefs or principles that are taken by their advocates as intractable (see also Chapter 3.7.6). But science is about new insight rather than fixed beliefs. By avoiding fixed beliefs or sources of authority, the discussion remains open to alternative perspectives and new evidence that may challenge established beliefs or assumptions.

Dogmata, doxas, and doctrines constrain free thought.

16.5.12 Coherence

The ideal system of argumentation provides a comprehensive explanation for the phenomena and relationships within the investigated system of assumptions. Although this cannot always be achieved, we at least attempt it.

In the same way, we scrutinise existing sources for their comprehensiveness and adherence to their research objectives and assumptions before we consider them relevant to our study. The main indicator for comprehensiveness is whether the research objectives – presupposed they are clearly explicated – are comprehensively addressed. For our own system of explanations, we ensure this by explicating the achievement of our research objectives in a synopsis.

16.6 WRITING A SYNOPSIS

We recommend ending the discussion chapter with a subchapter containing a synopsis of the research objectives. Such a synopsis includes the concrete answers to the research questions, the summarised assessment of hypotheses, and the arguments for theses or the synthesis achieved. This subchapter

Synopsis of the research questions

³¹⁹ (American Association for the Advancement of Science, 2012)

ensures we address all research objectives comprehensively and helps the reader to obtain answers quickly.

16.6.1 Answers to Research Questions

In the case of research questions, we provide short concrete answers. It is not necessary to repeat the entire research question; a short heading suffices to remind the reader. Figure 16.11 shows an example of a synopsis relating to our original storyboard.

Achievement of the generic object

Research questions and short answers

4.7 Synopsis

The study determined several exceptional situations that pose a conflict potential and revealed distinct behavioural patterns contributing to conflict escalation and impacting the conflict resolution strategy. The initial research questions can be answered as follows.

Perception of exceptional scenarios

Five scenarios have been found to be perceived as critical in terms of severity, risk, and uncertainty: (a) sudden resource deprivation; (b) changes in the hierarchy; (c) collusiveness in decision-making; (d) inability to delegation; and (e) overestimation of experience. Other scenarios could not be conclusively assigned to be perceived as critical throughout the teams.

Contribution to the probability of conflict occurrence

It was found that perceived uncertainty is the determinant in the occurrence of conflicts, particularly in situations where resources are limited.

Reproducible behavioural patterns

Amongst the recurring behavioural patterns, three affective patterns (collusiveness, seclusion, and accusation) and two conative patterns (plan dogmatism and competence-grabbing) were found.

Parameters affecting the consensus

It could be confirmed that the correlation between the perceived severity of a situation and the found reproducible patterns depends on the difficulty and the discriminative potential of proposed solutions and – to a minor extent – on time and duration.

Figure 16.11 Excerpt of a synopsis chapter answering research questions

16.6.2 Answers to Explanatory Hypotheses

If you state explanatory hypotheses, you either refer to evidence for its confirmation or falsification (see Figure 16.12).

The results of the hypothesis verification are summarised in the following.

H1: Cultural diversity in project teams contributes to the chance of conflict.

The results showed that all project teams perceived cultural diversity as contributing to the chance of conflict. Cultural diversity is therefore assumed to be one of the determinants of conflict.

H2: Affective cultures show a higher tendency to resolve conflicts immediately.

Concealed observations revealed only one out of ten cases in which affective cultures approached a conflict resolution not or too late. In comparable cases of neutral cultures, four out of ten achieved an immediate conflict resolution. The hypothesis is therefore rejected.

Figure 16.12 Excerpt of answers to explanatory hypotheses

16.6.3 Answers to Statistical Hypotheses

In the case of statistical hypotheses, you either present evidence for accepting or rejecting the null hypothesis. In both cases, you present the hypothesis together with the test statistic, including the statistical significance (see Figure 16.13).

The results of the statistical hypothesis tests are shown in the following.

H1: Collusiveness in decision-making increases the probability of conflict occurrence.

Collusiveness in decision-making increases the probability of conflict occurrence statistically, $F(1, 225) = 42.6$, $p < .01$, $R^2 = 0.76$. A statistically significant difference between males and females was not found, $t(29) = -1.85$, $p = .174$.

Figure 16.13 An answer to a statistical hypothesis

Please remember to use an appropriate number of decimals (don't use the complete precision shown with statistics software).³²⁰

³²⁰ see also chapter 3.7.8. For further advice on how to present statistical data, look at the guide from the UN Economic Commission for Europe (United Nations Economic Commission for Europe, 2009).

16.6.4 Argumentation for Theses

The argumentation for theses is typically part of the conclusion section if there are no other objectives in the form of research questions or hypotheses. However, if thesis statements are combined with research questions, you should consider providing a short argumentation in a synopsis to prevent the conclusion from becoming too extensive.

If a synthesis was achieved, you state it supported by its arguments. Otherwise, you present the main arguments accounting for the thesis (or antithesis) you retained, as shown in Figure 16.14.

4.7 Synopsis

The study showed that the limitations of existing cultural models in the context of distributed teams' conflict assessment are multifaceted. For the initial thesis:

Cultural differences in distributed teams cannot be overcome by a formal assessment of cultural diversity using existing cultural models.

the following main argument was found:

Firstly, these models tend to focus on generalizing cultural traits, overlooking the individuality and diversity of team members. This oversimplification neglects the uniqueness of each team member's cultural identity and fails to recognise the impact of personal experiences on intercultural interactions.

Secondly, the fluidity of virtual interactions and the reliance on digital communication platforms introduce novel complexities to cultural dynamics. Existing cultural models often struggle to account for the nuances inherent in digital communication, further limiting their capacity to identify and address cultural conflicts.

Moreover, the constantly evolving nature of global interconnectedness and cross-cultural influences challenges the static nature of many existing cultural models. As cultures adapt and intermingle, the boundaries between them become more porous, leading to a blurring of cultural lines that traditional models may not adequately capture.

Therefore, the suitability of existing cultural models in overcoming cultural differences within distributed teams is not confirmed. Instead, a more nuanced and adaptive approach is required to foster harmonious collaboration and unleash the full potential of intercultural diversity in distributed team environments.

Figure 16.14 Excerpt of an argumentation for a thesis

16.6.5 Answers to Development Objectives

When describing the outcome of system development, you address the extent to which the system requirements have been fulfilled. In case of partial fulfilment, you explain which requirements still need to be addressed. This includes describing any work that needs to be done to fully meet the requirements and potential limitations or trade-offs made in the development process. An example to describe partial fulfilment is:

While the system has successfully met the functional requirements specified requirements in Chapter 3, operational requirements were only partially met. Further work is required in the following areas:

Filtration. Laboratory tests of filtered solutions show a considerable concentration of polychlorinated biphenyls exceeding the specified limit of 500 ppt. Potential countermeasures include identifying the level of filter redundancy and assessing whether test results verify the removal efficiency of the membrane filtration adequately.

Secondary Disinfection. Significant bacterial release from pipe biofilms in sections C1 and D3 with a total cell count $> 1.5 \times 10^3$ cells mL^{-1} gave rise to an ineffective UV system used for secondary disinfection. The log inactivation coefficient of the UV system should be tested under comparable laboratory conditions.

16.7 RESULTS AND DISCUSSION CHECKLIST

The following checklist allows you to ensure your argument and inferences.

Table 16.2 Checklist for Results and Discussion

<i>Arguments and inferences are</i>	<i>Passed</i>
relevant to the research objective	<input type="checkbox"/>
falsifiable	<input type="checkbox"/>
supported by evidence or logical reasoning	<input type="checkbox"/>
supporting or contradicting other evidence	<input type="checkbox"/>
without internal contradictions	<input type="checkbox"/>
lacking plausible alternative explanations	<input type="checkbox"/>
not missing evidence that might cause a different conclusion	<input type="checkbox"/>
not unnecessarily complicated	<input type="checkbox"/>
considering ethical implications	<input type="checkbox"/>

16.8 THE WORST PRACTICE

In the magical realm of academic writing, the discussion section ends in a controversy between a nerdy scientist and an opinionated philosopher. While the first wields the statistical wand to generate graphs that are more tangled than Rapunzel's hair after a wild techno party, the philosopher wields the mighty pen of interpretation to arrive at deep thoughts on the reasons for reasoning. How to present this is explained in the following.

The Grand Debate

Presupposed you achieved some results at all, there are different options of textual and visual styles to present them (the visual examples are shown on the following pages):

- **The Holistic Style:** using flowing text that is rich in content while avoiding visually distracting elements.
- **The Excursive Style:** like the holistic style, but with emphasis on valuable secondary thoughts.
- **The Spotted Style:** taking advantage of a detailed subchapter structure.
- **The Incidental Style:** characterised by the unexpected appearance of visual artefacts.
- **The Self-explanatory Style:** taking seriously the valuable advice "A picture says more than a thousand words"
- **The Conceptual Style:** taking advantage of high-level abstraction and clever use of whitespace.

In contrast to the research design section, where you needed to explain the research terminology, the results section does not require any further assessment beyond the presented raw data. Following the recommended approach, we first announce a figure:

One of the figures below shows the rate of acceptance of a doctor's advice.

You then present the figure with a meaningful caption, ending with a full stop, if not a full sentence:

Figure 11. The acceptance.

Then, explain the meaning of what is seen:

The chart shows how often the doctor's advice has been accepted.

followed by the interpretation in your context:

Since the study is about the behaviour of chicken, the result is irrelevant.

The discussion may become more extensive:

The question whether doctor's advice is somehow related to the behaviour of chicken is still under discussion. It became prevalent that there exists a serious gap in the literature.

The interpretation of verbal statements must rely on multiple pieces of evidence:

The patient repeatedly made negative comments about the doctor's lack of professionalism and – in his opinion – unethical advice not to smoke and explicitly confirmed his displeasure later in multiple personal conversations during his cigarette break.

When following the idiographic approach, you should keep in mind that you need to interpret not just verbal expressions but also semiotic clues to come to credible conclusions:

However, since his stomach grumbled during the conversation, it can be concluded that the respondent suffers from hypoglycaemia.

Still, you need to exclude alternative explanations:

Although the bad hospital food may account for an alternative explanation, further gastronomical trials with the respondents in the nearby chicken restaurant did not confirm this.

and relate the results to the literature:

There was a significant discrepancy between the behaviour of chicken in their natural surroundings (as described in the literature) and the corresponding behaviour on a restaurant dish, where they seemed surprisingly uninvolved. At this point, it is reasonable to assume a close relationship between the doctor's advice and the chicken's smoky look.

With presenting statistical data, you can be even more convincing by using the p-value:

The linear regression shows that the number of chickens running around increases their occurrence on restaurant dishes ($n = 12$, $r^2 = 0.12$, $p < 0.5$).

In the end, you should be more flexible with your conclusions and avoid clear statements; otherwise, you run the risk that you will be asked for it during your thesis defence. The last sentence in your discussion could be:

In light of the inherent complexities and multifaceted intricacies within the chicken data, it becomes unequivocally evident that the attainment of conclusive evaluations from doctor's advice remains a perpetual enigma, thereby rendering unequivocal deductions an unachievable undertaking.

The **holistic text style** emphasises that individual insights can only be seen in the entire context.

Risk is everything, it could be said, against which preventive or damage-compensating measures can be taken, and is thus not an "objective" feature of reality, but equally not just a social construct or a mere subjective assessment, but a "rationality scheme", a way of ordering certain elements of reality, making them calculable and acting on them in a targeted manner, or in other words: Risks are tied to the existence and use of risk technologies, and different risk technologies correspond to different types of risks, and two basic strategies of dealing with risks or contingency control can be distinguished: On the one hand, contingency can be managed, i.e. the range of the possible can be limited by preventive regulations, whereby the ideal here is risk avoidance. On the other hand, contingency can be "managed", i.e. the horizon of possibilities can be used and expanded, but its threatening aspects can be absorbed by suitable safety precautions, and the ideal here is risk management, because one can try to prevent the occurrence of possible future undesirable events, or one can take precautions to compensate for the damage in the event of their occurrence - for example, by taking out insurance, but the two strategies are not mutually exclusive, rather they are complementary and occur in multiple combinations, with the limitations of one acting as justification for the other: because even the most comprehensive prevention cannot guarantee absolute security, residual risks are cushioned by insurance, because insurance companies capitalise risks, they are concerned to limit the number and extent of claims through preventive measures, and so insurance companies make their benefits dependent on the fulfilment of certain preventive obligations - without an annual visit to the dentist, for example, only a smaller proportion of the costs of dentures is covered, But conversely, regular preventive check-ups will hardly induce anyone to forego taking out health or accident insurance, and so the rise of the insurance industry has historically been accompanied by critical voices accusing insurance companies of undermining the principle of individual provision for one's existence and tempting people to be careless and irresponsible. Regular payment of premiums replaced the virtue of preventive prudence, whereas the advocates of insurance countered that the individual could not protect himself against many of the risks of industrial society - a prime example being accidents at work - no matter how cautiously he behaved, and therefore the risks had to be socialised and the consequences of damage had to be absorbed collectively, so that prevention shared the probabilistic calculation with insurance, while the insurance industry compensated for damage that had already occurred by paying out money and raising the funds for this purpose through the premiums paid by its members, prevention is to prevent in advance that the damage and thus also the insured event will occur.

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The **excursive text style** illustrates the relevance of valuable secondary ideas in footnotes and is preferred in philosophy and history.

The measuring procedures supported by the ideal of the phenomenological approaches aiming precisely at the non-antagonistic concept.²⁵

²⁵David Matza (1973, 22), on the other hand, states an opposition of prevention and understanding perspectives, at least as far as the study of deviant behaviour is concerned: "A fundamental difficulty of the preventive perspective is that it systematically interferes with the ability to empathise with and comprehend the objects of study. Only with the perspective of understanding can the structure of social patterns of behaviour and the multiple nuances of human responses to these patterns be grasped and analysed. Without understanding and empathy, we may be able to gather the overt facts concerning a particular phenomenon and criticise the measures directed at it, but we will not succeed in considering in sufficient depth its meaning for the subjects involved and its position in the overall social context. [...] The prevention point of view prevents us from getting a proper view of the deviant phenomenon in the first place, since it is determined and motivated by the goal of eradicating it". Admittedly, the opposition is rather to be understood as a historical transitory stage: Matza's accusation refers to an early phase of US deviance research, when sociology, social work and social reform were closely linked and sociological research, according to its self-conception, wanted to contribute directly to the healing or prevention of social pathologies. In this way, it not only based its studies on the dominant social norms as a yardstick and obstructed the possibility of describing deviant behaviour from the perspective of the actors, but the methodological bias also limited the effectiveness of the prevention concepts based on it. Later studies, such as those of the Chicago School, which approached deviance phenomena from an ethnographic perspective, no longer led directly to social reform programmes, but it was precisely this integration of the "understanding perspective" and the associated loosening of the relationship between research and application that enabled the refinement and differentiation of preventive measures. Thus, epidemiological surveys on the one hand, individual diagnostics and case management on the other, form the two indispensable pillars of preventive health care. The duality of preventive knowledge production corresponds to the simultaneity of decentration and recentering of the subject in preventive practice: on the one hand, prevention, as the French sociologist Robert Castel writes, "is associated with the dissolution of the concept of the subject or the concrete individual, which is replaced by a complex of factors, the risk factors" (Castel 1983, 51). On the other hand, preventive strategies precisely make the side of the subject strong and inaugurate it as a self-responsible and competent agent of its own life. Those who want to prevent must not only know what to do, but must also be able to enforce it. Prevention implies the ability to control behaviour and change conditions, whether this ability is based on the power of sanctions or persuasion, on technical devices or social arrangements. Preventive measures may authoritatively curtail individual freedom or - as self-control - confirm the autonomy of the individual.

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The **spotted text style** – popular among natural scientists – pays special attention to a clear structure of individual thoughts using appropriately numbered subchapters.

2.2.2.3.4 Function

The next step is to assign one of the available functions of the business unit. When the function is selected, the rights defined there are taken over.

2.2.2.3.5 Location

The employee's location is entered automatically by selecting the office or workstation. The building, floor, room number, etc. are taken from the location database.

2.2.2.3.6 Access Rights

Basic read and write rights (create, delete, change, download, print), process rights as well as module access rights are predefined by the function.

2.2.2.3.7 Login

In addition to assigning a user to a function, a new user can also be derived from an existing user. In this case, the user takes over all functions and rights of its ancestor. This facilitates the creation of several similar users and ensures the traceability of user rights.

2.2.2.3.8 Authorisation

The signing authorisation is normally derived from the user's function. It is the only feature that can be changed independently of the function in the user administration.

2.2.2.3.9 Authentication

The authentication ensures the access to restricted areas and is realised independently of the function in the user administration.

2.2.2.3.10 Hierarchy

At this point, only a restriction of these rights is possible, but no extension. This increases the flexibility of the signature processes independent of the specifications of the personnel management.

2.2.2.3.11 Qualification

At this point, only a restriction of these rights is possible, but no extension. This increases the flexibility of the signature processes independent of the specifications of the personnel management.

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The **incidental visual style** supports the interpretation rather accidentally by a self-explanatory illustration occurring suddenly before the next chapter.

and raising the funds for this purpose through the premiums paid by its members, prevention is to prevent in advance that the damage and thus also the insured event will occur. Risk is everything, it could be said, against which preventive or damage-compensating measures can be taken, and is thus not an "objective" feature of reality, but equally not just a social construct or a mere subjective assessment, but a "narrative scheme", a way of ordering certain elements of reality, making them calculable and acting on them in a targeted manner, or in other words: Risks are tied to the existence and different risk technologies correspond to different types of risks, and two basic strategies of dealing with risks or contingency control can be distinguished: On the one hand, contingency can be managed, i.e. the range of the possible can be limited by preventive regulations, whereby the ideal here is risk avoidance. On the other hand, contingency can be "managed", i.e. the horizon of possibilities can be used and expanded, but its threatening aspects can be absorbed by suitable safety precautions, and the ideal here is risk management, because one can try to prevent the occurrence of possible future undesirable events, or one can take precautions to compensate for the damage in the event of their occurrence.

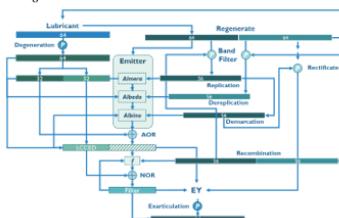


Figure 12.32-1 Emergent dereplication procedure

12.33 Other Effects

Regular payment of premiums replaced the virtue of preventive prudence, whereas the advocates of insurance countered that the individual could not protect himself against many of the risks of industrial society - a prime example being accidents at work - no matter how cautiously he behaved.

The **self-explanatory visual style** illustrates that the results are obvious and do not deserve further discussion.

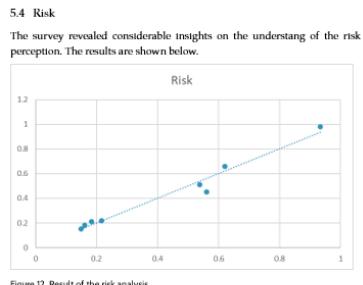


Table 9. Details of risk analysis

	B	SE	t	p
(intercept)	18.3	1.13	0.001	.001
Perceived risk	-0.021	0.007	-0.203	.004
Risk perception	0.081	0.056	0.915	.009
Perceived risk perception	-0.005	0.008	-0.521	.001

5.4 Risk Management

The interviews supported the above results. Interviewee 2 stated:

"Risk management is important, because one can try to prevent the occurrence of possible future undesirable events, or one can take precautions to compensate for the damage in the event of their occurrence."

5.5 Conclusion

Because of the results, it can be clearly shown that risk management is important.

The **conceptual visual style** is utilised for abstract results in cognitive sciences and takes advantage of whitespace and larger font sizes.

2.1 Dimension and Impact

The dimension of the effect can be categorised in terms of impact. The effect-relatedness is a dimensionless quantity.



Figure 5: Comparison of dimension and effect

2.2 Effect and Dimension

In contrast to the dimension of the effect, the dimensionless impact of effect represents a dimensioned area of effect, whose dimension is *per definitionem* ineffective.

17 THE CONCLUSION

Bringing all the loose ends together should create a fabric rather than a collection of threads.

The conclusion in thesis writing is often misinterpreted as a summary. But a conclusion is a theme that concentrates on the takeaway messages and the big picture. It is a synthesis on a higher level of abstraction. It is the point where you emphasise what was learned. And it provides a bridge to the introduction chapter.

Probably the biggest mistake you can make is underestimating the time you need to write a good conclusion. A conclusion is compiled by extracting the most significant information and elevating it to a higher level of abstraction. Intermediate thoughts and ideas turning up while interpreting or discussing results can make important contributions to this chapter. Therefore, we recommend writing down notes in this section during the evaluation.

Don't write this chapter under pressure.

17.1 OUTLINE OF THE CHAPTER

The actual *conclusion* follows the chapter heading. In addition to the conclusion, a *critical reflection* must take place, addressing the limitations found in the own study. Such reflection leads to *recommendations for future research*. If appropriate, you may add an *outlook*. We recommend dedicating separate sub-chapters to these aspects.

17.2 THE CONCLUSION

The introductory sentences of a conclusion refer to (do not repeat) the generic research objective stated at the beginning. The following text includes affirmative statements: what was found, verified, or what was working. We may also address selected limitations found during our investigation and the solutions we proposed in the study.

Provide a sense of closure.

The final statement should close the topic. You write your thesis to argue for something, and you must finally take position. Examples of conclusive statements are shown in Figure 17.1.

<i>Objective and high-level outcome</i>	7. Conclusion The investigation of exceptional situations in distributed teams revealed recurring behavioural patterns that function as determinants of the emergence, evolution, and escalation of conflicts.
<i>Affirmative statements</i>	It is shown that both team diversity and rigid team hierarchy have adverse effects on conflict resolution, which can be overcome through ...
<i>Found limitation and ...</i>	The proposed model provides adequate descriptors for a wide range of conflict scenarios ...
<i>... proposed solution</i>	It was found that the model validity can suffer from inconsistencies in conceptualization and operationalization.
<i>Closing remark</i>	Adhering to the presented operational conditions increases the reproducibility and minimises the bias of the model's predictions ... The monitoring of distributed teams and deriving conflict resolution strategies are alleged to be continuous processes. The study revealed that an ongoing reflective investigation is required to anticipate changes in the project and to account for an increasing transition to agile methodologies.

Figure 17.1 Excerpt of a conclusion on the topic of team conflicts.

Ideally, the conclusion does not exceed much more than a page per hundred pages of a thesis. More pages leave the impression that you are unable to reach the required level of abstraction.³²¹

17.3 CRITICAL REFLECTION

The conclusion must include a critical reflection of your study. After looking at your results, you will find weaknesses in your research design, your

³²¹ Remember that an abstraction is a simplification that focuses on the major concerns and neglects the minor ones.

analysis, and your interpretation. This includes any restrictions experienced during the research, limited applicability of methods or instruments, changes in the research environment or the research objectives, encountered risks, or ethical limitations.³²² Also, acknowledge the limitations, such as small sample size, potential biases, or constraints in data collection, which may impact the reliability and generalizability of the findings. Potential sources of bias or error and how they may have influenced the results.

Don't be afraid of critically reviewing your research approach, as this self-reflectiveness is taken for granted by scientists. While you will refrain from derogative wording or a negative attitude, you still need to be critical.

The findings of a thesis don't have to be necessarily positive. Although positive results in a thesis are often desired, not reporting negative results contributes to publication bias, a severe problem in sciences. Negative results can prevent other researchers from pursuing similar dead-end paths, save time and resources, and ultimately support the positive results.

Results don't have to be positive.

7.1 Critical Reflection

The results revealed that nomothetic investigations may not be adequate to assess the relationship between spatial distribution and behavioural patterns of team members.

Interviews and observations were conducted according to phenomenological assumptions and interpreted under subjectivist epistemology. Since the latter does not allow for generalization, the corresponding results were solely used to obtain explanatory hypotheses.

Due to the limited accessibility of experts, only two semi-structured expert interviews were conducted to foster conclusions drawn. The responses cannot necessarily cover all aspects of validation.

While the proposed model takes multiple reflective measures into account to support the identification of the formative model, the latter is limited to the specific case. Other cases require reconsidering the adaption of reflective measures.

Several results contradicted findings from previous studies: notably concerning group distribution and group cohesion. Besides methodical differences, environmental conditions, such as workplace environment and the effectiveness of the virtual communication equipment, may affect these phenomena.

Figure 17.2 Excerpt of a critical reflection.

³²² Do not confuse the critical reflection with the delimitations, you addressed initially. The 'Scope and Delimitations' chapter (Introduction) addresses intentional delimitations to the scope of your study, whereas the 'Methodological Constraints' chapter (Research Design) addresses known limitations of the chosen methodology.

17.4 RECOMMENDATIONS FOR FUTURE RESEARCH

The critical reflection will most probably raise further questions, which are addressed in the recommendations for future research. The goal of this sub-chapter is to indicate continuing knowledge gaps and provide starting points for studies to the scientific community. The recommendations should give your fellow researchers concrete hints, preferably addressing individual questions and proposing a study approach.

7.2 Recommendations for Future Research

Considering the study's findings and limitations, several recommendations for future research can be proposed.

- The development of a structural equation should be considered to provide insights into the reliability of conflict predictions.
- The investigation of the long-term effects of the observed phenomena over an extended period could improve the sustainability of conflict resolution strategies.
- Investigating the influence of demographic factors, such as age, experience, or cultural background, on the identified patterns could provide deeper insights into the underlying mechanisms at play.
- Incorporating other empirical research methods, such as interviews or focus groups, would allow for a more nuanced exploration of participants' subjective experiences and perspectives.
- Lastly, conducting cross-cultural studies to compare the phenomenon across diverse cultural contexts could shed light on potential cultural influences and enhance the generalizability of the findings.

Figure 17.3 Example of recommendations for future research

17.5 OUTLOOK

An outlook provides recommendations for new application areas or may argue for the reuse in a different discipline or recommendations for interdisciplinary collaborations.

An outlook is only recommended if changes in the context of the study area are anticipated. For instance, in the field of engineering, it is used to address emerging technologies and in social sciences, it may cover evolving perspectives and paradigm shifts. However, an outlook should be meaningful and necessary. If your research is highly specific or focused on a narrow context that does not have broader implications or applicability, an outlook may not

be appropriate. The same applies when the research topic lacks practical feasibility for further exploration or goes considerably beyond the scope of the current study.

7.3 Outlook

The findings of this and comparable studies suggest that the development of a systematic approach has the chance to become a leading instrument in conflict resolution in distributed development teams. Taking advantage of artificial intelligence, a prediction of conflicts and their impacts may be fully automated.

Similar approaches can be easily adopted in different scenarios, such as in conflict situations in classrooms for educators, in a cybercriminal context for incident response managers, in legal disputes for lawyers, or even in the political sciences to support diplomatic efforts.

Figure 17.4 Excerpt from an outlook

17.6 CONCLUSION CHECKLIST

With the conclusion, you end your writing, and you are ready to perform a final revision. The following checklist ensures a meaningful outlook.

Table 17.1 Checklist for the Conclusion

Category	Criterion	Passed
Conclusion	Generic research objective referenced	<input type="checkbox"/>
	Key messages selected	<input type="checkbox"/>
	Found limitations and their solutions addressed	<input type="checkbox"/>
	Closure statement	<input type="checkbox"/>
Critical reflection	Appropriateness of the chosen methodology.	<input type="checkbox"/>
	Credibility of the primary sources.	<input type="checkbox"/>
	Issues in data collection and sampling.	<input type="checkbox"/>
	Comparability of the findings.	<input type="checkbox"/>
Recommendations	Generalizability of the findings (if intended).	<input type="checkbox"/>
	Concrete research hints	<input type="checkbox"/>
	Potential methods for research	<input type="checkbox"/>
Outlook	Future development	<input type="checkbox"/>
	Reuse of insights in different application scenarios	<input type="checkbox"/>
	Interdisciplinary aspects	<input type="checkbox"/>

17.7 THE WORST PRACTICE

"The conclusion is the climax of the thesis narrative, where the hero's journey comes to an end in the hope that the wisdom revealed will be graciously accepted by the academic overlords." At least that is what ChatGPT can contribute to the topic. Nevertheless, since it does not seem appropriate to end the story with "And they lived happily ever after", we must find a more sophisticated solution.

The End is Nigh: Concluding an Epic Tale

Unlike what you may have heard, the conclusion is not a particularly crucial chapter of your thesis. Since you have already described all the results and your reader does not remember the original research questions anymore, there is not much more to say.

You have two options: you can blandly re-summarise your results by copying and pasting the paragraphs you used previously. The other option is to make it more interesting by mentioning aspects that were never addressed before, providing the advantage of re-opening the discussion and ending your conclusion with more questions than answers.

Provide as many details as possible to account for the higher abstraction level. Ideally, you use lots of citations to back up your own results, ultimately showing that your research was performed so comprehensively that you inevitably couldn't find anything beyond what was already well known.

You ideally use confident claims, like the findings *clearly show* and are *highly significant*, without providing actual evidence. To eradicate the last doubts on your self-critical attitude, you may end with a convincing: '*This study verified nothing less than the eminent truths.*'

When addressing limitations, do not forget to mention that you did not receive enough responses to your questionnaire, that interview partners cancelled at short notice, or that the companies you studied incomprehensibly refused to share their internal data with you. If none of this applies, mention that time was too short and the topic too complicated; for the latter, you can clearly blame your supervisor.

The recommendations for future research should clearly express your confidence that '*other researchers should investigate this further*'.

Like with any good TV series, you should end your outlook with a cliffhanger:

It seems that the new drug has some effect and may show a non-negligible potential for the treatment of cancer and other crustaceans. However, medical treatments have both positive and negative aspects, and side effects are not easy to predict. The future will show whether this approach is successful.

PART V

THE PRESENTER'S GUIDE



18 PRESENTATIONS

Death by PowerPoint is akin to a relentless tidal wave of text and complex graphs, submerging the audience's attention and curiosity until the vitality of the message is drowned in a sea of excess.

This chapter is about guiding you to deliver memorable presentations in general. However, because this book deals with *The Art Of Thesis Writing*, we focus on a thesis defence presentation whenever possible.

The first subchapter briefly explores principles for successful presentations. Topics covered include understanding your audience, structuring your message, engaging listeners, refining delivery skills, utilizing visual aids, managing time, handling questions, exhibiting enthusiasm, and embracing feedback for continual improvement.

As PowerPoint is probably the most often used visualisation tool for presenters, the next subchapter deals with the best practices for creating PowerPoint presentations. Finally, we guide you on how to approach a presentation.

18.1 PRINCIPLES OF PRESENTATIONS

Embracing the potential for failure is part of becoming a successful presenter. Every stumble is a steppingstone towards improvement. Remember, even the most accomplished speakers have faced their share of failures. It's not about avoiding mistakes but learning and growing from them. Your courage to stand before an audience and share your ideas makes you a winner. Keep practising, keep refining, and keep pushing forward. The following principles will help you to succeed.

Table 18.1 Principles of effective presentations

<i>Principle</i>	<i>Description</i>
Understand Your Audience	Tailor your presentation to the audience's knowledge level, interests, and expectations.
Clear Structure	Organise your content logically, typically with an introduction, body, and conclusion.
Keep it Concise	Be succinct and avoid unnecessary detail. Stick to key points and messages.
Engage the Audience	Use questions, activities, or discussions to involve the audience.
Practice Delivery	Presentation skills, including vocal variation and body language, can enhance your message.
Use Visual Aids Effectively	Not only slides but also videos, props, or demonstrations can aid understanding.
Manage Time	Ensure you stay within your allotted time. Rushing affects the clarity and audience reception.
Be Prepared to Handle Questions	Know your material well enough to address queries or challenges.
Show Enthusiasm	If you're excited and passionate, engaging your audience is easier.
Evaluate and Improve	Seek feedback and strive to improve your presentations based on the input.

18.2 BEST PRACTICES

Learning from the experts

When you give a presentation, you market yourself and your ideas to your audience.³²³ How you present yourself, your message and your visuals can impact how your audience perceives you and your message. Learning from marketing means using effective visual aids and delivery techniques to engage and hold your audience's attention.

Effective presentations are for conveying ideas and engaging with an audience, but unfortunately, many presenters make common mistakes that can detract from their message. Learning from the mistakes of previous presenters can help you avoid making the same errors in your presentations.

³²³ A researcher should be good at self-marketing because effectively communicating their results and ideas can lead to increased visibility, collaboration opportunities, and funding for their work. Additionally, being skilled in self-promotion helps researchers create a positive impact by inspiring others and facilitating the translation of their findings into practical applications.

In his famous TEDx talk "How to avoid death by PowerPoint," David J.P. Phillips³²⁴ highlights some common mistakes presenters make when using PowerPoint and offers tips on how to avoid them. By implementing these strategies, presenters can improve the effectiveness and impact of their presentations and create a more engaging experience for their audience.

There are six easy-to-implement principles which improve presentations dramatically:

1. How many messages per slide?
2. How do motion, contrast, and colour help?
3. How does size help?
4. How do you make sure that the audience is listening?
5. What is the best background colour?
6. How many elements should be on a slide?

The Best Practice Guideline (Figure 18.1) shows a summary. Details are explained in the following paragraphs.

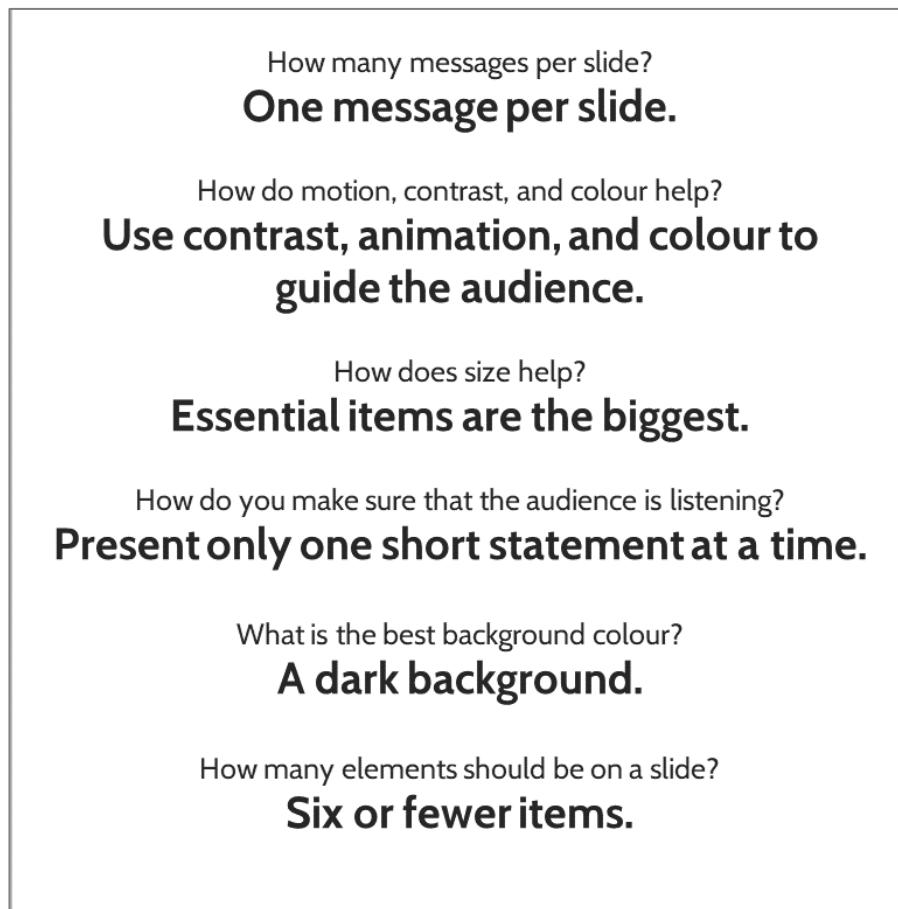


Figure 18.1 Basic Best Practices Guideline

³²⁴ (Phillips, 2014) More than 4.5 Mio. views on youtube.com until June 2023.

18.2.1 Slide Messages

What is a message?

Having only one message per slide in a presentation is beneficial because it allows the presenter to focus the audience's attention on a single idea, concept, or point. Doing so makes it less likely that the audience will become overwhelmed or confused by too much information presented at once, enabling them to retain and comprehend the direct message more efficiently.

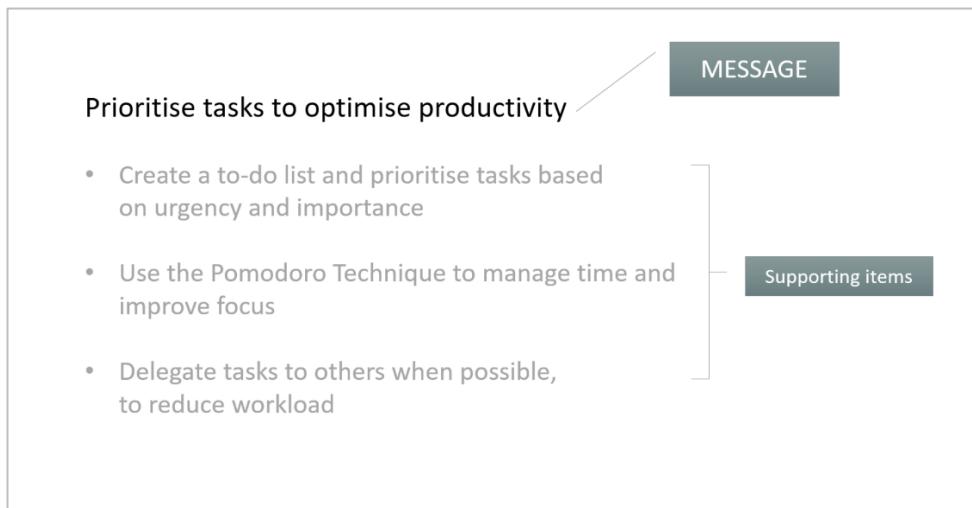


Figure 18.2 Slide with one message

In contrast, when too much information is on a single slide, the audience may struggle to keep up with the presenter's message, resulting in a loss of interest and engagement.

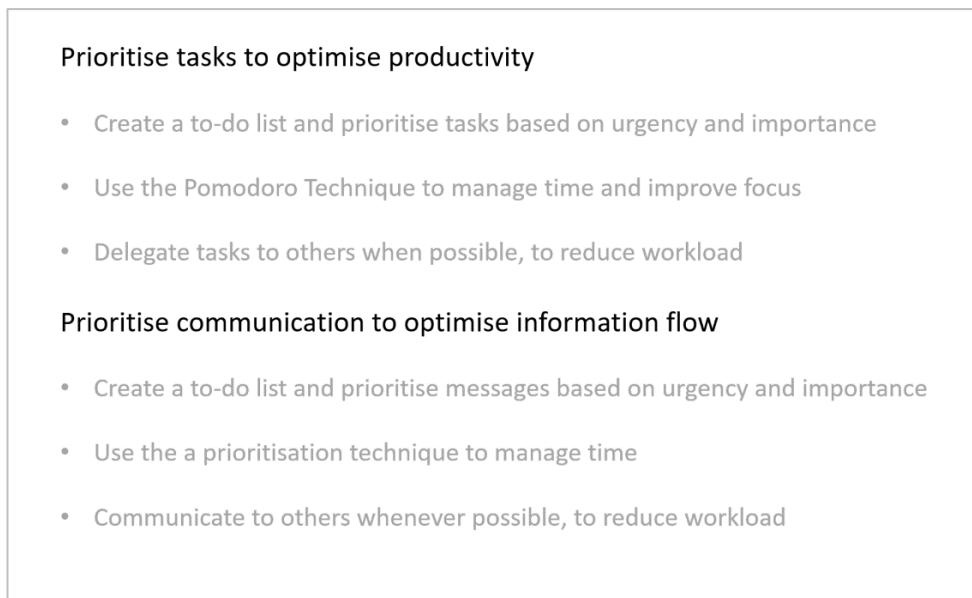


Figure 18.3 Slide with two (too many) messages

Additionally, presenting too much information on a slide can cause the audience to become distracted and miss the presenter's main point.

For several reasons, having multiple slides with only one message on each is better than having various messages on a single slide.

More slides are not a problem.

- *Improved Clarity:* Multiple messages on a single slide can confuse and overwhelm the audience. By presenting one message per slide, you can ensure that each message is communicated and understood.
- *Better Focus:* By presenting one message per slide, you can keep the audience's attention focused on the topic. When you show too many messages on a single slide, it can be difficult for the audience to stay focused and engaged.
- *Increased Retention:* Presenting one message per slide can help the audience remember the information better. When you show too many messages on a single slide, it can be difficult for the audience to remember all the details.
- *More Flexibility:* Having multiple slides with one message each gives you more flexibility in terms of presentation style. You can spend more time on important messages and move quickly through less important ones.

Overall, using multiple slides with one message on each is an effective way to communicate information in a clear, focused, and memorable way. The number of slides you need is not an issue.

18.2.2 Motion, Contrast, and Colour

Visual attention is often an underestimated aspect of effective presentations, and there are several ways in which moving objects, contrast, and colour can control and direct attention.

Moving Objects

Moving objects are a powerful attention-grabbing tool. Research has shown that motion can effectively capture and hold attention, especially when the motion is unexpected or unpredictable. We use them to direct the audience to specific slide points or emphasise key information.³²⁵

Moving objects create attention.

³²⁵ (Smith & Abrams, 2018, pp. 1775-1784)

Robotic arm

A programmable mechanical device designed to perform tasks with high precision and repeatability.

Use cases

- Industrial manufacturing
- Medical procedures
- Space exploration
- Scientific research.



Figure 18.4 Motion grabs attention

There are several ways to illustrate motion in a PowerPoint slide. Here are some suggestions:

- *Animations*: You can use animations to show the movement of objects on your slide. For example, you can have an image move from one side of the slide to the other or have text appear letter-by-letter to create the effect of movement.
- *Transitions*: You can use slide transitions to create the illusion of movement between slides. For example, you can have one slide "fly" off the screen while the next "fly" in from the opposite side.
- *Video*: You can use videos to show real-life movement. For example, you can show a video of a car driving on the road or an aeroplane taking off.
- *Motion paths*: You can use motion paths to show the movement of an object along a predetermined path. For example, you can have an image move along a curved path to show the motion of a ball being thrown.
- *3D models*: You can use 3D models to show the movement of objects in a 3D space. For example, you can create a 3D model of a car driving on the road and then animate the vehicle moving along the route.

Overall, the best way to illustrate motion in a PowerPoint slide depends on the context and what you want to achieve. Experiment with different techniques to find what works best for your content and audience. Ensure the motion element does not distract the audience from your intended message.

Contrast

Contrast is the difference between two or more visual elements, such as light and dark, or opposite colours on the colour wheel. High-contrast elements tend to draw attention more than low-contrast elements. Therefore, using high-contrast elements, such as bold text or bright colours, can help to highlight key points and direct engagement to specific areas of the slide.³²⁶

*Contrast fosters
attention*

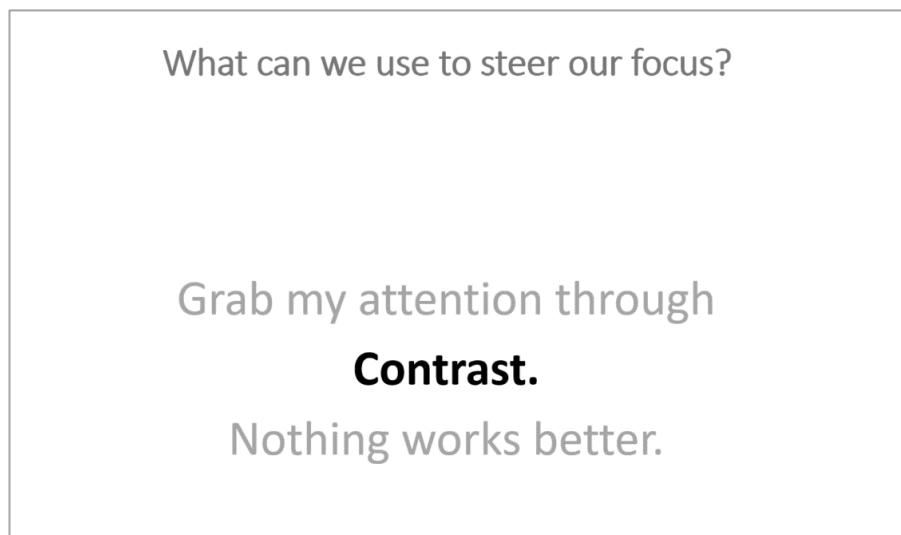


Figure 18.5 The contrast effect on a slide

If you have several lines of text on your slide, direct the attention to the line of interest using a moving contrast with animations.

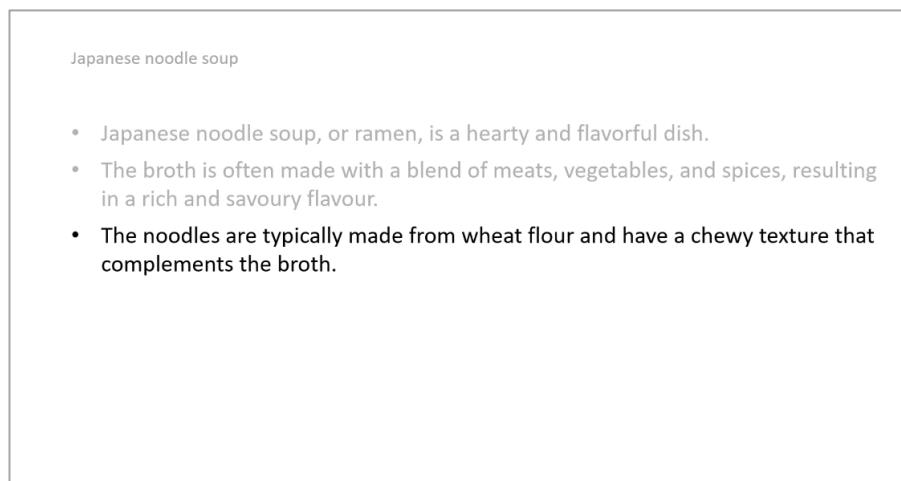


Figure 18.6 Animated text in PowerPoint

The workflow in Figure 18.7 shows how to create this effect in PowerPoint.

³²⁶ (Ansari, Lyons, van Eimeren, & Xu, 20, pp. 1845–1853)

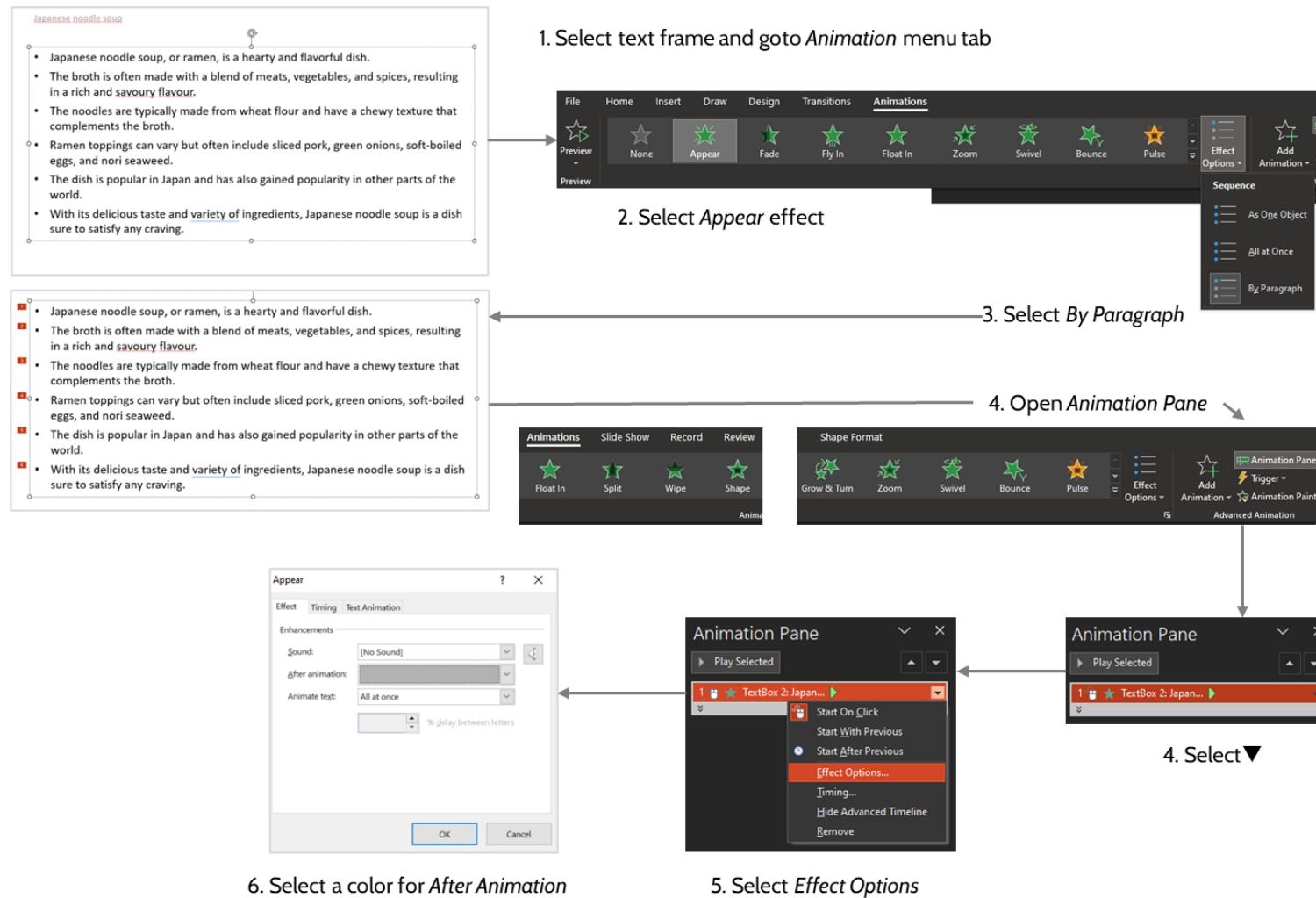


Figure 18.7 Workflow for animated contrast in PowerPoint

Designers use contrast as a design element to enhance the visual impact of both text and graphics. They often use contrast in text animation to create emphasis and draw attention to important information by contrasting the font colour, size, or style, which makes a hierarchy of information that guides the viewer's eye and highlights key points.

Contrast for emphasis

Contrast is not limited to text animation. Designers highlight specific zones in a graph with contrasting colours or shades, drawing attention to critical areas and helping the viewer understand the presented information better. The following series of figures illustrates the benefits of contrast.

In the following figure, the presenter speaks about sociology. Can you listen to him while searching for the corresponding row?

POLITICAL SCIENCE:	Democracy	Dictatorship	Bureaucracy	Political ideology	Political participation
SOCIOLOGY:	Social inequality	Socialization	Social mobility	Social network	Social norms
ANTHROPOLOGY:	Cultural relativism	Ethnocentrism	Cultural diffusion	Social organization	Symbolic anthropology
ECONOMICS:	Supply and demand	Market equilibrium	Fiscal policy	Monetary policy	International trade
PSYCHOLOGY:	Cognitive psychology	Developmental psychology	Personality psychology	Social psychology	Abnormal psychology

Figure 18.8 A complex diagram without focus

The next figure uses a focus to show the row, but it is still difficult to read.

POLITICAL SCIENCE:	Democracy	Dictatorship	Bureaucracy	Political ideology	Political participation
SOCIOLOGY:	Social inequality	Socialization	Social mobility	Social network	Social norms
ANTHROPOLOGY:	Cultural relativism	Ethnocentrism	Cultural diffusion	Social organization	Symbolic anthropology
ECONOMICS:	Supply and demand	Market equilibrium	Fiscal policy	Monetary policy	International trade
PSYCHOLOGY:	Cognitive psychology	Developmental psychology	Personality psychology	Social psychology	Abnormal psychology

Figure 18.9 Almost a little helpful example of how to create a focus

Presenting graphics with dimmed areas

A better use of contrast is dimming the unimportant rows to emphasise the important one. An additional advantage is that no new colours are required.

POLITICAL SCIENCE	Democracy	Dictatorship	Bureaucracy	Political ideology	Political participation
SOCIOLOGY:	Social inequality	Socialization	Social mobility	Social network	Social norms
ANTHROPOLOGY :	Cultural relativism	Ethnocentrism	Cultural diffusion	Social organization	Symbolic anthropology
ECONOMICS:	Supply and demand	Market equilibrium	Fiscal policy	Monetary policy	International trade
PSYCHOLOGY:	Cognitive psychology	Developmental psychology	Personality psychology	Social psychology	Abnormal psychology

Figure 18.10 An excellent example of how to create contrast by dimming table parts

Nothing disturbs your focus. However, you need to decide whether the dimmed components still need to be readable if the context requires it.

By strategically incorporating contrast in their presentations, designers can use this powerful design tool to make text and graphics more engaging and effective. Doing so creates a more impactful and memorable experience for the audience. This feature is well-suited for infographics as they tend to be crowded with content.

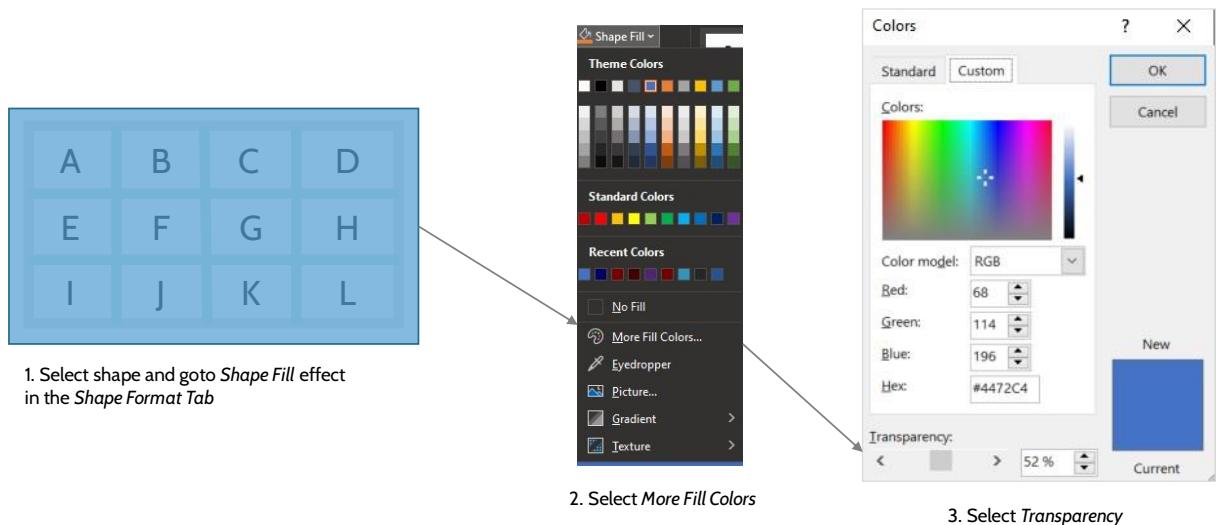


Figure 18.11 Workflow on how to adjust transparency in PowerPoint

Colour

You can use colour to control attention during a presentation. Research has shown that certain colours can elicit specific emotional and cognitive responses, which can influence how the audience perceives and processes information. For example, warm colours, such as red or orange, can create a sense of urgency or importance, while cool colours, such as blue or green, can develop an understanding of calmness or relaxation. Marketers knew that for years.³²⁷ As presenters, we take advantage of colours.

Bright colours grab attention.

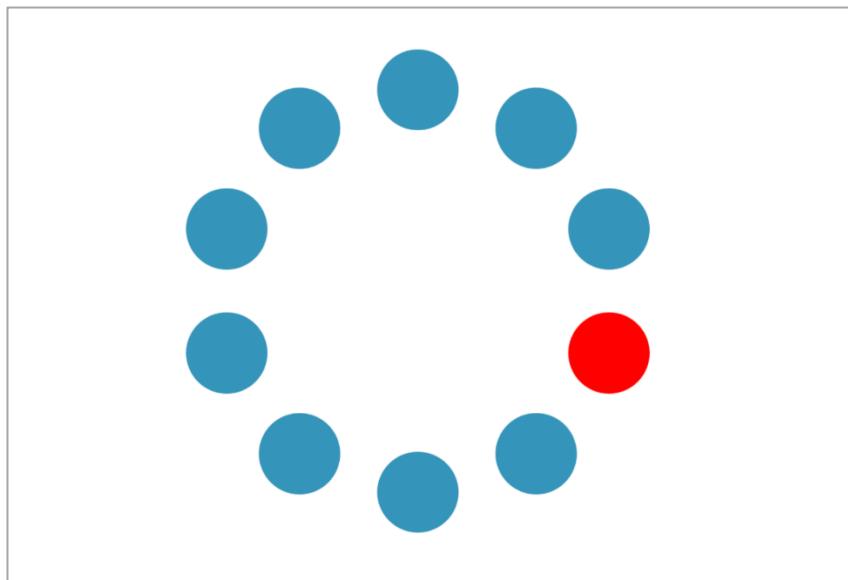


Figure 18.12 Colours get attention. Red stands out.

How many blue points and how many red points do you recognise? Do you feel the difference in recognition?

Colour has a significant impact on attracting and retaining the attention of the audience in marketing.

18.2.3 Font Size

Research in psychology has shown that the size of stimuli can affect attention.³²⁸ According to the principle of saliency, larger stimuli tend to be more attention-grabbing than smaller stimuli. This has been demonstrated in studies of visual perception, where larger objects or features in a scene tend to capture attention faster and more strongly than smaller ones.

Large objects grab attention.

³²⁷ (Singh, 2006)

³²⁸ (Itti & Koch, 2001)

In the context of presentations, research has found that larger font sizes, images, and other visual elements can increase audience attention and comprehension.³²⁹ For example, one study found that increasing the font size of the text in a presentation led to better memory recall of the passage presented.

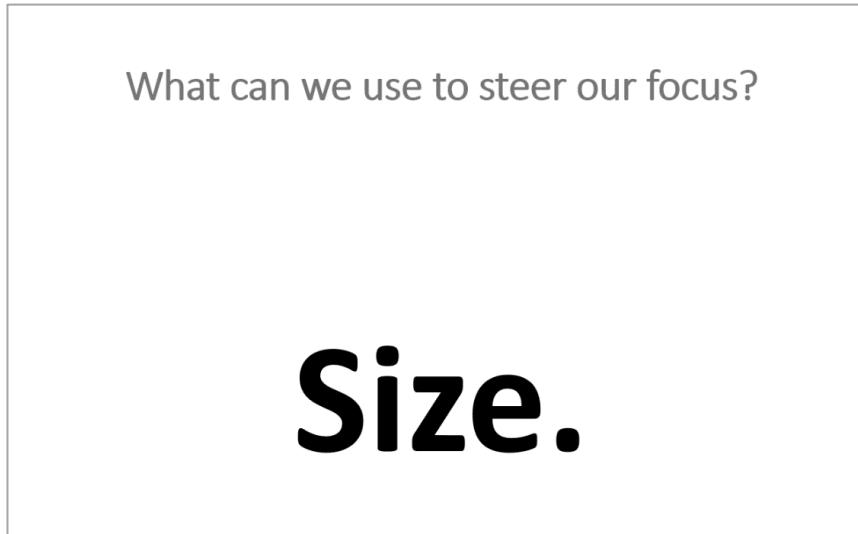


Figure 18.13 Size matters (self-explaining)

A common mistake of most presenters is that the headline of a slide has the largest font size. If the headline is not the most important message on the slide, make it small or use a less contrasting font colour. Compare the two following slide examples. What do you recognise first: message or headline?

Manage Tasks

Prioritise tasks to optimise productivity

- Create a to-do list and prioritise tasks based on urgency and importance
- Use the Pomodoro Technique to manage time and improve focus
- Delegate tasks to others when possible, to reduce workload

Figure 18.14 Font size emphasising the headline.

³²⁹ (Bayer, Sommer, & Schacht, 2012)

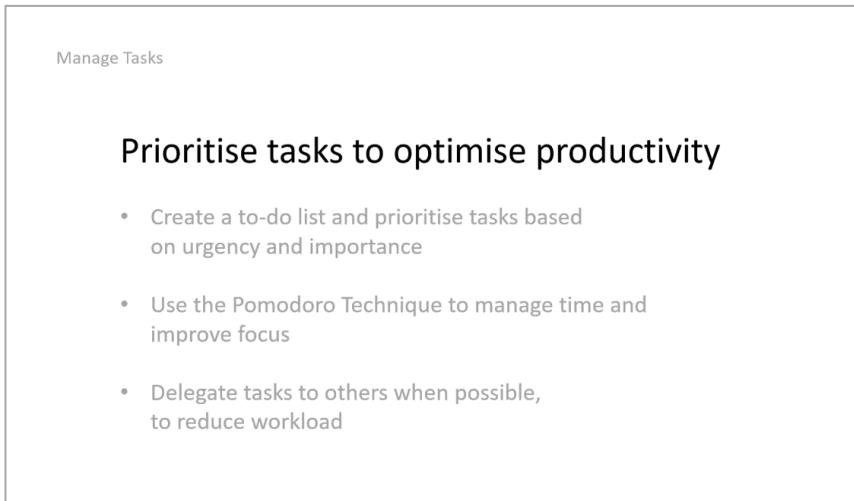


Figure 18.15 Font size emphasising the message.

Unfortunately, most PowerPoint templates (commercial and free) come with a hierarchy where the title is the most oversized item on the slide: aesthetic-driven impression overrules message transportation and memory. As we have shown, you can do it better.

Here are some tips on how to effectively use font size to guide attention:

- *Emphasise key points:* use a larger font size for important or emphasised words or phrases, such as the main points of your presentation. Larger fonts can help draw the audience's attention to these critical ideas.
- *Create hierarchy:* Use different font sizes to create a visual information hierarchy. For example, use a larger font size for the message, and a smaller font size for the supporting information. This can help the audience easily distinguish between different sections of your slide and understand the structure of your content.
- *Avoid excessive variation:* While using different font sizes can be effective, be careful not to use too many sizes or styles, as this can be distracting and make your presentation cluttered.
- *Consider the viewing distance:* When selecting a font size, consider the size of the screen and the distance of the audience from it. Text that is too small can be challenging to read from a distance, so be sure to use a font appropriate for the viewing conditions. Online and live presentations may require different font sizes.
- *Be consistent:* Use consistent font sizes throughout your presentation to provide a sense of continuity and make it easier for the audience to follow along.

18.2.4 Cognitive Load

Simultaneously listening to the presenter and reading sentences on a slide can be cognitively demanding and lead to ineffective information processing. John Sweller explained this phenomenon with his *Cognitive Load Theory*, which he first introduced in the late 1980s.³³⁰ The theory asserts that our working memory possesses a limited capacity, and exceeding it causes learning and comprehension to suffer.

According to the theory, there are three types of cognitive load:

- *Intrinsic load*: The material's inherent difficulty is presented.
- *Extraneous load*: The presentation format or design imposes a load that does not contribute to learning.
- *Germane load*³³¹: Cognitive resources are dedicated to processing, organizing, and integrating new information into existing knowledge structures.

When a presenter speaks while the audience reads sentences on the slides, both auditory and visual channels of the working memory are engaged. This can lead to a split-attention effect, where the human divides cognitive resources between the two tasks. As a result, the audience's ability to process and retain the information is compromised, leading to reduced comprehension.³³²

To avoid this issue, presenters can apply the following strategies:

- *Use the multimedia principle*: Combine text with relevant visuals (for example, diagrams, images) to improve understanding and retention.
- *Minimise text on slides*: Use bullet points, keywords, or short phrases instead of complete sentences to reduce cognitive load and keep the audience focused on the presenter.
- *Align spoken words with visuals*: Synchronise the presentation's spoken content with the visuals on the slides so that the audience can process both simultaneously.
- *Manage pace*: Give the audience enough time to process the information on each slide before moving on.

³³⁰ (Sweller, 1988)

³³¹ Germane Cognitive Load: Learning-related resultant cognitive load arises from the interaction of intrinsic and extrinsic cognitive load.

³³² (Mayer & Moreno, 2003)

By addressing the cognitive load during a presentation, presenters can facilitate more effective learning and comprehension for their audience.

The following two slides illustrate the cognitive load from reading during a presentation. The first slide requires more time to read, so the presenter must wait longer before speaking about the topic. The second slide supports a better pace because the shorter reading time fits the presenter's speaking flow.

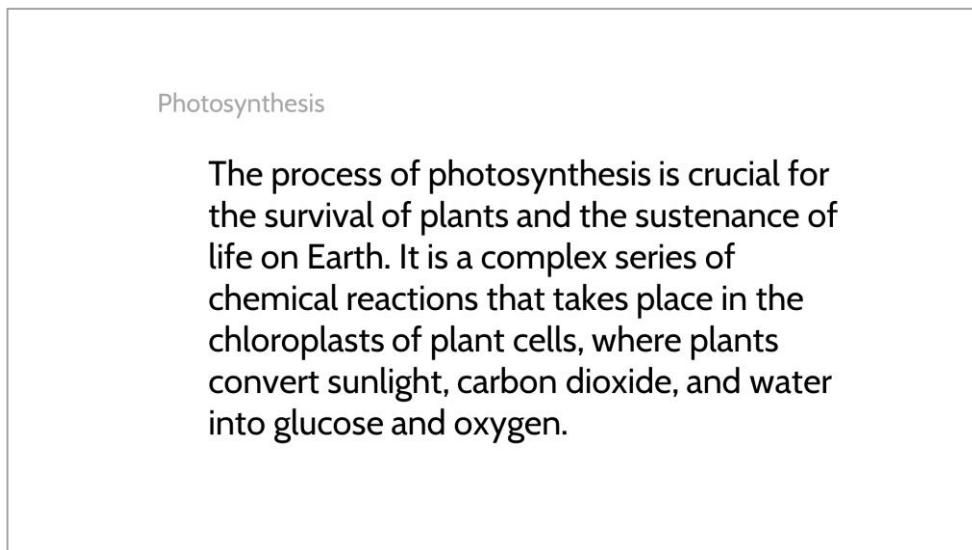


Figure 18.16 Too-high cognitive load

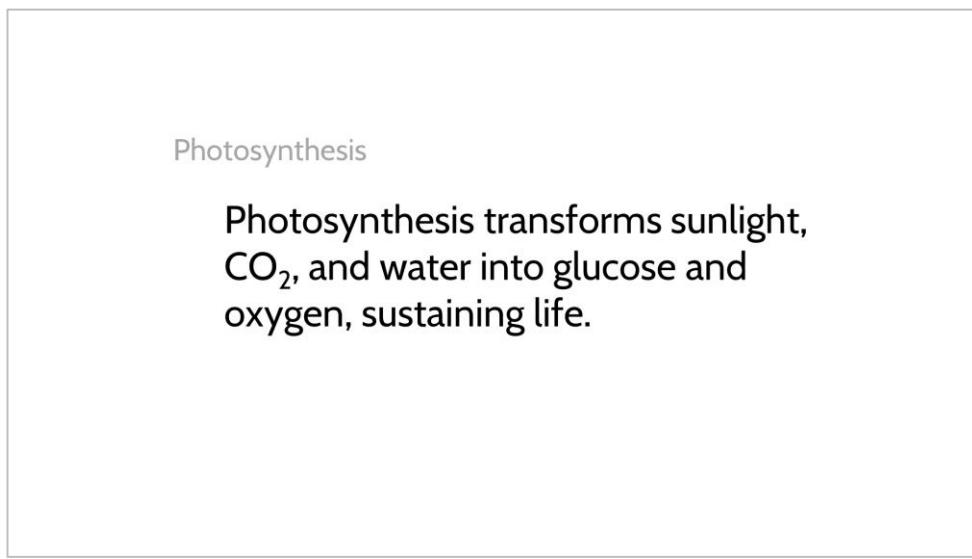


Figure 18.17 Ideal cognitive load

After a few seconds, the audience has read the slide, and the presenter continues with his oral presentation telling some details of the first slide.

Where is a higher chance that the audience will remember the content?

18.2.5 Background

Background colour plays a significant role. A dark background can be better for presentation slides for several reasons, including reduced eye strain, improved contrast, and increased focus.

- *Reduced eye strain:* A dark background with light text can reduce eye strain for the audience, particularly in low-light settings such as conference rooms or lecture halls. The lower overall brightness causes less stress on the eyes, allowing the audience to focus on the content more comfortably.
- *Improved contrast:* Dark backgrounds with light text often provide better contrast, making the content easier to read. This is particularly important when presenting data, charts, or graphs that require precise interpretation.
- *Increased focus:* Dark backgrounds can help direct the audience's attention to the content and minimise distractions. Bright backgrounds can sometimes overpower the content, making it difficult for the audience to concentrate on the key points.

However, the preference for a dark or light background may depend on the specific context and audience.

While no specific scholarly reference universally supports dark backgrounds for presentation slides, there is research on the readability and legibility of text based on background colour and contrast.

For example, a study by Hall and Hanna³³³ found that dark text on light backgrounds and light text on dark backgrounds provided the best readability for on-screen text. The choice between these two options ultimately depends on the context and preferences of the audience.

When deciding on a background for your presentation slides, consider the context, audience preferences, lighting conditions, and the content you will present. The primary goal is to maximise readability and maintain audience engagement, whether using a dark or light background.

As a presenter, using dark backgrounds on your presentation slides can significantly enhance the overall viewing experience for your audience. We recommend experimenting with dark backgrounds and contrasting text colours to optimise your presentation's visual appeal and effectiveness.

Compare the following two example backgrounds. Try it also on a monitor. You will encounter that your eyes feel more relaxed with a dark background.

³³³ (Hall & Hanna, 2004)

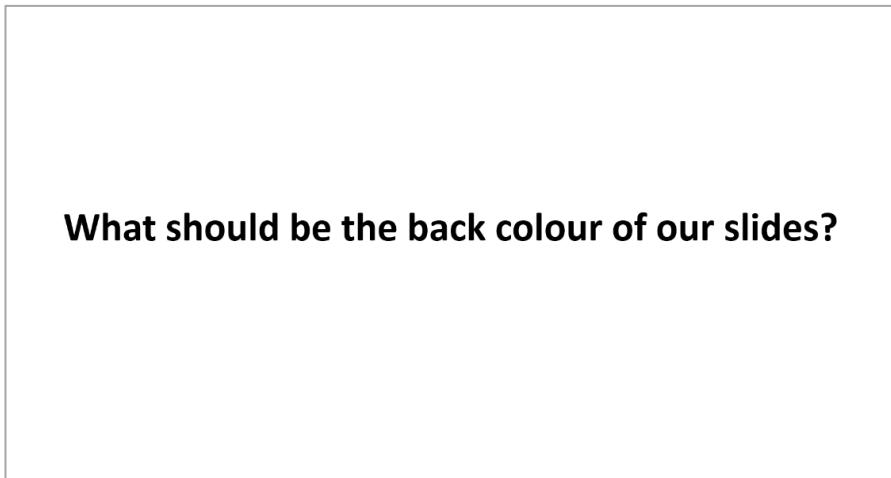


Figure 18.18 White presentation background

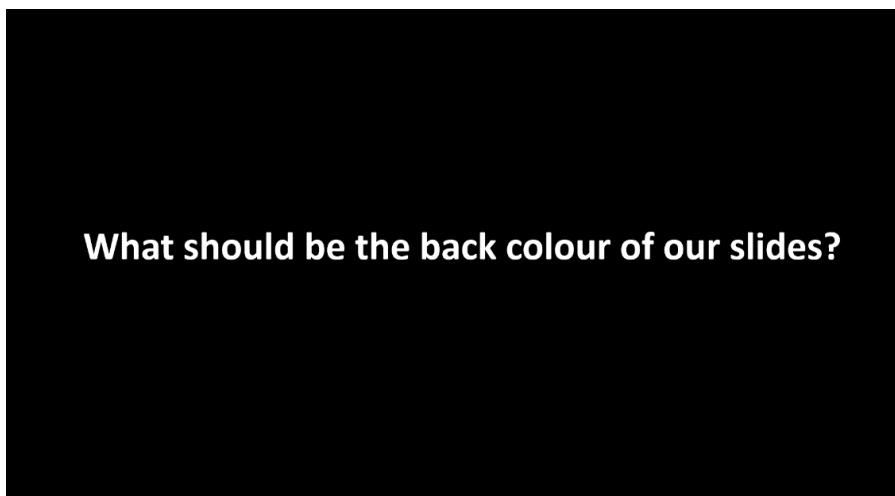


Figure 18.19 Dark presentation background

In live presentations, dark backgrounds create the impression of a seamless projection screen with no slide borders.

Dark does not necessarily mean only black. When choosing dark colours for a slide background, consider the following options that offer good contrast and are visually appealing. Figure 18.20 shows examples of alternative background colours.

Remember to pair your dark background colour with light-coloured text, such as white, light grey, or pastel shades, to ensure readability and enhance contrast. Test your chosen colours on the intended display device, as colour rendering may vary between screens and projectors.

<i>Colour alternatives</i>	Charcoal grey:		A dark grey colour provides a neutral backdrop that allows text and images to stand out clearly.
	Forest green:		A rich, dark green can create an elegant and engaging atmosphere for your presentation.
	Maroon:		A deep, warm red adds sophistication and can evoke strong emotions or highlight important points.
	Plum or deep purple:		These colours can add a touch of luxury and make your slides appear more dynamic.
	Dark blue:		A deep navy blue is a classic choice that offers a professional look while maintaining readability.

Figure 18.20 Alternative dark slide background colours

18.2.6 Number of Elements per Slide

The magic number is six.

There is no absolute number of elements that a human can easily recognise on a slide, as this depends on factors such as the complexity of the elements, the layout, and individual cognitive abilities. However, George A. Miller's 1956 paper, "The magical number seven, plus or minus two: Some limits on our capacity for processing information,"³³⁴ provides a widely cited guideline for the limits of human short-term memory. Miller proposed that humans can hold approximately 7 (plus or minus 2) items or chunks of information in short-term memory.

When applying Miller's findings to presentation slides, experts recommend including 5-9 elements to ensure the audience can easily recognise and process the information. These elements include text, images, bullet points, and other visuals.

It's important to note that Miller's research isn't the sole source of guidance on this topic. More recent studies on cognitive load theory and multimedia learning also contribute to best practices for slide design.³³⁵ Key principles from these studies advocate for creating visually simple slides, avoiding information overload, and combining text and visuals to enhance comprehension and retention.

³³⁴ (Miller, 1956)

³³⁵ (Sweller, 1988)

A Little Experiment

Let us do a little experiment to understand how our brain processes information. Have a look at the following counting examples. Ask yourself how long it took to count the circles?

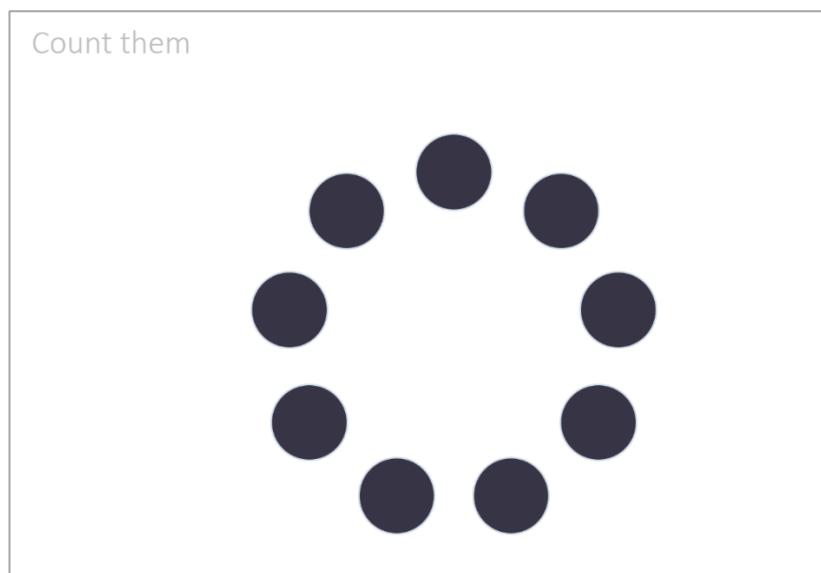


Figure 18.21 Counting Example I

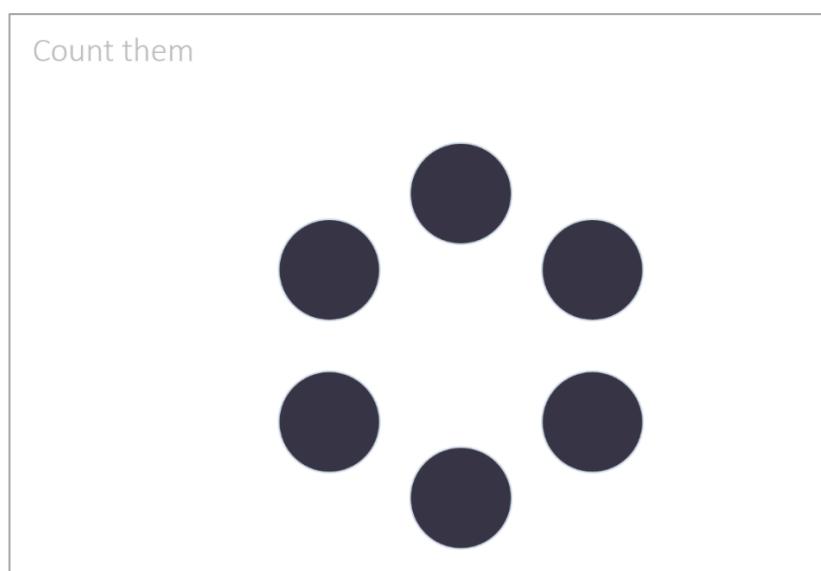


Figure 18.22 Counting Example II

This simple experiment illustrates the different working modes of your brain. You will encounter that the first example (9 circles) took much longer than the second example (6 circles). In the first example, you must count the circles, ensuring you end at the right circle. In the second example, you immediately recognise the pattern of 6 circles.

Subitizing

When the number of points or items is less than 7, we can quickly and accurately estimate the quantity without consciously counting them. When the number of points is larger, we typically rely on counting, which takes more time and cognitive effort as following two figures show. The phenomenon of recognising the number of objects without counting is called *subitizing*.³³⁶

Aircraft properties

- Aerodynamic design
- Wing shape
- Fuselage
- Propulsion system
- Landing gear
- Control surfaces
- Avionics
- Fuel storage
- Material composition

Figure 18.23 Counting text example

Aircraft properties

- Aerodynamic design
- Wing shape
- Fuselage
- Propulsion system
- Landing gear
- Control surfaces

Figure 18.24 Subitizing text example

³³⁶ One of the earliest and most influential papers on the topic is (Kaufman, Lord, Reese, & Volkmann, 1949)

Subitizing is an efficient, rapid, and automatic process that helps us instantly recognise the number of items in a small group. It is thought to involve minimal cognitive effort and energy consumption. Ideally, the maximum number of objects on a slide should be six.

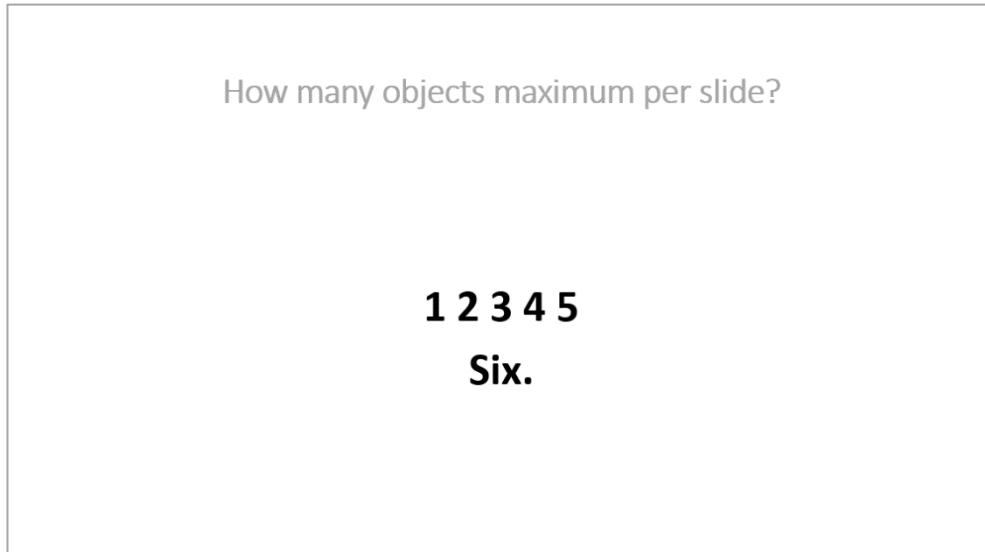


Figure 18.25 Maximum number of objects on a slide³³⁷

18.2.7 Summary

In a presentation, the primary goal is effectively communicating the message to the audience. While an aesthetically pleasing design can contribute to audience engagement and comprehension, it should never overshadow or detract from the core message. Therefore, a presentation's most important aspect is conveying the audience's message.

A well-designed presentation can enhance the communication of the message by:

- Organizing information clearly and logically.
- Visuals to support and clarify complex ideas or data.
- Maintaining audience interest and engagement through a visually appealing design.

However, it becomes counterproductive if the design is overly complicated, distracting, or depreciates the message. In such cases, a presenter should prioritise a more straightforward design focusing on clarity and effective communication over aesthetics.

³³⁷ The attentive observer will discover seven objects. Or only three? It seems that the number of objects depends on the definition of an object.

To ensure we effectively convey the message to the audience, consider the following:

Focus on the content: The presentation should be well-researched, accurate, and relevant. Clearly articulate your key points and ensure your audience quickly understands them.

Keep it simple: Simplify your design to avoid overwhelming or distracting the audience. Use visuals and design elements purposefully and in moderation to support the message.

Adapt to your audience: Understand the needs and preferences of your audience, and tailor your presentation accordingly. Understanding may involve adjusting the content's design, tone, or complexity to match their expectations and level of expertise.

Practice delivery: Effective communication also depends on your delivery. Practice your presentation to ensure you are confident, articulate, and engaging.

In summary, while an aesthetically pleasing design can enhance a presentation, the primary focus should always be effectively communicating the message to the audience.

18.3 HOW TO PRESENT

Improving presentations

A presentation in the defence is the central component. It allows students to display their research findings, methodology, and contributions to the field. Through the presentation, students can demonstrate their knowledge, critical thinking skills, and ability to communicate complex ideas effectively.

Typically, students must pass both the written thesis and the defence. Additionally, the presentation allows students to receive constructive feedback and engage in scholarly dialogue with the panel members. Overall, a well-delivered presentation in the defence can help to strengthen the student's academic and professional reputation and enhance the visibility and impact of their research work.

18.3.1 Timing

Planning the timing for a presentation ensures that you can effectively convey your key messages within the allotted time. A typical defence presentation takes about 15 minutes and includes the following:

- *Introduction:* Briefly introduce your research topic, its significance, and the context or background information.

- *Research objective:* Clearly state the research question, hypotheses, or theses you aimed to address.
- *Objectives:* Outline the main goals of your study.
- *Methodology:* Summarise the research methods and techniques, including the study design, sample, data collection, and analysis.
- *Results:* Present your research's key findings or outcomes, focusing on the most significant results using visuals like graphs or tables.
- *Discussion:* Explain how your findings address the research question or hypothesis and discuss the implications of your results within the broader context of your field.
- *Conclusion:* Recap your research's main points and contributions, and briefly mention any limitations and future research directions.
- *Acknowledgements:* Thank your supervisors, committee members, and individuals or organizations that supported your study.

In simple terms: follow the same storyline of your thesis but focus on results and conclusion. The following figure illustrates the timing.

Timing	Part	Duration	Slides	Content
Before	Test			Equipment & media check
00:00				
00:01	Introduction	00:01	1	Welcome, introduction of speaker
00:02	Outline	00:01	1	Topic introduction and contents
00:04	Background	00:02	1	Context information
00:04				
00:09	Topics	00:09	6-8	Subject matter
00:13				
00:13	Summary	00:02	1	Summary, outlook, and/or recommendation
00:15	Discussion			Open discussion

Figure 18.26 Timing plan for a 15-minute presentation

In the first part of the presentation, you start with the introduction and outline, which takes about one minute each. After two minutes of background

information, you continue with the core of your presentation. The last two minutes you reserve for the summary of your work.

Remember to practice your presentation beforehand to ensure you can cover all the points within 15 minutes and prepare to answer questions from the committee members or audience.

18.3.2 Preparation

The three steps to a successful presentation are preparation, planning, and design. Preparing a presentation can seem daunting, but breaking it into manageable steps can make the process much more straightforward:

1. Firstly, preparation involves understanding your audience, identifying your key messages, and your goal.
2. Secondly, planning involves creating a structure for your presentation and deciding on the storyboard and the main statements.
3. Finally, design involves using visuals, such as slides or handouts, to reinforce your message and make your presentation more engaging.

Following these three steps, you can create a compelling presentation that effectively communicates your message to your audience. The following figure illustrates the process:

In advance	Know your goal. Know your topic. Know your audience.
Plan	Create a storyboard. Select main statements (presentation time / 5). Select the main visuals Do not present everything you know about the topic. Adapt your terms and scope to your audience. Distinguish between technical and persuasive presentations.
Design	Avoid stock templates. Use whitespace and remain simple. Create illustrations carefully.

Figure 18.27 Preparation steps

In Advance

The best is to start your presentation development by answering initial questions. You can use the following table to address the starting parameters.

Table 18.2 Checklist for beginning a presentation development

<i>Questions</i>	<i>Answer</i>
What is my goal?	I want to present the thesis topic in an understandable but not too simple form.
What is my topic?	The Impact of Oversalting on Fishing in Inland Lakes: A Case Study Analysis.
What is my audience?	1st and 2nd supervisor at my university

Plan

Using a storyboard eases the process of creating a presentation. It helps to visualise the presentation's content, structure, and flow. Instead of simply writing out bullet points, a storyboard allows you to map out the narrative of your presentation, including key messages, supporting visuals, and transitions. Figure 18.28 shows an example.

In a storyboard, you can easily make changes and adjustments before creating the final version of your presentation. It can also help ensure that the presentation stays on topic and is well-organised, leading to a more engaging and effective final product.

Once you have created your storyboard, select the visuals you like to present. Here are some steps to help you select visuals for your presentation:

- *Identify your key messages:* Before choosing visuals, identify the key messages from the storyboard you want to convey. This will help you determine what visual aids would best support your message.
- *Consider your audience:* Consider who your audience is and what they might find most engaging. Different types of visuals may be more effective for different kinds of audiences.
- *Choose relevant and high-quality visuals:* Make sure your chosen visuals are relevant to your topic and support your message. Additionally, ensure that the visuals are high-quality and easy to read.
- *Use variety:* Incorporate a variety of visual aids, such as graphs, charts, diagrams, images, and videos, to keep your audience engaged and enhance your message.
- *Keep it simple:* Avoid cluttering your slides with too much information or visuals. Keep your visuals simple and easy to understand.
- *Practice your presentation with visuals:* Finally, practice your presentation with the selected visuals to ensure they flow well and effectively support your message.

Slide 1: Introduction

- Title of the presentation: "The Impact of Oversalting on Fishing in Inland Lakes: A Case Study"
- Background information on oversalting and its impact on freshwater ecosystems
- Goal: The research investigates the effects of oversalting on fishing in inland lakes, focusing on changes in fish species, abundance, and the ecological impact of salinisation on lake ecosystems."

Slide 2: Methodology

- Case study selection and justification
- Sampling techniques and data collection
- Statistical methods

Slide 3: Results - Fish Species (Part 1)

- Title: Changes in Fish Species Abundance and Diversity
- Graph showing changes in fish species abundance and diversity
- Key message: Oversalting has a significant impact on the abundance and diversity of fish species in inland lakes.

Slide 4: Results - Fish Species (Part 2)

- Title: Shifts in Dominant Fish Species
- Graph showing changes in the dominant fish species before and after oversalting
- Key message: Oversalting can lead to the displacement of certain fish species, which can have cascading effects on the ecosystem.

Slide 5: Results - Fish Species (Part 3)

- Title: Implications for Fishery Management
- Discussion of the implications of changes in fish species for fishery management practices
- Key message: Understanding the impact of oversalting on fish species for developing effective fishery management strategies.

Slide 6: Results - Fish Abundance and Size Distribution

- Graph showing changes in fish abundance and size distribution
- Discussion of the impact of oversalting on fish abundance and size distribution

Slide 7: Conclusion

- Summary and implications for the management of inland lakes
- Future research directions
- Acknowledgements and thank you slide

Figure 18.28 Example storyboard for a defence presentation

Useful Bits of Advice

Presentations serve as powerful tools for conveying ideas, inspiring engagement, and sharing information. To ensure an impactful and effective presentation, a few key pieces of advice can significantly enhance your delivery, such as structuring content, engaging the audience, and utilizing compelling visuals and storytelling techniques.

Do not present everything you know about the topic.

This advice suggests avoiding overwhelming the audience with too much information is important. Instead, focus on the key messages and details to help convey your message effectively.

Adapt your terms and scope to your audience.

This advice suggests considering your audience's background and expertise when preparing a presentation. Using technical terms or presenting too advanced information for your audience can be confusing or intimidating. By adapting your language and scope to your audience, you can make your presentation more accessible and engaging.

Distinguish between technical and persuasive presentations.

This advice suggests that different types of presentations require different approaches. Technical presentations may require more detailed explanations and technical terms, while persuasive presentations may focus more on emotional appeals and storytelling. Understanding the purpose and audience of your presentation can help you choose the most effective approach and tailor your message accordingly.

Design

When designing a presentation, remember the audience's experience. The design of a presentation should be easy to follow, light, and not cluttered or confusing. The goal is to make it easy for the audience to understand the message without being distracted by design. The audience can focus on the content and retain the information by keeping the design simple. Additionally, a cluttered or confusing design can be overwhelming and lead to confusion or disengagement. Therefore, choosing a visually appealing design that is easy to navigate reinforces the presentation's key messages. Ultimately, the creation of a presentation should support the content, not distract from it, to create a memorable and impactful experience for the audience.

If you follow the guidelines from the *Best Practices* chapter, you have already made most of your design decisions. The general design has two parts:

- Title page design
- Slide template design

The following is a short guideline on how to design the title page and slide template for a presentation.

Design of the Title Page

- *Please keep it simple:* The title page should be simple, visually appealing, and easy to read. Avoid cluttering the page with too many graphics or information.
- *Use a precise title:* Use a clear, concise title that accurately reflects the presentation's content.
- *Include key information:* Include the name of the presenter, the date, and the audience if relevant.
- *Use appropriate graphics:* Incorporate relevant graphics, such as images or logos, to make the title page more engaging.

Design of the Slide Template

- *Choose a colour scheme:* Choose a colour scheme that is visually appealing and appropriate for the presentation's content. Consistency is important when it comes to colour choice. Use the advice from the *Best Practices* chapter.
- *Use simple fonts:* Use simple, easy-to-read fonts for titles and body text. Avoid using too many different fonts, as this can be distracting. Serif fonts are easier to read but not mandatory.
- *Incorporate visuals:* Use images, charts, or graphs to support and enhance the presentation's message. Ensure that these are relevant to the content and are of high quality.
- *Keep it consistent:* Ensure that the design of all slides is consistent in terms of font, colour, and graphics. Consistency will make the presentation look more polished and professional.

The following two examples show designs we should avoid. Decide for yourself what design is more convincing.



Figure 18.29 Difficult to read title slide³³⁸

Click to edit Master title style

• Click to edit Master text styles

- Second level
- Third level
- Fourth level
- Fifth level

Research Center

3/16/2023 Footer (#)

Figure 18.30 Confusing slide template with the wrong emphasis through contrast and colouring

³³⁸ Photo by (Beaumont, 2023)

In contrast, by understanding the *Best Practice* guidelines, the designs will look like the following two figures.

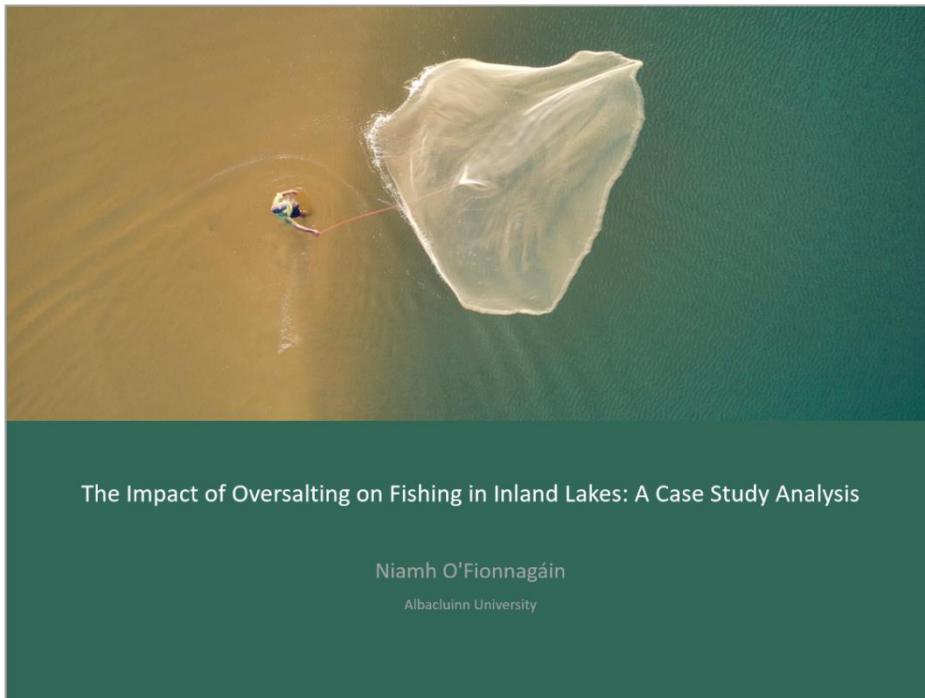


Figure 18.31 Compelling title page³³⁹

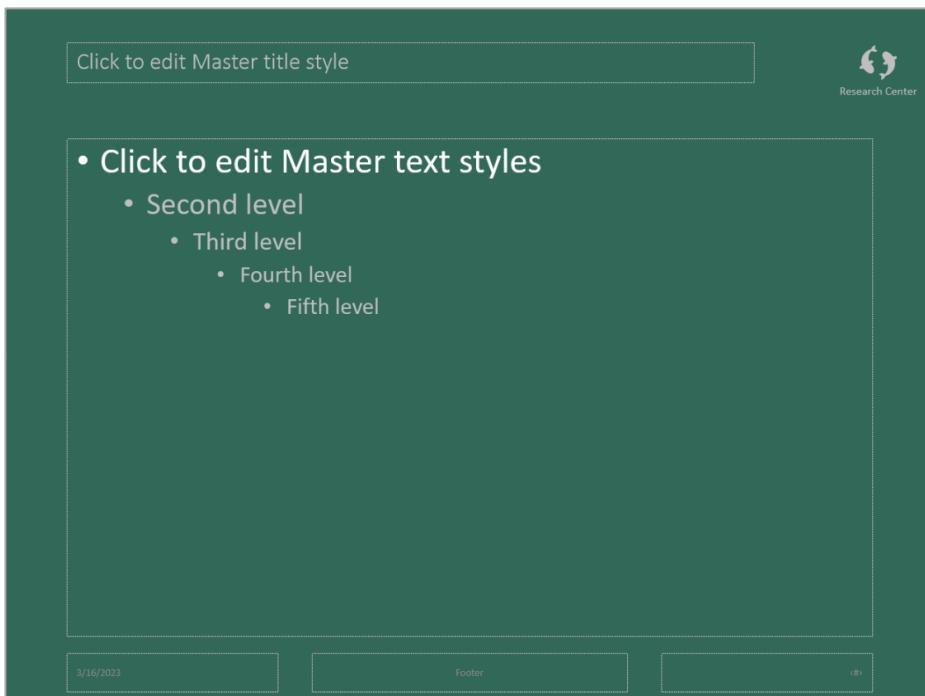


Figure 18.32 Example of a lightweight slide template emphasising the main message

³³⁹ Photo by (Iddamalgoda, 2020)

18.3.3 Practising

Here is a guideline on how to practice your thesis defence presentation:

- *Time yourself:* Time your presentation to ensure that you are within the time limit. A thesis defence presentation typically ranges from 15 to 30 minutes.
- *Record yourself:* Record yourself while presenting and watch the recording to identify areas for improvement. This can help you determine pacing, tone of voice, and body language.
- *Practice in front of a mirror:* Practicing in front of a mirror can help you focus on your body language and facial expressions. This can help you to appear more confident and engaging during your presentation.
- *Rehearse with friends or colleagues:* Rehearsing with friends or colleagues can help you to receive feedback and identify areas for improvement. It can also help you to gain confidence in your delivery.
- *Use visual aids:* Use your visual aids, such as slides or handouts, during your practice sessions to ensure they are effective and engaging.
- *Practice your responses to potential questions:* Practice your responses to possible supervisors' questions during your defence. This will help you feel more prepared and confident during the defence.
- *Get feedback:* Seek feedback from your advisor or peers to help you improve your presentation. This can help you refine your message and ensure you effectively convey your research.

19 THESIS DEFENCE

*Success in a thesis defence isn't about having all the answers.
It's about the willingness to deal with a question and engage in a
discourse about potential answers.*

The requirement for an oral thesis defence (sometimes called a thesis colloquium) varies depending on the academic institution and the degree program. In some institutions and degree programs, a thesis defence is mandatory for all levels of degrees, including bachelor, master, and doctoral degrees. In other institutions, you do a defence only for specific degree programs or levels. For example, some master's degree programs may require a thesis defence, while others may not. Some doctoral programs may require a preliminary examination or qualifying exam and then a final defence of the dissertation.

Check with your academic institution and degree program to determine the specific requirements. Your thesis supervisor should be able to provide you with more information about the conditions for your study program.

A thesis graduation defence is an academic event typically occurring at the end of a thesis writing process. This defence allows the researcher to present and defend their thesis in front of a panel of experts, including their thesis advisor and/or other faculty members.

When finalising a thesis, there are several ways to complete the process. Depending on your institution's regulations, you are done after you submit the thesis, or you must pass a defence, a rigorosum, or a disputation:

- **Defence:** more of a general term, typically with supervisors and focus on students' expertise in the field.

- **Colloquium:** presentation or lecture with a Q&A session (public or private).
- **Rigorosum:** a rigid form of oral exam performed in front of a committee with a focus on students' knowledge and understanding.
- **Disputation:** a debate with scholars with a focus on defence against criticism.

19.1 OBJECTIVES OF A THESIS DEFENCE

The main objectives of a thesis graduation defence are explained in the following sections.

To demonstrate proficiency in subject matter and research.

During the defence, the panel members expect the researcher to present their thesis chapters focusing on results and responding to questions. Both allow the panel to evaluate the student's knowledge and understanding of the subject matter and their ability to conduct independent research.

To assess the quality and significance of the thesis.

The panel members will evaluate the quality of the student's research and the importance of their findings. They will consider factors such as the research's originality, the methodology's soundness, and the thesis's overall contribution to the field.

To provide constructive feedback.

The panel members will provide feedback on the student's research, highlighting strengths and weaknesses and offering suggestions for improvement. This feedback can be valuable to students as they progress in their academic or professional careers.

To determine whether the requirements for graduation were met.

Finally, the thesis graduation defence serves as a formal evaluation of the student's work and determines whether they have met the requirements for graduation.

Overall, the purpose of a thesis graduation defence is to provide an opportunity for the student to demonstrate their academic and research skills, receive feedback from experts in the field, and assess whether the student has met the standards for graduation.

To verifying the authorship.

Verifying the authorship of the thesis is typically done by the academic institution or department as part of the thesis submission process. Before a student can defend their thesis in a graduation defence, they would have already submitted their thesis document for review and approval by their thesis advisor and/or a committee of faculty members. These reviewers would have assessed the originality and authorship of the work to ensure that it meets the institution's academic standards and is the student's original work.

Academic dishonesty

The defence focuses on students' ability to present and defend their work rather than verifying their authorship. However, suppose there are any concerns about the originality or authorship of the work during the defence. In that case, the panel members may ask the student to clarify or provide additional information to address those concerns.

19.2 PARTS OF A THESIS DEFENCE

As every institution has its regulations, the format of a thesis defence may vary. Nevertheless, a regular defence consists of three parts shown in the following table.

Table 19.1 Typical defence parts

Part	Description
Presentation	Your presentation. Typically, it would be best to briefly address the context, research questions, value, and methodology and then focus on key findings.
Question & Answer	A dialogue about your thesis: you answer questions from the panel or the supervisors.
Feedback	The grading: feedback on your research, highlighting strengths and weaknesses and offering suggestions for improvement.

19.2.1 Presentation

Besides the recommendations described before, there are two central aspects to consider for presenting the outcomes of your thesis: appearance and enthusiasm.

Your university might have defined a dress code to adhere to in a thesis defence or there might be unwritten expectations of the committee members. If

no dress code is defined, business casual attire is recommended.³⁴⁰ The key is to look neat, well-groomed, and professional while not being overly formal.

When you speak, use an appropriate pace, and do not rush through your statements. Take advantage of pauses after key messages and between sections of your topic.

Be enthusiastic.

Even more important is your enthusiasm. If you leave the impression that you are not really interested in your research project or do not recognize the value of the defence, you have already lost. This means you should smile, be positive, and convince the audience that you are committed to your study and that you consider the defence event a special moment in this project.

19.2.2 Question & Answer

The question & answer part deals with a series of items where questions will be asked. Expect questions about, for example:

- terminology
- explanations for statements, figures, tables, or equations
- explanations for arguments
- interpretation of results
- assessment and opinions
- recommendations and outlook

Technical terms

A common problem students face during a thesis defence is explaining a term they used in their presentation or thesis. You may find it challenging if you did prepare adequately to provide a clear and concise definition of the term.

To avoid this issue, you need to understand all the technical terms and jargon used in your thesis. This means you should research the meaning of any unfamiliar terms and be able to provide a clear definition in their own words. You may also create a glossary of terms used in your thesis and hand it out to the committee members before the defence.

How to answer

During the defence, the committee may ask to explain technical terms found in your thesis, models or theories used, or can ask for clarification on the specific meaning of text, visuals, arguments, or results.

³⁴⁰ Business casual is a dress code that offers a more relaxed and comfortable alternative to traditional business attire. It's often seen in professional settings that don't require a formal suit and tie but still expect a polished and business-appropriate appearance.

The first advice for answering is to remain calm and composed. Take a moment to gather your thoughts before responding. Even if you know the answer immediately, give the committee the impression that the question was important enough to consider it a moment to phrase your answer.

Take a moment,

A second advice is to never interrupt the questioner. Wait until they fully formulated and explained their question.

Never interrupt.

A final advice is to not try to bluff or pretend to know the answer if you are unsure. It is always better to give an honest answer than a fuzzy one. If you don't know the answer, try to at least assess potential answers. Be honest and acknowledge that the question is challenging and that you might not have a ready answer, but you could imagine one. If possible, relate the question to something you do know. If you have no answer ready, you should remain confident, assess the relevance of the question, and express willingness to follow up.

Do not pretend,

The more the committee dwells on details of terminology, text, graphics, or justifications, the less you have reached a state where you are taken seriously as an expert on the subject matter. The more often the committee asks for your assessment, seeks your opinion, or asks for your recommendations, the more you can assume that you have been accepted as an expert.

19.2.3 Feedback

The feedback session of a thesis defence provides an opportunity for scholarly exchange and critical evaluation of the research work. These sessions force insights into alternative perspectives, identification of research gaps, and suggestions for future exploration. This constructive criticism enhances your learning experience and fosters academic growth. The feedback can also improve the final manuscript's quality before publication. Lastly, this interaction aids you in developing presentation and defence skills, which will be helpful for your future career.

Having successfully defended your thesis is a testament to your diligence, intellectual rigour, and commitment to your field of study. This achievement marks not the end but the commencement of your professional journey, where your research could significantly contribute. Take time to celebrate this milestone, as it represents the culmination of your academic journey thus far and the fruit of your hard work and dedication. A brief respite to acknowledge your accomplishment can rejuvenate you for the challenges and opportunities ahead.

And do not forget to thank your teachers.

19.3 THE WORST PRACTICE

A final piece of advice on how you can mess up everything you carefully constructed before is provided in the following.

Attack is the Best Thesis Defence

Since your thesis was already graded before you received the invitation to the thesis defence, any further effort does not pay out. To make it simple, you prepare for the defence by using one of the fancy-looking PowerPoint templates provided by the Microsoft Office package.

Look at your thesis and copy large text passages to the slides. When you arrive at 50 to 60 slides for a 15-minute presentation, you're done. The longer your presentation, the shorter the Q&A session.

In the defence colloquium, you should first share your desktop with all these little fancy icons and a wallpaper of an erotic photo of your favourite anime character before you start PowerPoint. Then, search extensively for the presentation file by showing all your subfolders with dubious content one by one.

If you found the file, open it and search in all PowerPoint menus for the function to start the presentation. If you finally found it, begin your presentation by buttering up your supervisors obediently with warm thanks for the incredible chance to present your topic to such a distinguished audience.

During your presentation, read the statements on your slides one after another at an adequately fast pace to cover all slides. In live presentations, avoid eye contact with the audience by turning to the presentation screen. In online presentations, look at your slides rather than the camera. Put on your most expressionless face and mumble the statements at a consistent intonation. After the last slide, stop the presentation mode, immediately close PowerPoint to show the erotic wallpaper again, and express your confidence that no questions were left.

Experience shows that most supervisors can't stop themselves from asking questions to show that they are better than the candidates. Some typical questions and potential answers are:

Q: What was your motivation for doing this study?

A: Close to zero.

Q: How would you describe the value of your research?

A: I discovered how to use Microsoft Word.

Q: What were the limitations of your study?

A: That I didn't have enough time to think about the limitations.

Q: Did your findings support your hypothesis?

A: All p-values showed I was completely right.

Q: Please explain the methodology you used.

A: I employed a mixed-method approach to turn real data into mysterious ones.

Q: What was the most important outcome of your study?

A: I'm sorry, but due to the confidentiality agreement with my company I'm not allowed to talk about it.

Q: If you were to repeat the study, what would you do differently?

A: Probably selecting another supervisor that does not ask such silly questions.

If you are unlucky, you may have a vile audience that asks questions that you cannot answer. In this case, put on an important face and talk about anything using the terminology of your study program. The following list helps you with some common special terms:

Abductive inference: A criminal's decision on the amount of ransom.

Abstract: A painting that no one understands.

Action research: Having more fun during the investigation.

Amnesia of genesis: A disease of politicians involved in corruption affairs.

Analysis: From ancient Greek: the dissolution of the rear.

Antinomy: The element with the atomic number 51.

Antithesis: The thesis you don't have to write when expelled from your university.

Bayes' theorem: The strange belief that something could change a strange belief.

Beta distribution: A distribution better than another.

Case study: The investigation of containers.

Concealed observation: Spying on your fellow student's exam answers.

Constructivism: What architects belief in.

Corollary: An unspeakable word.

Correlation: Having two spouses at the same time.

Dark Matter: The stuff in your fridge with an expired best-before date.

Deductive inference: The fact that you're always right.

Dialectic: Argumentation based on the interviewee's peculiar accent.

Doxa: A horde of dogs.

Eliminative induction: Predicting the disappearance of money in your bank account..

Empiricism: Trying to guess something without having an idea.

Entropy: What reaches a maximum in your kitchen after dinner.

Epistemology: Astrology in the realm of sciences.

Face validity: If what you see is what you get.

Fallacy: Being careless when walking downstairs.

Focus group: The people selected for a prank.

Forest plot: A conspiracy theory of trees taking over the world

Fundamentum divisionis: The main reason for divorce.

Gaussian distribution: The reason why everything is normal

Generalisation: Advancement in military rank.

Grounded theory: A model of soil composition.

Hypothesis: A tiny thesis

Idealism: What appears when I look into the mirror.

Idiographic: A method for describing fools.

Inertia: The laziness of matter.

Internet of Things: When your toaster has more followers than you have.

Interpretivism: A strange method of everyone guessing what's going on.

Likelihood: The chance of your feelings being returned.

Mind-body dualism: The inability to get out of bed in the morning.

Mixed method: A way to create arbitrary cocktails.

Null Hypothesis: Having not the faintest idea.

Ontology: A district of Ontario.

Paradox: Two dogs, side by side.

Parallel Universe: Where your socks disappear to when I do laundry.

Philosophy: The love for complicating things.

Plagiarism: The plague of not finding own words.

Positivism: The optimistic attitude of physicists.

Post-Positivism: The disappointment when the experiment went wrong.

Postulate: Sending a letter.

Pragmatism: Making the smallest effort to research something.

Probability Theory: Guessing results by chance.

P-Value: The appreciation of finally having found a toilet.

Quantum Leap: What Schrödinger's cat did when he stepped on its tail.

Research Proposal: A declaration of intent to marry your professor.

Rhetorical Argument: The reasoning when she refuses.

Significance Level: A method for eliminating undesired results.

Standard Normal Distribution: The ordinary, usual, typical, and common spread.

Synthesis: Trying to put things together that do not fit at all.

Taxonomy: The reason for paying taxes.

Typology: The science of writing on a typewriter.

Uncertainty Principle: The fact that you're unsure about the answer.

Universal Hypotheses: What a famous film studio believes.

Virtual Reality: Putting on your headset and suddenly finding yourself in the Matrix.

Working Hypothesis: The strange belief that your work is appropriately paid for.

If you cannot answer a question, pretend you know the answer, but you have trouble in formulating it:

I know exactly what you mean, but how should I put it? I remember, I read about it, but it does not occur to me at the moment...

In online defences, it is advisable to pretend to have bad Internet connectivity and interrupt your answers from time to time by switching off your network card.

When the supervisors tell you the grading, behave shocked, look depressed, and argue against it by blaming the poor presentation conditions or by pretending to have bad mental health and disruptive family affairs.

Finally, don't forget to publish a formal complaint on pertinent social media channels, clarifying that the only reason you failed your thesis must have been the dreadful supervision of professors at this horrible university.

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Markus C. Hemmer is a professor and program director at IU International University. He started his scientific career as a chemical engineer and worked at the universities of Mainz and Hannover in analytical geochemistry. Markus Hemmer continued with chemistry studies in Hannover and Erlangen and received his PhD in computational chemistry on mathematical models for molecular representation. After years in research, he moved to the software industry as a product innovation manager and project manager for scientific information systems.

If asked about his motivation, he would answer, "Bridging the gap between science and business." Always interested in sharing his experiences, he continued to educate and lecture throughout his career in analytical chemistry, research methodology, artificial intelligence, programming, computer networking, and IT security. He used his experience in business to add IT management, quality management, and project management to his portfolio. He supervised more than 250 theses, preferably with his colleague Thorsten Fröhlich.

Thorsten Fröhlich, a professor at IU International University, has been a persistent force in entrepreneurship since 1991. His academic roots trace back to the University of Cologne, where he studied Chemistry and obtained a PhD for his research on application-oriented computational models for chemical multicomponent analysis using spectroscopy. Parallel to his academic pursuit, he ventured into the entrepreneurial realm by launching a scientific software company, providing advanced solutions in analytical evaluation and laboratory information systems for several years.

In 2000, Prof. Fröhlich manifested his entrepreneurial acumen by initiating and developing information portals such as chemie.de, chemeurope.com, and bionity.com with students from Freie Universität Berlin. His motivation resides in reconciling information technology and business, a vision reflected in his teaching areas at IU International University. As a lecturer in IT Management, Big Data, AI in Business, and the application of computational models to various business applications, he has supervised and co-examined over 200 theses, often in collaboration with his colleague, Markus Hemmer.

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