Masters Research Handbook

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Foreword

You have just about embarked in your very first Masters research project. That's both exciting and daunting.

Exciting because you will be able to focus on a topic of your own choice and to investigate in depth an issue or problem which is of particular interest to you, either personally or professionally. In doing so, you will acquire a deep knowledge of that topic, conduct a unique and novel research study, and develop and apply a wide range of research skills.

Daunting because your success will depend on you demonstrating your mastering of the topic and of the research process, that you can exercise competently a wide range of research skills, and can communicate your work effectively through an academic dissertation, possibly the largest and most demanding piece of writing you will ever undertake.

The aim of this handbook is to support you in taking your first steps into academic research at Masters level. It will provide you with a solid scaffolding for you to become a competent and confident researcher. It will demystify the language around academic research and, through practical advice and activities, will help you plan, manage and execute your project work successfully from start to finish.

But the benefits don't stop with the completion of your Masters project. In succeeding in your research project, you will have also gained and demonstrated a wide range of skills which are professionally relevant and valued by employers, from problem solving to effective communication, digital and information literacy, self-management and resilience. These transferable skills will serve you well in your profession and your life, regardless of the path you will take after your Masters course.

Chapter 1

So, you want to do a research project!

Well, you've come to the right place...

1.1 What is academic research?

In its most general sense, research is investigation, fact-finding, exploration and analysis. However, academic research is first and foremost about the *generation of new knowledge* with respect to what is already known in a field of study. New knowledge is what academic research must deliver.

Academic research is therefore about *the process of knowledge generation* and how it is executed. The expectation is that of a *systematic and rigorous process* of collecting, analysing and interpreting data, of drawing well-founded conclusions from evidence and explicitly stated assumptions, and of presenting findings in a clear and logical manner. There is also an expectation that your work is legal and ethical in all respects, both in the treatment of other participants and of any sensitive information, and in the way you report your work. It is this rigorous process of academic research that you will learn and practise by following the guidance in this handbook.

Academic research is also a *collaborative endeavour* within a field of study: even if you are conducting your project on your own, you will build on what researchers have done before – standing on the shoulders of giants as one great scientist once said, adding one more piece to the jigsaw puzzle so that future researchers can build on what you have done – by standing on yours!

With the completion of your Masters, as a new researcher you will join a community of peers.

Activity: What is academic research? #1

You will have been involved in a process of personal research already in your life, probably daily, discovering knowledge that is *new to you*. Every time you search the web and find information about something you didn't know, for instance, your own personal knowledge grows.
Take five minutes to think about how this personal research process differs from academic research. Write down your answer[a].

Discussion

If the knowledge you seek is something you can easily find in existing sources, e.g., books, articles, the web[b], etc., then it is already part of the existing body of knowledge, so there is no new knowledge generated in a general sense. It is also unlikely you will have followed a rigorous and systematic process in collecting and analysing data to draw your conclusions, possibly because data are incomplete or of poor quality, or your analysis is not very rigorous. The issue you are investigating may also be of no relevance to a wider community. Rather than academic research, this is a process of personal learning.

[a] This book is full of activities like this. Each one is designed to help your personal research process about your Masters project. Each asks you to think about something and then write down your answer, which you should always do. Writing down your answer means you can revisit it later.

[b] Of course, we're talking reputable sources. All that is on the web isn't knowledge! Your studies will lead to new *reputable* knowledge.

1.1.1 Masters level research

Now that you know what academic research is about, you may be wondering what is special about Masters level research. This is research in the context of a Masters programme: typically such programmes have capstone• projects as their final module.

• A *capstone* is a large flat stone that completes a tomb. A capstone project completes a degree or other programme of study. The two are not related:)

Masters research is no different from any other kind of academic research in that it you will be expected to generate some original knowledge within your field of study, perhaps by addressing a relevant, non-trivial issue or problem within that field. It will be conducted in a rigorous, systematic and ethical manner, by applying accepted research methods and techniques.

However what makes your project Masters level compared to a Doctorate or post-doctoral research is primarily its scope: you must complete your Masters project within the time constraint of your Masters course, which will be a small fraction of the time you would have to spend on a Doctorate•. Therefore, at Masters level you must trade off your ambition as a researcher with what you can realistically achieve within the available time. Often Masters projects take an existing idea or approach and apply it in a novel way, while a Doctorate project may come up with a ground-breaking, completely new approach.

• A Masters capstone module is usually 600 hours of study. A Doctorate could be as much as 10 times that.

Masters degrees leave very little room for trial and error, hence it is critical to identify a scope appropriate for your intended research very early in your studies. This might well involve choosing a topic proposed by an academic who will become your supervisor. In addition, your choice of topic will be limited by the degree for which you are studying. If you're doing a Masters in Geography, for instance, a capstone project in the area of information security is not going to be relevant.

Lastly, the range of methods and techniques• you will apply at Masters level is likely to be narrower than those used by a Doctoral researcher, as the latter may be too time consuming to be feasible. This, too, limits the type of the research problems you will be able to address in your project.

• You'll hear a lot about methods and techniques that apply at Masters level in the following chapters. The skills you will build on top of them – critical thinking, problem solving, reflection, for instance – are generally useful, particularly in your professional career. So, there are very good reasons to study them well, even if you might get a bit sick of them during your project.

Example

The recent explosion of AI solutions has been driven by the creation of technology which is able to do human-like things, for instance the creation of images and text that is sometimes indistinguishable from what you or I might write. Some might go as far as to say that AI is creating new knowledge!
A good topic for a Masters' project might be to investigate the extent to which AI technology can be said to be 'doing research'.
The originality of such project comes from the novel combination and application of existing techniques, or might build a framework for distinguishing new knowledge from the simpler re-hash of old knowledge. This project might come up with new Intellectual Property[a] (IP) capturing ways of distinguishing AI- and human-knowledge generation that leads to practical tools for use by business and education.

[a] Intellectual Property (IP) is the practical part of new knowledge. Many Masters projects have led to IP that has been developed, franchised, and/or sold. Many areas, including law, health, software engineering, and others, recognise that IP is an important way of delivering economic benefits to a client base, business, or public body. Your university will have an IP policy that you should know about before signing up if there's any chance your IP will be valuable. There's more – much more – about this in Section ?

1.2 What you will have achieved as a Masters' graduate

While there may be differences in the specifics of each Masters, there are benchmarks which define the knowledge and skills all Masters' graduates must attain. Many countries use standard frameworks to define their academic qualifications. In the UK, for instance, the UK Frameworks for Higher Education Qualifications align to the Framework for Qualifications of the European Higher Education Area, bringing together standards across the European Union to ensure comparability between European degrees.•.

The UK has adopted the following definitions:

• The ENIC–NARIC Networks are notable in ensuring the academic recognition of qualifications across 55 countries. See https://www.enic-naric.net/page-framework-qualifications-europe-and-north-america-region

Quote

Master's degrees are awarded to students who have demonstrated:

1. a systematic understanding of knowledge, and a critical awareness of current problems and/or new insights, much of which is at, or informed by, the forefront of their academic discipline, field of study or area of professional practice
2. a comprehensive understanding of techniques applicable to their own research or advanced scholarship
3. originality in the application of knowledge, together with a practical understanding of how established techniques of research and enquiry are used to create and interpret knowledge in the discipline
4. conceptual understanding that enables the student:
    - to evaluate critically current research and advanced scholarship in the discipline
    - to evaluate methodologies and develop critiques of them and, where appropriate, to propose new hypotheses.

Typically, holders of the qualification will be able to:

1. deal with complex issues both systematically and creatively, make sound judgements in the absence of complete data, and communicate their conclusions clearly to specialist and non-specialist audiences

2. demonstrate self-direction and originality in tackling and solving problems, and act autonomously in planning and implementing tasks at a professional or equivalent level
3. continue to advance their knowledge and understanding, and to develop new skills to a high level.

And holders will have:

1. the qualities and transferable skills necessary for employment requiring:
   - the exercise of initiative and personal responsibility
   - decision-making in complex and unpredictable situations
   - the independent learning ability required for continuing professional development.

This definition establishes key *learning outcomes*• for a Masters graduate, primarily:

- Advanced knowledge at the leading edge of an academic discipline
- Critical thinking in evaluating existing knowledge, research methods and their application to generate new knowledge, and in making judgements and deriving conclusions
- Originality in applying knowledge and techniques to address complex problems and generate new knowledge
- Effective communication to diverse audiences
- Self direction, autonomy and independent learning

• A *learning outcome* defines what a student should be able to do after their study. Learning outcomes are tested in assessment, exams and, in the case of research, the dissertation or thesis. Although, in this case, they are based on a standard, they may be described differently in for your Masters – often useful detail is added. Knowing the learning outcomes for the Masters degree you are studying can give you a real advantage when it comes to writing!

1.3 The role of your supervisor

For your Masters, you will be assigned an academic supervisor to support you throughout the project – a research expert highly knowledgeable in the subject area of your research. It may even be the case that your project topic comes from suggestions from, or previous research conducted by, your supervisor.

There's a hint in the title – your supervisor is there to supervise your studies: to guide, make suggestions, and engage in discussion on all aspects of your research. They are unlikely to want to micro-manage your project (but it does sometimes happen!). But, whatever, ensuring that you make the required progress and meet the required standards remains your responsibility.

It's sometimes that case that, as you make progress in your research your knowledge and expertise will grow to rival that of your supervisor. However, your supervisor, as an expert in the *process* of research, will continue to provide invaluable guidance and support throughout your project.

Depending on your course regulations, your supervisor may have additional roles. For instance, your supervisor may be required formally to assess whether you are making the necessary progress as you reach each milestone, or may be required to validate that the research carried out is indeed your own work. Missing their assessment and validation is very likely to slow progress, and in the worst case, stop you completing your Masters.

So, to discharge their various roles, your supervisor must have sight of your work and how it develops throughout the project: engaging with your supervisor regularly, discussing your ideas and their development in detail will be a very important part of conducting your project.

It is therefore essential to your success that you develop a close working relationship with your supervisor as early as is possible and engage in an active dialogue on all aspects of your research on a continuing basis.

You supervisor may have more than one student conducting research with them. This means that there will also be an expectation that *you* drive and manage the interaction with your supervisor.

Activity: Managing the interaction with your supervisor #2

If you haven't already done so, get in touch with your supervisor to introduce yourself and discuss how they want to work together.

After the meeting, write down what you have agreed and create diary appointments in your favourite calendar app accordingly.

Make sure your supervisor formally agrees – although, these days, this is usually just a matter of RSVPing to a calendar invitation.

Guidance

Before contacting your supervisor, you should think about *your* availability for a 30 minute meeting every week, for instance, or 60 minutes every fortnight. This will make it easier for you to identify and agree with your supervisor a regular slot to discuss your ideas and work progress. You should also

account for periods when you or your supervisor may not be available.
It is important to book regular diary slots for the duration of the project. It may not be that you need every meeting you arrange, especially in the later stages of your research, but it will be good to know that the time is there if you do need it.
This activity is particularly important if you are a part-time student, possibly juggling study, work and family commitments.

1.4 What is expected of you

There are key differences between doing a research project and studying a taught course. Awareness of those differences will help you prepare better for your Masters research.

These differences arise because of the higher demands of an academic research project to demonstrate i) self-direction, ii) critical thinking, iii) time and task management, and iv) information management.

1.4.1 Self-direction

A Masters' research project requires you to be in the driving seat•, including identifying relevant materials you must study and skills you need to develop and apply to carry out your project.

• This includes "managing" the interaction with your supervisor, as mentioned earlier.

While in your previous studies, most of the materials were likely to be provided for you alongside detailed advice on how and when to study them, on a research project those decisions are left up to you to a large extent. In particular, you will need to decide what to read and what to ignore in relation to your chosen topic, determining its relevance and how to use it in your research.

You will also be responsible for understanding the academic standards required, and for organising your research work. This is part of demonstrating that you can exercise self-direction in planning, executing, and critically reviewing your work and that you are truly an independent learner.

This handbook will provide plenty of advice as to how direct your own research.

Activity – Self direction #3

Write down three areas of your life where you need to be self-directed. For each, write down how you go about being self-directed, from how you start to how you finish. What does it feel like to be self-directed? Is there some emerging pattern?

Guidance

Those areas might be from your work, your previous Masters studies, your personal interests, hobbies, or some other aspects of your life.

1.4.2 Critical thinking

Your Masters research will require you to think critically about all aspects of your work. In essence, critical thinking is about asking questions systematically to look for evidence and good reasons in order to form your own judgements, instead of accepting what you read or hear 'at face value'.

At the heart of critical thinking is an ability to maintain an 'objective' position by weighing up all sides of an argument, evaluating its strengths and weaknesses, and testing how sound the claims made and their supporting evidence are. This will require you to scrutinise arguments in great detail and with some degree of skepticism. Such an objective stance will help you judge good and bad arguments, regardless of whether you agree with them.

In your project, you will be expected to think critically about all aspects of your research and to capture such thinking in your writing. As the author of a dissertation, critical thinking will benefit your ability to build stronger arguments, avoid bias and link your claims to appropriate supporting evidence. As a reader of the academic literature, critical thinking will help you assess the strength of other researchers' arguments and identify unsupported claims and illogical reasoning.

Critical thinking is both an attitude and a skill essential in academic research, which this handbook will help you develop. It is also beneficial to your professional and private life. In fact, it is likely that you already think critically in many aspects of your life.

Activity – Critical thinking #4

Write down three areas of your life where you need to think critically. For each, write down how you go about thinking critically, from how you start to how you finish. What does it feel like to think critically? Is there some emerging pattern?

Guidance

These areas might be the same areas as for the previous activity, or might be different. You might even find that they are parts of previous activities.

1.4.3 Time and task management

For your research project, you may be provided with some broad guidelines and deadlines• around which you should conduct your project in general. However, you will be expected to organise your time, and plan and execute your work in detail to meet those deadlines.

• Deadlines for research tend to be absolute as they affect the cycle of Masters' assessment and validation.

Within the set duration of your project, you will need to plan, organise and execute your research and submit your final dissertation. It will be up to you to develop and keep under review your personal research plan, allocate time to tasks, and meet deadlines and milestones.

You will find that one of the challenges of conducting academic research is that it is open ended. Therefore you will need to learn how to set boundaries and use your limited research time effectively to meet the requirements of a Masters.

This handbook will help you plan your project work based on a 5-stage framework we have developed for this purpose.

Activity – Time and task management #5

Write down three areas of your life where you need to manage your time and tasks. For each, write down how you go about managing them, from how you start to how you finish. What does it feel like to manage tasks and time? Is there some emerging pattern?

Guidance

These areas might be the same areas as for the previous activity, or might be different. You might even find that they are parts of previous activities.

1.4.4 Information management

The volume of materials you will need to read and study during your project is considerable: you will need to read extensively around the topic of your choice, as well as research approaches to apply in your research. This will result in a large amount of information that you will need to gather, organise, store and make sense of, including making copious notes as you go along.

You will also need to submit a substantial final dissertation. In the UK, for instance, a Masters research dissertation is usually in the range of 10,000 to 15,000 words. This is likely to be much longer than any other written work required by your previous studies. Therefore you will also need to structure your narrative appropriately and present your work in compliance with standards and conventions for academic writing.

All this will require you to develop and apply a range of new skills, which this handbook will help you develop.

Activity – Information management #6

Write down three areas of your life where you need to manage information. For each, write down how you go about managing information, from how you start to how you finish. What does it feel like to manage information? Is there some emerging pattern?

Guidance

Again, these might be the same areas as for the previous activities, or might be different. You might even find that it is part of previous activities.

1.5 Key skills

In this book, there are some basic skills that you will practice over and over again in your project. As they are critical to your success, it's worth considering them upfront. One benefit of thinking about them early is that, if you feel that you're lacking in any of them, you can prioritise their study early on.

1.5.1 Active reading and note taking

Throughout your project, and particularly when reviewing the literature, you will read lots of materials, and you are likely to spend more time reading and assimilating new content than you may have experienced in your previous studies.

It is important, therefore, that you become both effective and efficient at reading and note taking. The key points you need to keep in mind are:

- You take notes as you read.
- You should be disciplined and systematic in your note taking, so that you can easily locate and review your notes when you need to during your project.
- You won't need to study in depth all that you read, so you should develop reading techniques both to grasp the essence of an article very quickly, and techniques to dig deeper into content and meaning.

These practices will help you become an **active reader**, that is one who engages with the materials and is able to assimilate the important points in an effective manner.

Activity: Your note taking practice #7

Think of how you take notes when reading new materials. Write down key practices you apply and how effective they are in helping you assimilate new materials.

Discussion

These are things I usually do. While reading, I highlight definitions and word or phrases of interest, and make annotations in the margin next to paragraphs which make significant points, or provide useful summaries or raise interesting questions. If reading a physical book, I attach post-it notes to pages which are of particular interest, so that I can return to them easily.

After reading a whole article or a chapter in a book, I jot down some bullet points summarising key insights from my reading, my overall judgement of the whole reading, and how it may be useful, or otherwise, for my work.

I usually keep my notes and summaries with the physical or digital copy of what I have read, and I also keep together related articles within my file system — in the past, I used to have a physical filing cabinet for this, but these days I work almost exclusively with digital content appropriately organised in folders

and sub-folders.
You will have come up with a different set of practices. What matters is that you reflect on how effective they are or where improvements may be needed.

1.5.2 Digital literacy and tools

Unless you're thinking of handwriting your dissertation•, you're going to make use of digital tools for text preparation, bibliographic management, note taking, etc.

• *And it has been done, although perhaps not that recently, check out* `https://www.reddit.com/r/Handwriting/comments/b9vmss/my_mums_handwritten_thesis_from_1982/`*, for instance.*

There is a vast range of tools, some of which you will be already familiar with (but might not be suitable for the very long document you're going to have to write) and some that you are going to have to learn how to use – and find time for that learning. The most important of this latter group is probably those for *bibliography management*.

So, why don't we start with these?

1.5.3 Bibliographic management tools

During your project, it is essential that you keep track of the articles and papers that you read, alongside your notes on their content and relevance, or otherwise, to your project. Some you will access over and over again during your research; others you will only cite as part of your literature review; others still, you may just discard as not relevant. Whatever their final use in your project might be, it is important that you keep track of what you have read and the use you can make of it as you go along.

As the amount of reading grows, keeping track can quickly become overwhelming. This is where a **Bibliographic Management Tool• (BMT)** can help you. If you are not already using a BMT, this is the time for you to pick one and master its basic functionalities.

• These are also known as Reference Management Tools,' 'Reference management software' or 'Bibliographic management software.' Wikipedia has a comparison of bibliographic management tools here: url{https://en.wikipedia.org/wiki/Comparison_of_reference_management_software}

Briefly, a BMT is a software tool that can help you collect and save details of documents you have used in your research, and from which you can generate easily references, reference lists and bibliographies in a variety of bibliographical styles, to include in your dissertation and other reports you may have to produce during your studies. Hence, its basic functionalities include:

- a repository into which you can store the details of each document that you have read (authors, title and so on), your notes on the document, and even a copy of the document itself. Where the repository is online, the tool may allow you to share your collections with other users. In addition, in many cases, the reference sharing service will enable you to download many of the necessary citations from the database.

- an export mechanism to desktop word processors, such as MS Word, Apple Pages or Apache OpenOffice, so that you can include your citations in your text and generate your reference section automatically. The exact mechanism and its accuracy vary between tools, but it is likely to generate a list of references with most (if not all) the required elements of your chosen bibliographical style — some manual checking and editing may still be needed to ensure that the output conforms to the required style.

Activity: Investigating BMTs #8

Visit the wikipedia article that compares notable reference management software (the link is in the related note above). Count how many are included, which ones are free or licensed, and which operating systems, devices and work processing software they are compatible with.
Choose a couple which may work with your computing devices and software. Review their key features.

Guidance

If you already know or use a BMT, you may wish to compare its features with those of others in the wikipedia article. If you don't know where to start, you could consider Zotero first.
It is also possible your university has licensed one BMT that you can use for your project, so you should find out whether that is the case and what its key features are.

1.5.4 Keeping track of your digital assets

Beside your growing repository of articles from the literature, which you should manage through your chosen BMT, during your project you will be collecting and producing lots of other digital **research assets** which are needed for your research and will contribute to your dissertation. These may include data, images, tables, your own notes, comments from your supervisor, etc. All these assets will need organising and managing in a disciplined and systematic manner.

The simplest and cheapest way to manage digital assets is to organise your file system appropriately. Here are two basic practices you could apply:

- Establish a naming convention, so that the content of each file is clear from their name.
- Establish a coherent folder structure, so that the relation between files within each folder is clear, as is the relation between folders.

Activity: Organising your digital assets #9

Think of how you currently organise and manage your file system. Write down any rule or convention you usually apply and reflect on the extent it helps you keep track and locate easily the information you need.

Discussion

I try to keep my file system well organised and ensure I review it and clean it up on a regular basis. My file system is partitioned between personal and work-related assets. Under each category, I organise assets thematically, using folders and sub-folders structures. For instance, in my work-related folder, I keep a list of my projects organised into current, completed or terminated sub-folders, the latter for things I started but for one reason or other couldn't complete. Under each sub-folder, each project has its own folder, appropriately named with the project name. When folders become too crowded, I tend to refactor them, by creating more sub-folders to group related assets.
You will have come up with a different set of practices. What matters is that you reflect on how effective they are or where improvements may be needed.

1.5.5 Managing document versions

As you progress in your project, you will generate several versions of parts of your reports, for instance as your literature review grows or your chosen research methods change based on your growing research knowledge and feedback from your supervisor.

All these versions should be kept and carefully managed to ensure you can always access the latest version, but also refer back easily to previous work should you need to.

Your word processor may already include some functionalities to manage versions. If so, you should make sure you can use them effectively.

Equally there are bespoke **version control systems** you can use for this purpose, like Git•, which is free and open source.

• https://git-scm.com

However, you can simply use your file system wisely by applying an appropriate versioning convention to keep successive versions of your files in good order.

Activity: Thinking about how you manage document versions #10

Think of how you currently manage different versions of your documents or other digital assets. Summarise your practices and reflect on the extent they help you keep track and locate easily different digital versions.

Discussion

Part of keeping my file system well organised is to ensure I keep track of the most recent version of any document, but can also locate previous ones easily. While I don't use a separate version control system, I make sure that I keep previous versions of a document I'm working on in a separate folder within my working folder. I use a simple number system to identify versions, that is 1.0, 2.0, 3.0, etc. I only generate a new version when there is a significant departure from the current document, for instance, if I decide to restructure it significantly, or remove a substantial amount of content. I also generate new versions if I share a document with somebody for feedback, while still carrying on working on it.
This is not a perfect system, but it is simple and works for me. You will have come up with a different set of practices. What matters is that you reflect on how effective they are or where improvements may be needed.

1.5.6 Choosing the right word processor

If you have not written a substantial document, like a dissertation, before you should put some thought into how you are going to write up your project work. Your final dissertation is likely to be between 10,000 and 15,000 words, plus appendices, which makes it a substantial document. By following the advice in this handbook, you will also write reports at each stage, which will build on each other, so that you will be editing, reshaping, extending and re-versioning content you have written as you progress in your project. Therefore, you will need to choose the right tool for the job.

You could start by considering whether any word processors you may be familiar with and possibly used in your previous studies, is appropriate for these requirements. It is possible that you will need to develop more sophisticated word processing skills or use more advanced functionalities of your word processor of choice. You should also take into consideration the format your course requires you to submit your work in, and ensure your chosen software can generate documents in that format.

Whichever word processor you choose, you should ensure it allows you to:

- Manage multiple documents
- Structure and process large documents
- Back up your work regularly, possibly automatically, and restore documents which may have been corrupted by system errors or crashes
- Connect to your chosen Bibliographic Management Tool (BMT), so that citations and references can be managed easily and shared automatically between the two
- Generate documents in the formats required for submitting your dissertation and any other required assignment.

Activity: Investigating your word processor's advanced functionalities #11

Check the functionalities of your current word processor against the list above. Is it powerful enough to meet the above requirements? Write down the key functionalities you will need to use and make a note of any new skills you will need to develop, then set some time aside to practice them.

Discussion

LaTex is my favourite document preparation and typesetting system. It is a very powerful tool, particularly suited to scientific and technical content. It is also free and well supported by a large community of users.

Latex meets all the requirements above. I can use it to structure and process large documents, which I can split up and organise in separate sub-documents: for instance I can have different files for different chapters or different versions of a chapter, which I can then include flexibly in my final document.

The Latex system I use backs up my documents automatically and includes a recovery feature in case of system crash. It also connect with my BMT (I use BibDesk[a], but could use Zotero), so that all my

citations and references are easy to manage and shared automatically between the two systems.
One of Latex's most powerful features is that it separates output format from source text, so that I can change the style of citations and references, and in fact of the the whole document, very easily and generate outputs in different styles from the same source text.

[a] \url{Insert link} BibDesk is only available for the Macintosh Operating System

Although you might not like what we're about to say, the real Masters pros will use LaTeX, especially if you're writing:

- A mathematical or scientific dissertation
- A dissertation in which you will have lots of figures or tables
- A dissertation in which you will be cross-referencing between sections lots
- A dissertation that has a complex structure
- A dissertation that has many bullet points or enumerated lists
- A dissertation with many references and citations

You can find out why LaTeX is the document preparation system of choice at many blogs•.

• Including this one `https://blog.orvium.io/latex-over-word/`

However, LaTeX has a steep learning curve – or rather the investment of time that you will use for learning LaTeX will be considerable but it will, if your dissertation has any of the above characteristics, save you time and tears in the end, especially when you're making the final touches.

Activity: Investigating Latex editors #12

LaTex is a mature system and numerous editors are now available, from open source to proprietary, from desktop to web-based. My current favourite is Overleaf[a].
Conduct a web search to investigate its key features, and write down those which makes it particularly suited to writing a research dissertation.

Discussion

Overleaf is my favourite LaTeX editor for writing research documents of all size because it:

- Has all the power of LaTeX
- Is set up for research work
- Has a fantastic help system
- Has many, many templates – and may even have one customised for your university
- Can be used to track changes between versions
- Backs up your work
- Works through a browser, and so is available on all my smart devices[b].

[a] http://Overleaf.com
[b] It is quite difficult to see on my smartphone, though.

LaTeX also has a Word-like interface, through the LyX tool, which can reduce the learning curve. If you find it easier to use a Word-like interface, but want the benefits of LaTeX, you might like to try LyX.•

• LyX is available at \url{lyx}.

1.6 Takeaways

- academic research is about knowledge generation
- at Masters level it is critical you establish the right scope for your research as early as possible, as you have very limited time for remedial actions later on
- your supervisor is your best ally and you should establish an effective working relationship from the start
- as a Masters level researcher you are in the driving seat and expected to demonstrate critical thinking, self-direction, and competent time and information management throughout

- there are key skills (see Section 1.5) you must develop and practice from the onset
- choosing the right digital tools for your project will make your research life a lot easier in the long term, even if they require some investment upfront to learn how to use them effectively.

Chapter 2

The 5-stage Masters project framework

This handbook gives you a 5-stage framework with which to approach your research project. The framework has been refined over many years of working with hundreds of Masters students at the Open University•, UK.

• If you know anything about the Open University, you'll know that it is a distance–learning university, most of its students work at a distance and so don't attend lectures. If you think about it, the "at–a–distance" model is precisely what you'll be doing in your Masters project – you won't have lectures! This makes the Open University model really appropriate for a Master project.

We provide an overview in this chapter — we will break the framework down into stages in the following chapters, each chapter giving detailed guidance for that stage.

2.1 What do we mean by framework?

Writing a Master dissertation is a complex task: the goal is a complete 10,000–15,000 word dissertation on the research you have conducted which meets the required academic standards. There are many risks that you will face in writing it, which include:

- Misunderstanding what is required
- Running out of time
- Not having the skills or resources you need
- Choosing the wrong methods or techniques, or not applying them correctly
- Not having access to the evidence you need

- or simply, life getting in the way.

Our framework will allow you to manage these risks to give you the best chance of submitting something that will satisfy the examiners and show your Masters research skills off in their best light.

The framework comes with recommended stages and research activities, as well as metrics and guidelines to help you parameterise your project based on your course requirements, develop a work plan that meets your needs, and manage your work and your interaction with your supervisor effectively.

Study within our framework and you'll have your best chance of succeeding.

Because the key research requirement is for new knowledge, every Masters student will be working at the leading edge of their discipline. One corollary of this is that every dissertation will be different. Your project will allow you to show how your domain expertise in a focussed topic has developed through your studies and your dissertation will reflect that. That's your goal!

For us in defining our framework, it raises a problem – we cannot possibly know the details of your final dissertation. We can't know even simple things, like how many pages it will have exactly. We can't know what your arguments will be or what your conclusions or future work will contain. Neither can we know which literature you will consult, what the seminal paper in it is.

That would be a problem if our focus was only on the final form your dissertation will take. But we don't!

What we teach in this handbook is the process of arriving at your final dissertation. That's why we structure our framework into stages – each stage building on the previous, each moving you further down the line to your final dissertation. And because we have seen literally hundreds of students follow the framework as we have developed it, we know it can work and work well.

If this has convinced you that we're onto something, welcome aboard!

Your first step with us will be to learn about the research process that you will follow.

2.2 The research process and its key activities

A research process is the sequence of activities you undertake when conducting academic research.

Research is messy — looking into the unknown means there is no road map to follow and you will often have to retrace your steps and try different paths. So, moderate your expectations – you shouldn't expect a linear, orderly research process!

Instead, the research process is an iterative, incremental, and adaptive process of knowledge discovery — it iterates through its research activities in small incremental steps, adapting as your knowledge grows.

The exact path you will follow in your research project will be unique to you. However, you will go through some widely recognised activities, which are common to all research processes.

2.2.1 Identifying the research problem

A key concept in academic research is that of *research problem*. A research problem captures the knowledge gap to be addressed (*the need*) by the research within a particular field of study (*the context*). A well-defined research problem is the foundation of any research project as it clarifies the purpose of the research and its intended outcomes.

In this handbook, you will learn a practical approach to identifying and articulating your chosen research project.

2.2.2 Reviewing the literature

One of the major tasks you will have in compiling your dissertation is to give the reader sufficient background that they can check where you're coming from. To do so, you will be referring to the work of other authors and researchers throughout your project: this is collectively known as the academic literature. Depending on your degree, you may already have practise in doing this in your previous studies, for instance in writing academic essays for your assignments. For your Masters, however, the more definitive you can be in referencing the academic literature the better. This means that your review of the academic literature will be a significant part of your research project.

Your review has two key functions.

Firstly, it will help you contextualise your research in what is already known and where the knowledge gaps are, so that you can focus your research more tightly on a research problem which is relevant and significant to your field of study. This includes evaluating your own findings against those of others in your field.

Secondly, it will help you understand how to conduct your research: by reading your field's literature, you'll learn what is academically acceptable in terms of the methods and techniques which you can apply to address your research problem.

Reviewing the literature is both time consuming and demanding, and will require you to apply many skills which this handbook will help you develop.

2.2.3 Setting your aim and objectives

While your research problem helps you establish the contribution to knowledge of your research, your aim and objectives will help you establish the scope and boundaries of your project by stating the specific way in which your research will address the problem.

Scoping your project appropriately is necessary in all research, but is particularly critical at Masters level with its many constraints on the time you have and the methods you can feasibly apply.

2.2.4 Developing the research design

Your research design will summarise, explain and justify how your research is conducted for the benefit of your examiners and other readers•. As with your literature review, it will develop during your project: at the start, it will be a collection of your initial ideas; by the end, it will be an account of what you did.

Your research design will depend on many things. There are some obvious ones, including the type of research problem you are trying to address, the intended outcome of your research, the sort of evidence you will need, and the research strategies and methods that are acceptable within your chosen discipline.

There are others that are less obvious: you'll have to tailor your research design to the resources and expertise you easily have access to, and your preferred research style•. As a key participant in your own research, your own personal views and values will also affect your choices while developing your research design.

There are also some esoteric ones: some philosophical beliefs which are shared by researchers in your field in regard of how knowledge can be generated. Although fascinating, to really understand them well takes decades of study of others' writings, on top of which there will be hours on hours of conversations with other researchers. Clearly, this is not something you will have much time to dwell upon in your Masters project — you have a supervisor that can advice you, instead.

Research design is a field of study in its own right, one which has grown out of the many different academic traditions and ways of thinking across academic disciplines and subject areas. It's not easy to digest and is far from stable or complete: every so often a new book on research methods will be offered for review by a publisher. Research design is possibly one of the most challenging aspects of doing academic research and can be puzzling• for those just starting.

Because of this, you should rely on your supervisor for advice, particularly at the beginning, although your understanding will mature during your project. This handbook will help you develop such an understanding and assess which choices are most appropriate for your project.

• Although we all want to think differently, it is often the case that the examiners are the only people outside of your supervisory relationship that will read your dissertation. We'll talk later about how you can get your family involved – which may double your readership!

• You may have heard of a *learning style*. A research style is similar – you may prefer, for instance, to talk to people about the practical ways they work as opposed to building theories of how they do so.

• It can sometimes be puzzling for experienced researchers too!

2.2.5 Gathering and analysing evidence

This is where you use your research design to gather and analyse the data and evidence• you need for your project. This is possibly the most exciting part of conducting academic research!

You're going to spend a lot of time doing this, and you'll have to circle back• to this activity as you learn more about your field and as your research develops.

• Data is raw information with no interpretation attached, while evidence is information interpreted to support your academic arguments. The two are closely linked, with data forming the basis of evidence, so that they are often used interchangeably. We will return to this topic in Section 3.5.1.

• One PhD student we know got to within 2 months of finishing their PhD when they realised that their research design led them to incorrect data analysis. That was a real critical moment in their studies, but they got it done in the end. Just.

2.2.6 Interpreting and evaluating findings

This is where you review your findings critically to establish the extent your research has met its stated aim and objectives. Because it relies on the way you interpret your evidence, it is closely related to and typically influences evidence gathering and analysis, so that you will iterate between these two research activities for a large proportion of your project.

2.2.7 Reporting

Throughout your project you will need to report in a critical• and rigorous manner on all aspects of your research, including both new insights and the process you followed to arrived at them. Therefore, integral to your reporting is a critical appraisal of the strengths and limitations of the research you have conducted, the overall conclusions which can be drawn from it and what the impact on future research might be.

• Developing your critical voice is, er, critical to being a successful researcher. On a good capstone project, an effective critical voice will be highly valued by your examiners.

While your course may only require you to submit a final dissertation for assessment, it is essential that you write up reports throughout your project. This will allow you to improve your academic writing skills, share what you have done with your supervisor for feedback and formative assessment, and develop your dissertation incrementally.

2.2.8 Reflecting

Reflection is what makes your learning more effective, and relevant and useful to your own practice. Reflection is important in any kind of learning, but particularly in the experiential learning• of conducting research.

• Experiential learning is 'learning by doing,' using reflection to think critically about what you have experienced and relate it to knowledge and how it can apply to new situations.

Our framework therefore emphasises reflection as an essential activity within the research process, to develop and consolidate the knowledge and skills you need to be a competent and confident researchers.

2.2.9 Planning work

Some researchers will have worked much of their lives on one problem. You don't have that luxury – or burden, depending on your perspective!

Time-bound research, like that you are just about to start, must be planned carefully as early mistakes and missteps can be very difficult to correct later.

For this reason, we recommend that you build a *work plan*. At its core, a work plan summarises all activities and work to be conducted to complete the research, how to organise and execute them in the time-span of the project and which milestones must be met.

Standard project management techniques apply, but with the caveat that in academic research you are usually planning for the unknown, so not everything can be figured out upfront and some level of adaptation will be needed. Hence, understanding what might change, related risk and how to manage it is an essential part of planning your research project.

2.2.10 Managing risk

Risk captures the likelihood of something going wrong combined with the impact that will have on your project, both on time, resources and outcome. In theory, both positive and negative impacts can be assessed, but very often the focus is on what can affect your project in a bad way. It is essential that you make an assessment of risk at the start of your project and identify ways to manage it, then monitor and adjust as you go along.

2.2.11 How the activities relate to each other

Figure 2.1 depicts the relations between activities in the research process: as you can see, these are complex relationships, with much tangling and intertwining. Note also that reflecting, reporting, work planning and risk management apply to both individual activities, and the process overall, which is why in the figure they are separated from the other activities.

The main relations between activities are as follows (with reference to the numbering in the figure):

1. The research problem helps you identify relevant literature to review
2. The literature you review helps you identify current knowledge and existing gaps and frame the research problem

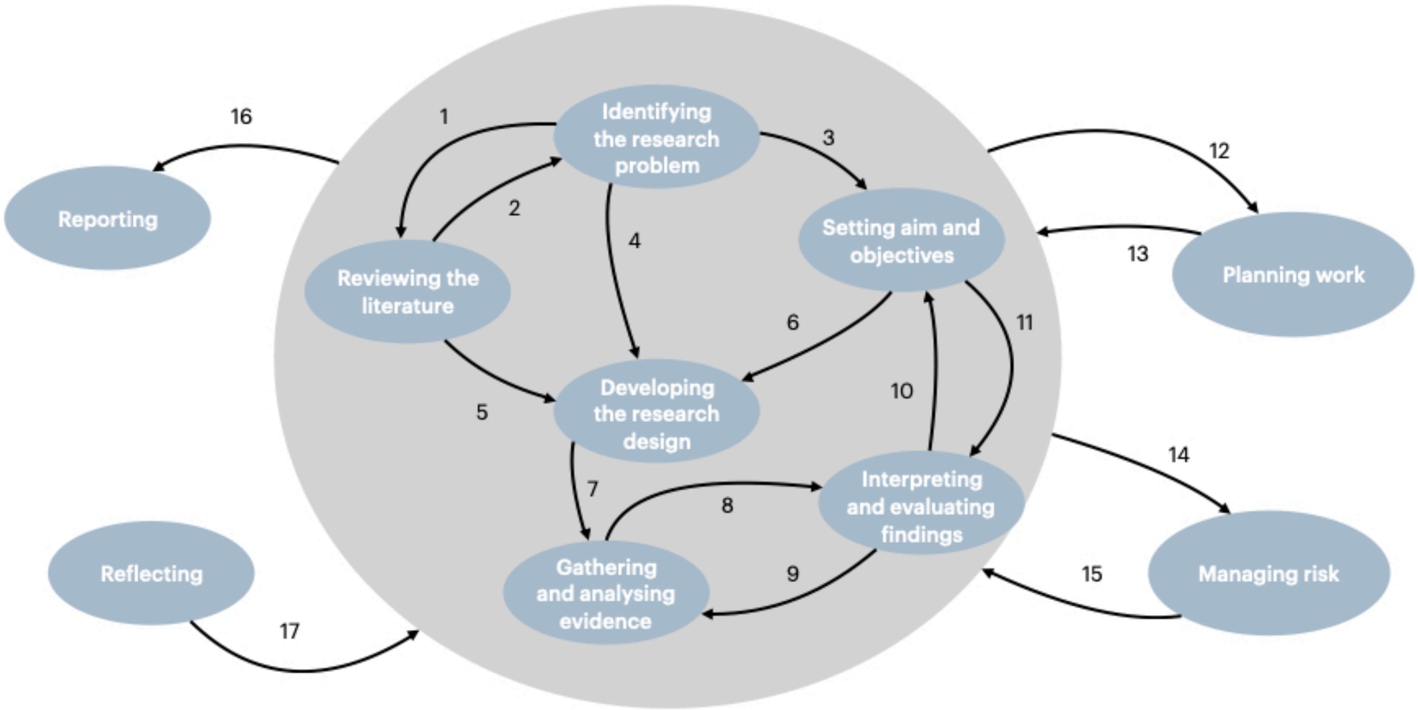

Figure 2.1: Research activities and their relations

3. The research problem informs what the aim and objectives should be
4. The research problem identifies the phenomena under study, which inform your choice of research strategy and methods within your research design
5. The literature also helps you establish which research strategy and methods to apply and how
6. The objectives inform the research strategy and methods to discharge them
7. The research designs tells you how to gather and analyse evidence
8. The analysis of evidence feeds your interpretation and evaluation

9. Your interpretation and evaluation may require further evidence gathering and analysis
10. Your interpretation and evaluation assess the extent aim and objectives are discharged
11. Aim and objectives gives you criteria for your evaluation and interpretation
12. Activities feed your project plan
13. Your work plan informs what you have to do and when
14. Activities give rise to risk to be managed
15. Managing risk will constrain the way you carry out activities
16. Activities and their outputs must be documented in your reports
17. Your reflection on all you do will trigger changes and adjustments to all your activities

The figure highlights the interconnected nature of everything you do during a research project, and how the need to revisit some activities, perhaps as the result of reflection, will trigger adjustments to others which are closely related, so that there is no linear path through that all projects will follow. The figure also does not assume there is a set starting point, although, as you will see in the next chapter, identifying the research problem from an initial topic is the way we recommend you get your project started. Equally, research can go on forever as reflecting of what you know may trigger new avenues of enquiry to follow. Of course, in the context of a Masters project you only have a set amount of time to complete your work, so that at some point you will need to decide that you have done enough and finalise your project dissertation.

2.3 The 5-stage framework for your research

This handbook recommends you organise your research project into five major stages. We've developed our 5-stage framework from our experience of working with hundreds of successful• Masters research students, our knowledge of the iterative, incremental and adaptive nature of the research process, and our awareness of the many risks that must be managed to be successful.

• And a few, a very few, unsuccessful ones...

Given this, the stages have the following characteristics:

- Each stage contains many interrelated research activities•, so that you will often revisit earlier activities as you learn more about research and move forward in your project. From one stage to the next, however, the balance between those activities will change reflecting your increasing expertise in them and the progress you have made

• Don't worry, we're going to go into exhaustive detail about this the remainder of the book!

- Each stage builds incrementally and adaptively on work from the previous stage(s)
- Each stage includes critical reflection on what you have achieved and learned, and how this should inform the work ahead
- Each stage includes some report writing so that your dissertation builds with your expertise
- Each stage includes re-assessing risk and adapting your work plan.

Because it sets up the whole research project, in Stage 1, alongside developing a deeper knowledge of the research process and its activities, you will do lots of prep, including identifying your project's scope and potential contribution to knowledge, doing an initial risk assessment, outlining an initial work plan, and setting up the relationship with your supervisor.

Given a successful set up of your research in Stage 1, from Stage 2 onwards you'll spend more time on the specifics of your research and less on the process•. Even so, in each stage, you will need to review your project risk and progress, adjusting your project plan accordingly.

• Which will probably come as welcome relief:)

The 5 stages are designed to balance the activities you need to carry out in your project; each is allocated a recommended proportion of the overall project time, as outlined in Figure 2.2. Their precise balance is influenced by many factors, including topic, your previous research experience, if any, and your supervisor's advice, so take the figure with a pinch of salt – it's only meant to show you how the focus on research activities changes in the stages. We will consider more detailed descriptions by stage in the follow-up chapters, including indicative timings, but again, nothing is written in stone.

Activity: Considering the stages and activities in the framework #13

Consider Figure 2.2 carefully, taking notice of which activities are more prominent in each stage, and the relative length of each stage within the framework. Jot down a timeline for your project based on your expected study length in weeks, identifying when each stage starts and ends.

Discussion

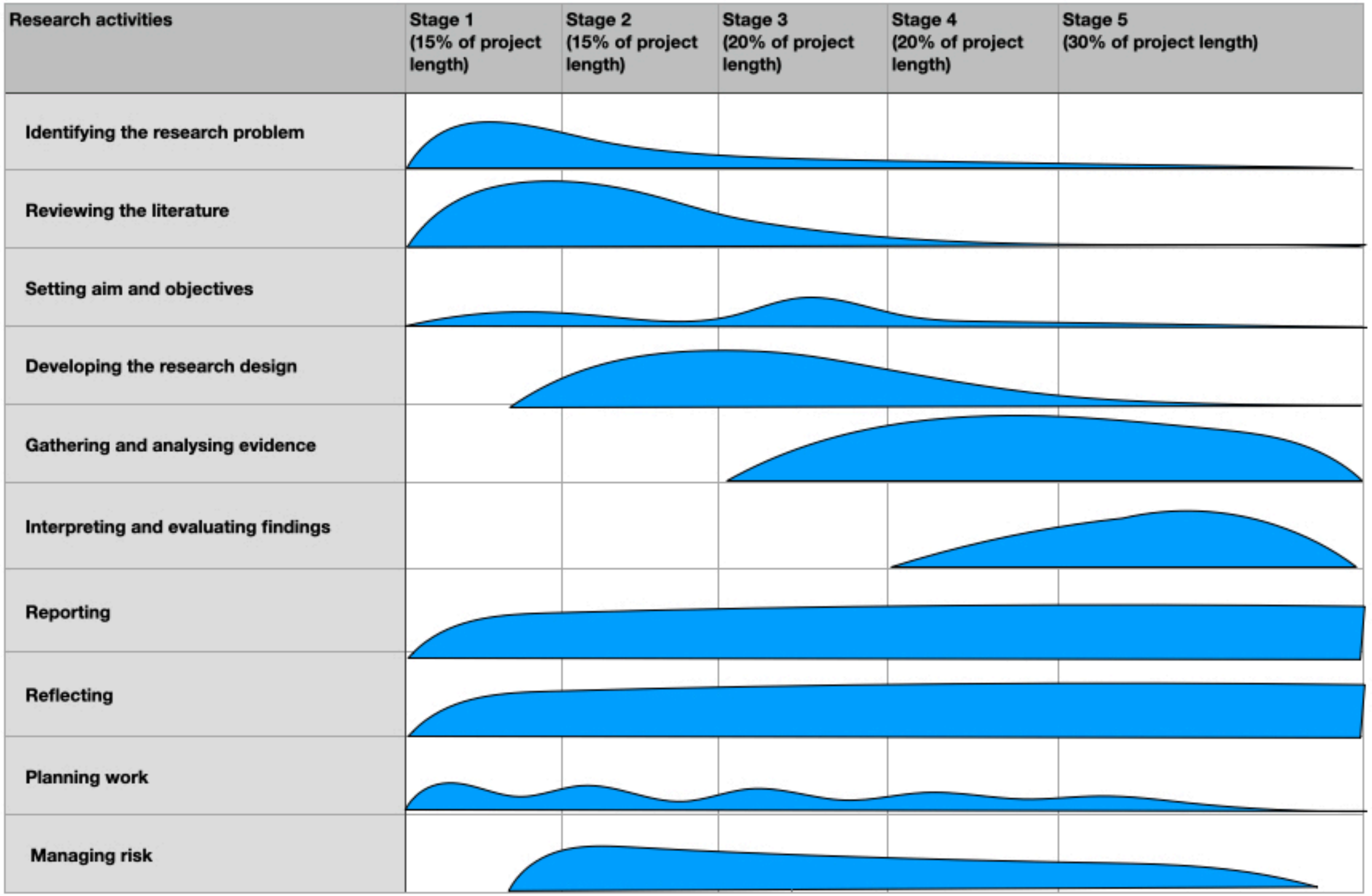

Figure 2.2: Change of focus between research activities across the project stages

Some activities are more prominent in the early stages, specifically identifying the research problem and reviewing the literature. Others become prominent in later stages, particularly gathering and analysing evidence, and interpreting and evaluating findings. Others still, feature throughout the project: this is particularly the case for reflecting and reporting.
Your timeline will be specific to your project, of course. Say, you have 48 weeks in total. Then, Stage 1 will take 15% of 48 weeks, or just over 7 weeks, Stage 2 will take the same length, Stage 3 will take 20% of 48 weeks, or just under 10 weeks, etc.

In the following chapters we will break down the research activities, stage by stage, indicating what is expected at each stage to help your organise and plan your project work in some detail. Alongside, we will provide recommendations on critical aspects of your work you should discuss with your supervisor: this should help you guide your interaction with your supervisor, ask key questions and make the time you spend together more productive.

2.4 Critical success factors

We conclude this chapter by summarising critical success factors you should keep in mind during your Masters research:

Making good use of the 5-stage framework The framework in this handbook is the result of decades of practice, helping Masters students like you succeeding in they first academic project. However, it is not a straightjacket, and you should adapt it to your own needs. The framework was developed with the novice academic researcher in mind, but it may be that you already have some research experience, in which case some of the the timing suggested by the framework may be too generous. Equally, your own course may require you to submit some interim report as formative assessment, in which case the stages length may need altering to match your course requirements. Nevertheless, the framework provides a scaffolding to help you take control when planning and conducting your project.

Making good use of this handbook and its activities This handbook is designed to accompany you in your first journey into academic research, so you should follow its stage by stage advice to guide your project work. The handbook is also designed to be very practical, so that there are plenty of activities for you to do. The activities are there to help you make steady progress with essential work for your project and to help you develop your research skills: we strongly advise you complete them systematically.

Your working relation with your supervisor Your supervisor is your strongest study ally, a research expert who can guide and advise you on all aspects of your project, with whom you can discuss your research ideas, and who can assess that you are making sufficient progress at each point in your journey. It is essential that you develop a good working relationship with your supervisor, meet regularly and have an open and honest dialogue throughout your project.

Your self-drive and commitment The course you are studying may provide you with some structure to help your progress your project, including, for instance formal assessment points. However, you will be in the driving seat most of the time. You must choose your topic and research problem, how to investigate it, and how to organise your research time in detail; it is also up to you to understand the academic standards required and to assess which research skills you must develop further to meet them. Above all, it is up to you to commit to a sustained effort for the duration of your project, which may be several months.

Continuous effort Successful research requires continuity, so that you will need to set aside a sufficient and regular time for your research project every week, ensuring you keep making progress as you go along. Long breaks are incompatible with conducting research: while in your previous studies you may have been able to stop and start, and possibly cram lots of work around assignment deadlines, conducting research requires lots of time for reflection and for ideas to develop and mature, something you can't compress close to a deadline. Conducting research requires endurance, perseverance and continuous effort: it is a marathon, not a sprint!

Thinking and writing There is a crucial interaction between reading, thinking, and writing in research: reading informs your thinking; your thinking is what you try to express in your writing; your writing helps you make sense of what you have read, and hence of what you think, and informs more reading, thinking and writing. Because of this, while you will spend a lot of time reading and thinking, it is also essential that you write as you go along. The more regularly you write, the easier it will be for you to develop academic writing skills and the more critical your thinking will be.

Your dissertation It is very likely that your dissertation will be the only way your research is assessed. To be successful, your dissertation must demonstrate that you have mastered a wide range of research skills and can communicate your academic research effectively in writing. In fact, this is usually more important than any feature your proposed solution to your research problem might have. At Masters level, that you 'solve' your research problem may not even be necessary! What matters most is your scholarly and critical attitude to each element of your research and your grasp of what academic research entails as demonstrated by your written dissertation.

Making good use of your study support Last but not least, it is important that you assess your progress as you go along, and make the most of the support which is provided to you by your supervisor, and any other adviser on your course. There will be times when you will find working on your project very challenging and may lose confidence in your ability to complete it. Those are the times when it is going to be particularly important for you to reach out and ask for extra help, even if your first instinct may be to hide. All researchers experience such feelings at one time or another, so do not be discouraged: talk to an adviser and work through the difficulties you are having to overcome them.

2.5 Takeaways

- the research process is the the process you undertake when conducting academic research; its many activities are deeply connected, so that the process is both iterative and incremental, and can be messy
- the 5-stage framework is designed to help you plan and conduct your project.It is a practical framework, with plenty of activities and guidance to help your develop your research skills and perform essential research tasks to complete your project
- you can use the guidance provided to map the 5 stages of the framework to your project timeline
- following the framework will help you succeed, but other factors matter too (see Section 2.4).

Chapter 3

Stage 1: Scoping your research project

In all research, but particularly at Masters where time is limited, it is important to establish the scope of your project early on: this is the focus of Stage 1.

Stage 1 is fundamental as it gives you the solid foundation for the whole of your research project. As such it is an intense stage, where you will be expected to undertake the wide range of research activities summarised in Table 3.1. The table has entries for all but two of the research process activities that were introduced in Section 2.2. We did say that Stage 1 was intense!

Looking at the table, of the activities covered in this stage, *Reviewing the literature* is the most demanding at 30% of overall effort for this stage, closely followed by *Reporting* at 20% and *Identifying the research problem* at 15%, the former consisting in putting a report together after you have developed its constituent parts. Together, reviewing and literature and identifying the research problem are your first steps to understanding what your project's contribution to knowledge might be and so it is good to invest a lot of time in these. Setting aim and objectives (5%) and starting to develop your understanding of research design (10%) follow from them.

We have already mentioned the importance of reflection in research, and how it is essential for you to reflect on your increasing understanding of the research process and your own research practice as you go along. Unsurprisingly, therefore, the framework accounts for 10% of your time spent doing just that.

Equally, we have also stressed the importance of considering risk in your research and to manage your time effectively, therefore 5% of your time should be devoted each to risk management and to work planning.

In this chapter, you will start by thinking about how you will organise your work in this stage, then look at the other activities in turn.

Table 3.1: Research activities addressed in Stage 1 (15% of project length)

Research process activities	Deliverables	Learning Outcomes: by the end of this stage you will:	Effort	Suggested focus of your interaction with your supervisor
Identifying the research problem	initial research problem statement	be able to express a well-formed research problem	15%	suitability in relation to study requirements
Reviewing the literature	summaries of literature reviewed, organised by theme	apply Keshav's process to assimilate the content of an academic paper; use a summary-comparison matrix to track the content of articles; use a concept matrix and concept map to identify emerging themes; write up summaries of the literature around emerging themes	30%	scope of literature review and remaining gaps
Setting your aim and objectives	initial aim and objectives statement	be able to write appropriate research aim and objectives	5%	suitability and feasibility
Developing the research design	kinds of data, evidence and methods your project may require; ethical considerations you will need to take into account	know the kind of data and methods used in research; know which ethical and legal issues may affect research	10%	ethical and legal regulations which apply to your studies
Reflecting	your collection of thoughts about your own learning and practice	know the role of reflection in research	10%	
Reporting	Stage 1 report	be able to assess your research progress; be able to apply the given template to write up your Stage 1 report	20%	improvements required
Planning work	outlined work plan	be able to use Gantt chart (or similar) to produce a work plan	5%	suitability and possible adjustments
Managing risk	summary risk table	know what risk is; know how risk can affect research; be able to assess risk in your project	5%	possible missing entries

3.1 Planning your work for Stage 1

We have stressed how, as a Masters researcher, you will be expected to manage your project to a large extent, including planning your project work in some detail, monitoring your progress and making appropriate adjustments to your plan as you go along.

Key activities for project planning and to keep on track include:

- Identifying key milestones for your project, and what you are required to accomplish or deliver at each milestone
- Identifying the work you will need complete to reach each milestone
- Breaking down that work into discrete tasks
- Scheduling those tasks in the time available, and
- Making an efficient use of the time you have available.

As an important caveat, you should not expect your plan to be cast in stone! There are too many unknowns in a research project for you to be able to predict upfront exactly what is going to happen. Therefore, you shouldn't spend too much time trying to plan every single thing, and you should review your plan often to monitor progress and make adjustments as needed. In summary, your project plan should keep you on track, but should not be a straightjacket.

In this section, you will use the 5-stage framework as a tool to help you put together an initial plan your project work, focusing on the activities required in Stage 1. You will extend this plan, stage by stage, adding details and making necessary adjustments as you go along.

Activity: Breaking down your study time #14

Consider the timeline for your project that you defined as part of the activity in Section 2.3. Based on the number of weeks you allocated to Stage 1 in your timeline and the number of study hours per week at your disposal, use the percentages in Table 3.1 to calculate the suggested study time for each of its activities.

Discussion

Assuming you have allocated 6 weeks to Stage 1, with an average of 20 hours of study per week, then you have a total of 6 x 20 = 120 hours of study for the whole stage. Of these, you will need to spend 18 hours on identifying your research problem (15%, that is 120 x 0.15), 36 hours on reviewing the literature (30%), 6 hours on setting your aim and objectives (5%), etc., including studying the relevant parts of this handbook and carrying out the activities within. While your actual study time may deviate from these calculations, they should still give you a strong indication of how you should allocate proportions of your time among the different research activities.

3.1.1 Milestones, deliverables and tasks

The 5-stage framework identifies for you key milestones and deliverables at a general level: each stage is broken down into research activities, each with clear deliverables, and a written report on the work completed by the end of each stage.

Within each stage there is much detailed work to be done to reach such milestones. Therefore, at the beginning of each stage, you will be encouraged to plan such work carefully, by matching the generic activities in the framework to specific tasks in your project.

Activity: Identifying your project tasks #15

Consider the deliverables in Table 3.1 and write down how they correspond to tasks in your own project. Allocate time to those tasks based on the study time you estimated in the previous activity.

Guidance

Feel free to break tasks down into sub-tasks, but be wary of your plan becoming too detailed at this point.

3.1.2 Producing a project plan for Stage 1

You can now produce a project plan based on the milestones, deliverable, tasks and their required time you have identified.

This is no different from any other kind of project, so that many planning charts and tools are available which you can choose; in fact, you may be already familiar with some of them. Gantt charts are one of them, which we recommend you use.

Briefly, **Gantt charts** are scheduling charts that you can use to plan and organise your project work. A Gantt chart is usefully to get an overview of how your work will be broken down and organised over time, including an indication of how much time you will spend on each task, when tasks should start and end, and which tasks might overlap at any point in your project. As such, it is also useful to communicate your project plan to third parties. As a generic project management tool, a Gantt chart can be quite sketchy or very detailed: you should aim for something quite light, but still including all main tasks and deliverables of your project.

Activity: Investigating Gantt charts #16

If you are unfamiliar with Gantt charts, conduct a web search on introductory materials and examples. Select and review a small subset of resources you have found. Write down key points about using Gantt charts.

Guidance

In your web search, you'll likely find several links to digital tools supporting Gantt charts, tutorials on how to construct one, or even ready-made templates to fill in. You should focus on materials which can help you construct your own project Gantt chart.

Activity: Constructing your Gantt chart #17

Based on the outcome of your previous activities, create a Gantt chart for your own project in relation to Stage 1.

Guidance

If you already use a different project scheduling approach for projects in your own practice, then feel free to use that instead, as long as it can be used to organise your project work effectively and in a way which is easy to communicate with your supervisor, with whom you should share and discuss your plan. You will augment and adjust your plan in all stages of your project.

3.1.3 Key practices for managing your time efficiently

Your plan is more likely to work if you make an effective use of your time. Here is some key practices you should keep in mind:

Finding time for your research You need to make a realistic assessment of how much time you will have for your project, considering other commitments you may have, professional or personal: this is important for all students, but crucial for part-time study. Your course will expect you to spend an average number of hours per week on your project work throughout its duration, so you need to ensure you can dedicate that time to your project on a regular basis. But it is not just about quantity: you should choose your most productive time to dedicate to your research— in may be that you are a morning person, or you can focus better at night. In either case, it is important you come to your work with a fresh mind, so that you can concentrate on the tasks at hand.

Ensuring continuity of effort As already noted, research requires continuity of effort, as you need the time to develop your critical thinking and other research skills, and that's a continuous process. If you fall behind, you may find it difficult to catch-up. In your project plan, you must therefore ensure that your study time is arranged evenly and regularly over its duration and that any study break you may take is short, not to affect your continuous progress.

Making your spare time productive There will be much to read through your project, so you should always keep something to read with you, which you can look at while waiting for something, say a bus, or in a queue or travelling on public transports. You may be surprised of how much reading you can do while waiting.

Avoiding postponing and procrastinating There will be tasks you may find harder than others, so it would be natural to put them off or engage in displacement activities. You should avoid that and focus on what must be done to meet your project milestones.

Scheduling extra time Inevitably things don't always go to plan or activities may take longer than estimated, so you should always factor in extra time for the things that may go wrong. If you find you don't need it, you can always allocate the time to other tasks or take a longer break, but at least you won't fall behind in subsequent tasks.

Being adaptive Research is about looking into the unknown, so you can't expect to be able to plan everything upfront and in great detail. Your planning should keep you on track to reach your major milestones, but should also be flexible. Don't spent too much time trying to plan every single thing to do: keep your planning light and ensure you return to your plan often to make adjustments as your project unfolds.

Investing in the right tools for the job While you may find it a nuisance to have to spend time learning new tools, such as a Bibliographic Management Tool (BMT) or some advanced word processing features, doing so will save you time in the long run, so make sure you invest in setting up your new systems and learning new skills earlier on in your project.

Activity: Reflecting on your study practices #18

Assess your own study habits and practices in light of the above advice. Write down things you think you do well and things you could or should change for your research project.

Guidance

You should take a balance stance and consider both your current strengths and weaknesses: build on the former and put some effort in addressing the latter.

3.2 Identifying the research problem

A research project gives you an opportunity to carry out a focused piece of academic research in the subject area of your degree and on a topic of your own choice.

It's a complex thing to do, but we'll walk you through it! You've got this!

3.2.1 Choosing a topic for your project

There is no single way to get started and inspiration can come from many places, from previous studies, any professional experience you may have, articles you have read, or even suggestions from your supervisor.

Activity: Possible topics to investigate #19

Write down possible topics to investigate for your research project.

Guidance

Think back[a] over your studies to this point. Did anything stick in your mind as very interesting, something you'd like to return to? What study topics did you particularly enjoy?
Next, think about what might be interesting within your industry. What are your industrial colleagues struggling with at the moment?
Next, look in the supporting materials that your course provides for your Masters, particularly those associated with possible Masters supervisors. It may be that you will find topic suggestions for Master projects.
Next, think about what has been happening in your discipline recently. Conduct a web search on recent topics that might interest you.
You should now have a long list of general possibilities for research.
Unless you already have something very specific in mind, you may start with a broad selection, then narrow down your choice to one or two candidate topics for further investigation.

[a] This might be your opportunity to find out more about them through research.

Before investing lots of your time looking into a particular topic, however, you should assess whether it is appropriate for Masters research. Here are some things to consider before you make your final choice.

3.2.1.1 Qualification fit

If your project is the capstone of a taught degree, you should ensure that the topic is appropriate to the degree you are studying. In many instances, this relevance will be obvious – you may well be exploring a topic you have encountered in your degree.

However, given the cross-disciplinary nature of many postgraduate programmes, it is equally possible that your topic will span boundaries between disciplines. In such a case, it is important for you to demonstrate that the emphasis of the research will be appropriate for the Masters degree you are aiming for.

ACTIVITY: Considering qualification fit #20

For each of the study options you identified in your last activity, write down how it relates to your previous degree studies, and particularly to its core modules. Identify those topics that are most suitable for your degree.

Guidance

You should make a note of key ideas, theories, approaches or principles covered in those modules, which are particularly relevant to the topic you have chosen, and identify specific materials you may like to revise or apply in your project.

3.2.1.2 Professional fit

At Masters level, your research should be of interest – and of potential value – to at least one of the following groups of people:

- Professionals• in organisations making up a particular industrial or economic sector that is within the scope of your research. This should be the case even if your research will be focused on a single organisation – some element of the research you produce must be relevant and applicable to organisations doing broadly similar things.
- Professionals in other sectors than that on which your research is focused but who experience similar problems or issues. A problem area for one industry may have relevance beyond that industry, or there may be implications for those setting policy or creating legislative frameworks.
- Professional researchers in the field – their interests are represented by the publications to be found in academic journals. Will your research contribute value to their future research?

• This may include both public and private enterprises – local and national government and agencies – as well as commercial organisations.

You will certainly need to argue the case for the professional fit and relevance of your research in your dissertation•: it may also be the case that early and/or intermediate reports will require you to do this too. This will be especially important if your primary investigation is exclusively within a single organisation, in which case it may not be obvious that the results are applicable elsewhere. It is not enough just to state that the relevance exists – you must provide some evidence in the form of logical argument or citation of

• And so it's really worthwhile thinking through professional fit very early on...

reputable sources identifying a problem common across a range of organisations or an entire industry. Your review of the academic literature plays an important role: as we will see, a key purpose of such review is to identify gaps in existing knowledge that your research is designed to fill. This alone may demonstrate clearly enough the relevance to the wider academic and professional community.

ACTIVITY: Professional fit #21

Consider your chosen topic. Write down who may be interested/benefit from research in this topic and why.

Guidance

You should also indicate any evidence you have to support your thinking. Ideally, you should talk to some of those people to explain what you intend to do and gain early feedback on the extent this may be of interest/benefit to them.

3.2.1.3 Personal fit

Through your Masters project, you will be living with your chosen research topic for many months•, so you *must* choose a topic that will retain your interest over that period. A deep-seated interest in a question• can carry you through the tough bits when your motivation might be flagging.

And, although your topic should interest you, even a passionate interest can only take you so far: you should also avoid topics in which you have little existing knowledge, for instance, or that will require you to learn and master major new skills•.

• It may even feel longer:)

• Great research often arises from the researcher's passion for the topic.

• The timescale for a Masters research project is usually relatively short and you will be very busy without having to learn completely new subject areas or master completely new skills.

ACTIVITY: Personal fit #22

Consider your chosen topic and write down the reasons why are you interested in it.

Guidance

You should also make a list any new skills, if any, you may need to develop in order to research such topic, and indicate how you will develop them and in the time available.

3.2.1.4 Organisational fit

Your Masters course may or may not require that you associate your research with a specific organisation. Particularly in part-time studies, work-inspired research is a good way of getting value out of your research beyond your studies, and to gain support or even sponsorship from your employer.

In case of employer-sponsored projects, however, a note of caution is needed to avoid too narrow a focus for research. A common misconception is that the research is an opportunity to complete a piece of work for the sponsoring organisation. That should not be the case: the organisation may well benefit from your research, but the research itself must address a *bona fide* research problem, i.e., one that has wider appeal and is beyond the needs of any single organisation. So, be careful that your research isn't linked too closely to the fortunes or objectives of a specific company or department.

If you are in the happy position of your employer offering sponsorship, make sure that you discuss with them the outcomes they expect from your research. Tell them about the broad focus that you will need to be successful. And make sure they understand that that broad focus will not stop you contributing to their desired outcomes. If needs be, you could always suggest that the skills and attitudes that you will develop during the course of the research and your findings will be available within your organisation, and that the Intellectual Property• that you create through your research may lead to:

• Intellectual property (IP) is property of things people create with their own intellect, such as an invention, an artwork, a design, etc. We will return to IP in Section XX

- Solutions to their specific problems
- New products and/or services that might generate a revenue stream that you can share.

If after this conversation, they remain unconvinced, then it may be better to choose a research topic that is not of immediate interest to the sponsor. It is a hard choice to give up sponsorship, but at least it will mean that you won't be constrained in conducting your research.

ACTIVITY: Considering organisational fit #23

If you're considering asking your employer to sponsor your Masters research project, or if they're already sponsoring your studies, write down how your chosen topic fits with their expectations, and how these compare to the requirements of your course.

Guidance

You should list possible constraints from your sponsor which may prevent you from conducting your academic research, and how you intend to deal with those constraints.

3.2.2 What is a research problem

Within your chosen topic, you will need to identify a specific research problem that your project is going to address. Your research problem narrows down your focus from a whole topic – which might be quite broad – to something very specific: a context, a knowledge gap and a justification.

A well-defined research problem is the foundation of any research project, clarifying the research purpose and intended outcomes, something all good academic research requires. As well as using it to drive much of the process of arriving at your dissertation, you'll also include a description of your research problem in your dissertation to tell a reader what you are trying to achieve.

All research problems you'll find in this handbook stem from the following research problem template:

> In the context C, with phenomena of interest P, to address knowledge gap G. This matters to W because R.

An example of this could be:

> In the context of 'the food industry', with 'plastic containers and wrappers' being the phenomena of interest, to address 'the reduction in the use of plastic containers and wrappers.' This matters to 'the food industry and to society' because '10% of all costs can be attributed to the use of plastic, and plastic is highly polluting'.

As written, this research problem may appear a little contrived, but this is only the starting point to identify its important constituents, that is:

- C: in which Context will the research take place?
- P: which are the Phenomena of interest?
- G: what is the knowledge Gap?
- W: to Whom does this matter...
- R: ...and for which Reasons?

It may be that in addressing the research problem, there may be other things generated: it might be, for instance, that a new process for manufacturing food containers is invented, which means that intellectual property will have been generated, or that other subsidiary questions are answered too, such as better container design. However, these are not part of the research project based on this research problem. Of course, you may wish to follow them up later, after your project has finished•, but typically you wouldn't consider them otherwise.

• And it may be that your project can help you to do this...

Ok, back to the template. Let's unpack each component in turn.

3.2.2.1 The context and phenomena of interest

The context in which the research will take place contribute to constrain the project scope, alongside the phenomena that will be considered, what is of interest about them, what they influence, how they are measured, how they are observed, etc. Different contexts and phenomena therein will typically lead the researcher in different directions: for instance, using wifi in a home will lead to different considerations of its behaviour that using wifi in a hospital, where it could interfere with delicate medical devices.

As we shall see, contexts can be embedded in other contexts or can overlap each other, so that, it's important to identify precisely the context of the research project.

Clara's research

Clara works for a large multinational engineering company in the production planning department of one of its small plants in Denmark. She finds that her planning department struggles to forecast resources and time accurately, so that production costs often escalate, reducing profit margins and lowering competitiveness. She has been asked to do some research to improve the situation.

Activity: Clara's context #24

Identify the context for Clara's research problem.

Discussion

Clara's problem is embedded in many contexts, including:

- Denmark, the country,

- a large multinational company,
- a small plant belonging to that company, and
- its production planning department.

If the scope was Denmark, then there would be crazily many phenomena that Clara could think about: choosing Denmark is just too large. The large multinational is beginning to be a more realistic scope, but there are other hints that make even more sense. She's been asked to investigate forecasting resources and time in her plant, so that the small plant and its production planning department are a most suitable context for her research, particularly if they share similarities with other plants within the company or in the industry sector.

Let's consider phenomena next. Technically, a phenomenon is an element of the world, the occurrences of which are observable. They can be a material thing, transient, like an event or a situation, or information-based, like a fact or a concept; like we said, anything you can observe.

Some phenomena arise naturally and others artificially: many proteins are phenomena that occurs naturally through protein synthesis, whereas the technologies underpinning social media are constructed by software engineers. If you look around the room in which you're sitting, every object you perceive – each light, each fly, your computer and its (virtual) files – every event that occurs – that light turning on, the creak of your chair, a bird flying into your window – is a phenomenon.

Phenomena can be really simple — a speck of dust, or very complex — the whole sequence• of steps that your computer goes through to connect to your wifi is a phenomenon. Complex phenomena are usually made of various observable elements, each a phenomenon too.

• Although without specialist equipment, you might not be able to observe it

Phenomena are a very rich source of research problems. They have many and various characteristics, not all of which may be fully known: these call for more research. There are also phenomena which haven't even been identified yet! At one point, although we knew how to send data over radio signals, wifi didn't exist and so the devices and protocols associated with it had to be invented. New phenomena are being created and/or discovered all the time. That means new knowledge is needed and so research. The existence of phenomena in one field might also suggest their existence in another – more research needed.

In summary, a phenomenological basis for research problems means there's a very rich seam for researchers to mine.

Activity: Clara's phenomena of interest #25

Identify phenomena of interest in Clara's research context.

Discussion

From the description above, the *forecasting of resources and time* and its *accuracy*, and the plant's *profit margins* and its *competitiveness* are all phenomena of interest. Also, forecasting is a complex phenomenon, possibly including a process, some techniques and some measurements. As part of Clara's research, each of its constituent parts (other phenomena!) may need investigating, alongside its relation to the other phenomena of interest.

3.2.2.2 The knowledge gap

You know by now that academic research aims to generate new knowledge in a field of study. It is therefore essential that your research problem captures the knowledge gap your research intends to address. To help you start thinking about the knowledge gap, let's go back to Clara's scenario once more.

Activity: Clara's candidate knowledge gap #26

Given the context and phenomena identified in the previous activities, write down a possible knowledge gap that Clara might address with her research.

Guidance

If you're having difficulty finding the gap, focus on what Clara has been asked to do, that is to investigate forecasting resources and time in her plant, which is found to be inaccurate.

Discussion

A possible knowledge gap we've come up with is:
"How to improve the accuracy of forecasting resources and time in the small plant."
Yours is probably similar. If it isn't, look again at the example initial description and focus on what Clara has been asked to do.

It is important to know that this is only a *candidate knowledge gap*: what we don't know at this point is whether Clara's planning department is just bad at forecasting, possibly not employing appropriate processes and techniques, or whether there is effectively a knowledge gap in the sector in that accurate techniques are unknown. To be able to judge, Clara will need to do more work, including looking at the literature, but we are not there quite yet.

3.2.2.3 The justification

Some research is motivated by the researcher' pure curiosity and desire to advance knowledge in a field of study, which is good justification to conduct research!

However, most research, particularly when located in a real-world context, matters to other people too, usually referred to as the stakeholders or beneficiaries• (these include the researcher, of course!) and may have measurable real-world impact.

Measuring• the real-world benefit delivered through research is an easy way of showing that it has value. Having beneficiaries also means that you can more easily conclude that the research problem has been solved in context – as you can ask the beneficiaries. Asking why the research is important to them is another good thing to know as you can then use their criteria to assess the value of your research.

• We will use the term beneficiary when they benefit from the research; a stakeholder means they will be affected by the research, but not necessarily positively.

• Universities these days are assessed on their real world impact, so it is possible that your project will have some form of impact assessment in it.

Activity: Who will benefit and why? #27

In Clara's case, identify who may benefit and how. Also consider who may be able to judge whether Clara's research has addressed the problem.

Discussion

Clara's research should lead to more accurate forecasting, which would save her organisation money and make them more competitive.
Her colleagues in the planning department should be able to help her work out why the current process is less effective than it could be, and assess the extent innovations from her research have made a difference.

It is very important to note, however, that it isn't the beneficiaries of the research that determine whether the research is actually research; that's a judgement based on the fact that new knowledge has been generated and this can only be judged by the larger research community.

Table 3.2: Elements of Clara's problem

Context C	Clara's engineering plant and planning department
Phenomena P	Forecasting of time and resources and its accuracy
Knowledge gap G	How to improve the accuracy of forecasting
Stakeholders S	Clara's company
Reasons R	Inaccurate forecasting increases production cost and reduces profit margins and competitiveness

For a Masters research project, that larger research community might be represented by a very small group of people: your supervisor and your dissertation examiners. In exceptional cases,• a Masters student might go on to report their research findings to a larger community of scholars at an academic conference, for instance, or even through a scientific journal: conference or journal publication is the pinnacle of validation that knowledge is new.

• Many of our research students have done this.

3.2.2.4 Problem formulation

It is now time to write down Clara's problem, by using the template we have provided, and based on what we have found out so far, which is summarised in Table 3.2.

Activity: Clara's initial problem #28

Based on the information in Table 3.2 and using the problem template, write down Clara's initial research problem.

Discussion

This is what we have come up with:
"To improve the accuracy of resources and time forecasting within Clara's engineering plant and planning department. This matters to Clara's company because inaccurate forecasting increases production cost and reduces profit margins and competitiveness."

You may have written something similar.

As stated, this problem formulation is only the starting point, as Clara has yet to establish that a knowledge gap actually exists. To do so, she will need to look into the literature and revise her problem statement accordingly. This is true in general: your initial problem will help you scope your review of the literature, which in turn will inform which knowledge gaps exist, and will help you reformulate your problem as a proper research problem.

In the next section we will look in detail at how you can do that, but first let's look more closely at diverse types of research problem.

3.2.3 Types of research problems

Research problems originated from our template depend critically on phenomena. And it won't come as any surprise then, that you can classify the types of research problem by the things you can do with those phenomena. And that leads to the different types of research that you can do, which we consider in this section.

3.2.3.1 Descriptive problems

Descriptive problems aim to describe phenomena of which we have little knowledge, accurately and systematically. The goal is to describe phenomena for the first time or to render existing descriptions more detailed or accurate.

Examples of descriptive problems

To characterise the present state of the European commercial synthetic biology ecosystem. This matters to both producers and consumers in that ecosystem because this knowledge can be used to inform effective routes to commercialisation.

To determine how UK organisations are using the ITIL framework to manage cloud-based IT services. This matters to IT managers within those organisations because it can help them improve their service management practices.

Activity - Descriptive problems #29

For each example above, identify its constituent parts with reference to the research problem template we have provided. Jot down any similarity between the problems.

Discussion

Here is our mapping of the problem statements onto the template:

Context C	European commercial synthetic biology ecosystem
Phenomena P	The current state of the ecosystem
Knowledge gap G	A characterisation of the present state the ecosystem
Stakeholders S	Consumers and producers within the ecosystem
Reasons R	To inform effective routes to commercialisation

Context C	UK organisations
Phenomena P	Those organisations' management of cloud-based IT services
Knowledge gap G	How they use the ITIL framework to manage cloud-based IT services
Stakeholders S	Those organisations' managers
Reasons R	To improve service management

In both cases, the goal is to provide a description where one is currently lacking: of a state-of-the-art in the first problem, and of the use of a framework in the second problem.

3.2.3.2 Exploratory problems

Exploratory problems aim to investigate phenomena of which little is known. The goal is typically to generate new ideas, hypotheses, theories, models or predictions which can be investigated in further research.

Lots of academic research is exploratory as it strives to develop a deep understanding of natural or social phenomena of which little is known. For instance, physicists try to explain the working of our natural world by making empirical observations of natural phenomena and conjecturing cause-and-effect relations, usually expressed as mathematical formulae or theories. This is the way natural sciences have developed over the centuries. This is also true of social scientists conducting observations in social settings in order to develop theories on human behaviour.

Examples of exploratory problems

Within public service providers, to investigate the relation between demographic and behavioural factors and end-users' awareness of cyber security threats. This matters to those providers as successful cyber security attacks can result in loss of confidential information. This also matters to their customers as such information may include customers' data.
To investigate the possible use of social media in the management of a natural disaster by government organisations. Given the spread of social media, this matters to those organisations, which could integrate them within their critical communication infrastructures.

Activity - Exploratory problems #30

For each example above, identify its constituent parts with reference to the research problem template we have provided. Jot down any similarity between the problems.

Discussion

Here is our mapping of the problem statements onto the template:

Context C	Public service providers
Phenomena P	End-users' demographic and behavioural factors; cyber security threats
Knowledge gap G	To investigate the relation between demographic and behavioural factors and end-users' awareness of cyber security threats
Stakeholders S	The providers and their customers
Reasons R	Successful cyber security attacks can result in loss of confidential information

Context C	Government organisations dealing with natural disasters
Phenomena P	Social media; the management of natural disasters
Knowledge gap G	To investigate the possible use of social media in the management of a natural disaster
Stakeholders S	Those government organisations
Reasons R	Social media could be integrated within critical communication infrastructures

In both cases, the goal is to explore a situation for which little understanding is currently available (this being the knowledge gap): in the first problem, the focus are possible effects of demographic and behavioural factors on awareness of cyber security threat; in the second, whether social media could be used effectively for communication in the management of a natural disaster.

3.2.3.3 Explanatory Problems

Explanatory problems aim to explain why certain phenomena occur or are related. The goal is often to test a conjecture, hypothesis, theory or model.

Example of explanatory problems

In the context of software development companies, to investigate how learning strategies adopted by software engineers allow them to develop new skills fast and efficiently. These matters to those companies as software technology changes rapidly, so that software engineers need upskilling and retraining very frequently.

Within the public sector, to investigate how practices adopted by organisations and employees lead to an effective and efficient use of teleconferencing technology. This matters to public sector organisations due to the recent significant increase in flexible and home working, so that much of their business is now conducted online.

Activity - Explanatory problems #31

For each example above, identify its constituent parts with reference to the research problem template we have provided. Jot down any similarity between the problems.

Discussion

This is our mapping of the problem statements onto the template:

Context C	The public sector
Phenomena P	Use of teleconferencing technology
Knowledge gap G	How practices adopted by organisations and employees lead to an effective and efficient use of teleconferencing technology
Stakeholders S	Public sector organisations
Reasons R	More and more business is conducted online

Context C	Software development companies
Phenomena P	Learning strategies; skills development
Knowledge gap G	How learning strategies adopted by software engineers allow them to develop new skills fast and efficiently
Stakeholders S	Software development companies and software engineer
Reasons R	Software technology changes rapidly, so that software engineers need upskilling and retraining very frequently

In both cases, the goal is to explore how and why certain phenomena are related. In the first problem, the focus is why certain learning strategies lead to more effective upskilling; in the second problem, why certain practices lead to a more efficient use of teleconferencing technology.

3.2.3.4 Predictive Problems

Predictive problems aim to predict future phenomena. The goal is usually to define a model, extrapolating from current knowledge, that allows predictions to be made together with an assessment of how accurate they might be.

Examples of predictive problems

To quantify the potential impact on fresh water consumption of recycling domestic bathroom water in the UK within the next decade. This is important both from an economical and an environmental perspective, as fresh water is becoming a scarce resource, so its preservation is imperative.
To use demographic and curriculum data to predict which current students are at risk of dropping out in the context of higher education. This matters to higher education institutions as retaining their students is their statutory duty, and because students not completing their degree results in fewer skilled people entering the job market, which may impact productivity.

Activity - Predictive problems #32

For each example above, identify its constituent parts with reference to the research problem template we have provided. Jot down any similarity between the problems.

Discussion

Here is our mapping of the problem statements onto the template:

Context C	UK in the next decade
Phenomena P	Fresh water consumption; recycling domestic bathroom water
Knowledge gap G	To quantify the potential impact on fresh water consumption of recycling domestic bathroom water
Stakeholders S	Water management agencies; water suppliers and consumers
Reasons R	Preserving fresh water is important as it is becoming a scarce resource

Context C	Higher Education
Phenomena P	Student drop-outs; Demographic and curriculum data
Knowledge gap G	To predict which current students are at risk of dropping out
Stakeholders S	Universities; their students
Reasons R	Student retention is a statutory duty; retentions means that enough skilled people enter the job market

In both cases, the goal is to make predictions. In the first problem, on the impact of recycling water on fresh water availability; in the second problem, on the likelihood of students dropping out.

3.2.3.5 Evaluative Problems

Evaluative problems aim to establish whether phenomena that have been introduced have achieved the desired outcome. These might be concepts, theories, products, technology, etc., and the goal is to establish how they have performed.

Evaluative problems may focus on testing the strength of an academic theory or model to ensure its long-lasting validity and scope of applicability. They may place an existing theory or model in a new context, or apply them to new situations, evaluating the effects of a change of conditions, what works, what does not and why, possibly leading to new theories or improved models.

Evaluative research may also take the form of a well-founded critique of diverse explanatory theories or potentially conflicting evidence put forward by previous researchers. A systematic and critical analysis of such evidence may lead to new knowledge on which theories are most reliable, so that future researchers may focus on those.

Examples of evaluative problems

To evaluate the effectiveness of Artificial Intelligence (AI) to reduce the occurrence and impact of successful cyber-security attacks within the financial sector. This matters to the sector because over 3 billion dollars are lost within the sector every year due to successful attacks, and efforts to prevent them are

also very costly.
Within non-clinical laboratories, to determine if lean techniques can improve process flow in the presence of unpredictable demand and supply. Inefficiencies in process flow are costly to non-clinical laboratories, so that improving it is beneficial to them and their customers.

Activity - Evaluative problems #33

For each example above, identify its constituent parts with reference to the research problem template we have provided. Jot down any similarity between the problems.

Discussion

This is our mapping of the problem statements onto the template:

Context C	The financial sector
Phenomena P	AI techniques and cyber security attacks
Knowledge gap G	To evaluate the effectiveness of AI in reducing successful cyber-security attacks
Stakeholders S	Operators in the sector and their customers
Reasons R	Significant financial losses are due to such attacks every year, and the cost of preventing them is high

Context C	Non clinical laboratories
Phenomena P	Lean techniques; process flow; demand and supply
Knowledge gap G	To determine if lean techniques can improve process flow in the presence of unpredictable demand and supply
Stakeholders S	Those laboratories and their customers
Reasons R	Inefficiencies in process flow are costly

In both cases, the goal is to evaluate how approaches applied within a certain context perform. In the first problem, the focus is on the performance of AI to counter cyber security attacks; in the second problem, the focus is on the effect of lean techniques on the flow of processes with unpredictable demand and supply.

3.2.3.6 Design problems

Design problems aim to create artefacts which embed new knowledge. The term 'artefact' is meant in its widest meaning, and includes tangible and intangible products, processes, novel combinations of ideas or technologies, etc. The goal is to embed within the artefact new knowledge which extends human and/or organisational capabilities, including improved ways of doing something.

Examples of design problems

In the context of data visualisation tools, to devise algorithms able to generate automatically text summaries of line graphs depicting multiple time series for the benefit of sight-impaired users. This matters to both tool providers and sight-impaired users as it would improve the accessibility of such tools.

To define a hybrid project management framework, based on complexity and volatility characteristics, to reduce project failure in the development of embedded software systems. Current project failure across the sector is above 70%, resulting in a high financial burden.

Activity - Design problems #34

For each example above, identify its constituent parts with reference to the research problem template we have provided. Jot down any similarity between the problems.

Discussion

Here is our mapping of the problem statements onto the template:

Context C	Data visualisation tool development industry
Phenomena P	Text summaries; multiple time series line graphs; algorithms
Knowledge gap G	To devise algorithms able to generate automatically text summaries of line graphs depicting multiple time series
Stakeholders S	Tool providers and sight-impaired end-users
Reasons R	To improve the accessibility of such tools

Context C	Embedded software systems development sector
Phenomena P	Complexity and volatility characteristics; project failure; project management
Knowledge gap G	To define a hybrid project management framework, based on complexity and volatility characteristics, to reduce project failure
Stakeholders S	Project managers in the sector
Reasons R	Project failure rate is high, resulting in a high financial burden for the sector

In both cases, the goal is to design something new. In the first problem, new algorithms for the automated generation of text summaries; in the second problem, a framework for hybrid project management.

Note that an essential characteristic of a design research problem is that the to-be-designed artefact is a genuine contribution to knowledge in that it augments what is currently possible. Some of the most exciting research in technology-related subjects is about developing new artefacts. However, for such development to fit academic research it is important to establish what the contribution to knowledge is, and assess its originality and significance. In particular, it is important to distinguish the very first development of an innovative artefact from the routine of implementation of known systems: the former augments knowledge; the latter does not.

3.2.4 Masters-appropriate research problems

Regardless of the type of problem you intend to address with your research, you will only have a limited amount of time to complete your project and write your dissertation, most likely no more than one year. It is therefore important that you think carefully about your research problem from the start as changing direction later on in your project could be very challenging and increase your risk of not completing it successfully.

In particular, you should focus on the following criteria:

Generality Your chosen research problem should not be so limited in scope to be irrelevant or of no interest to others. While your inspiration may well be something you have observed directly in your personal or professional life, your research problem should address a knowledge gap which is shared within your field of study, is of academic relevance and possibly of interest to professional practice, so that your findings can be generalised to some extent. Reviewing the literature is a way to ensure that what you have in mind meets these requirements.

Complexity You will only have limited resources for your project, so your problem should not be so complex that it cannot be addressed within those constraints. Some research problems are just too ambitious for Masters research, e.g., "To combat social inequality in the UK." However, there may potentially be suitable sub-problems you could consider, e.g., "To understand the role of food banks in alleviating poverty in the UK in the last decade."

Volatility Your chosen problem should remain current for at least the duration of your project and, ideally, present further opportunities for research in future. It is therefore important that you choose a problem which is not likely to become irrelevant too quickly. This can happen in technology-oriented projects that focus on specific products or tools, and their features. It could be avoided by considering if a more general problem can be found of which the original problem is an instance. For example, instead of "how to visualise data effectively in tool X", the problem could be generalised to "which design principles apply for effective data visualisation", regardless of the specific tool used.

Assessing Clara's problem

We left our example with Clara's problem expressed as follows:
To improve the accuracy of resources and time forecasting within Clara's engineering plant and planning department. This matters to Clara's company because inaccurate forecasting increases production cost and reduces profit margins and competitiveness.
Let's apply the criteria above to work out whether this is a suitable research problem or more work is needed.
In terms of generality, this problem is too specific to Clara's own company, so may not be indicative of a knowledge gap — for instance, it is possible that Clara's company applies outdated estimation approaches, and better approaches are known and applied elsewhere. Therefore, for Clara, the next step will be to do some initial reading of the academic literature to establish:

- What, if anything, is already known about this problem in its wider context, e.g., other engineering companies or industries
- Which specific aspects of this problem, if any, could be investigated to make a novel contribution to knowledge.

In terms of complexity, the problem appears tightly focusses and doable as part of a Masters; similarly, it is unlikely the problem will cease to be relevant in the time span of the project, so neither complexity nor volatility are of concern.

Activity: Appropriateness of research problem statements #35

Consider the following research problem statements and discuss the extent you think they are appropriate for Masters research based on the above criteria.

1. To analyse possible differences in people's web search strategies to inform the design of search algorithms in software. Some individuals are better at conducting online searches than others and this knowledge may lead to more efficient algorithms.

2. To establish which information should be displayed to end users to help them identify energy waste within their heating systems. Energy waste impacts negatively household finances and the environment, so raising end-users' awareness could help reduce waste.

3. To improve coding skills of students at a distance. Coding skills are in demand and there is shortage in job market.

Discussion

This is our assessment of each of them. Yours may be different, of course.

1. Web search algorithms are a very active field of study, so it is likely that a contribution to knowledge can be made which is of wide interest to both academia and industry, and likely to remain so for the foreseeable future. Some thought will be needed to ensure that the work can be conducted within the constraints of the project, for instance by containing the number of participants in the study or the length of observations of their search strategies. Therefore, overall, with appropriate adjustments, this could be suitable for Masters research.

2. This problem is both topical and specific, so it has a good chance to meet the criteria. Some work on contextualising the problem in the literature will be necessary to establish the extent of the potential contribution to knowledge, particularly if design guidelines already exist, in which case it would be important to establish how these are lacking. Overall, this too could lead to a suitable Masters project.

3. This problem is too broad and open-ended for a Masters project — it is a topic, rather that a specific research problem. A more suitable problem could be defined, for instance, by identifying which specific aspects of improving coding skills at a distance are problematic with reference to the literature, so that a much narrower knowledge gap can be established.

3.2.5 Formulating your initial research problem

It is time for you to have a go at formulating your initial research problem, based on what you have learnt in this section.

Activity: Your initial research problem #36

Apply the template provided to write down your initial research problem. Discuss what type of problem it is and assess it in terms of generality, complexity and volatility.

Discussion

Make sure you include all the elements of the template, i.e., C, P, G, S and R, and explain how your problem aligns with its problem type's goal. Argue concisely why your problem is appropriate for Masters research in terms of generality, complexity and volatility, or indicate further steps you will take to ensure that's the case.

3.3 Reviewing the literature

In this section, you will start your literature review, an activity you will continue in Stage 2•. In Stage 1 your focus will be on scoping and gathering what to read, assimilating and analysing relevant content, keeping track of emerging themes, ideas and findings, and writing up initial summaries. In Stage 2, your focus will be synthesising what you have learnt from the literature to support your arguments and justify your research. By the end of Stage 2 you will have produced a substantial draft of your literature review.

• Stage 2 is covered in the next chapter.

3.3.1 The role of the literature in research

Academic research does not take place in a vacuum. The academic researcher relies on a body of knowledge in their field of study, the cumulative result of collective research efforts over long periods of time. They then use their creativity to add to it, and collaborate with other researchers to develop new ideas and technologies. The main vehicle for the codification and sharing of that knowledge is the academic literature. So, reviewing the literature and adding to it are intrinsic to academic research.

Your literature review will help you frame, contextualise and justify your chosen topic and research problem and to investigate the methods and modes of research that are considered relevant to your discipline. It will also help you demonstrate• your understanding of the state-of-the-art, and to highlight knowledge gaps — the unknowns — to which your research will contribute.

• As always, you're trying to demonstrate this to the examiners and so it's their standards that you're trying to meet.

Towards the end of the project, your literature review will also help you establish precisely which knowledge you have created and so evaluate what you have achieved in relation to other published related work.

Our framework recommends you focus on your literature review in Stages 1 and 2•, although you will be maintaining your literature review throughout your project – incorporating newly published papers, adding or removing detail from what you've already written to support your dissertation as you progress.

• Stage 2 is the focus on the next chapter.

At Masters level, examiners will be looking for a literature review based on between 30 and 60 academic articles, and in the range of 2,000–3000 words.•

• Or something like 8 to 10 pages.

3.3.2 How to access the literature

As a Masters student, your university library will be your first point of call for the academic literature – probably online, unless you are able to travel to it every day•. It is highly likely that alongside their collection of printed materials, your library will provide you with online access to a wide range of digital resources and a selection of bibliographical databases. The latter are collections of ejournals, ebooks and articles that can all be accessed online and searched at the same time. Among those resources you will will probably find most, if not all, of what you need for your project.

• Most university libraries have single occupancy study rooms if you need to get away from the bustle of a home or work. Ask the duty librarian what facilities are available at your library.

Activity: Investigating your library resources and services #37

Investigate your library resources and services to identify those which are going to be particularly useful for your project.

Guidance

You should pay particular attention to those services which allow you to access resources online at any time and from everywhere.

Another source of articles is Google Scholar• which has collected together over 100 million• academic articles in English, with direct links to each. Google Scholar also has bibliographic citations for download for each article that you can cut and paste directly into your bibliographic database.

• Google Scholar is available at http://scholar.google.com

• This is wikipedia's estimate: https://en.wikipedia.org/wiki/Google_Scholar

Google Scholar provides access to the full-text of an article, particularly for published articles from commercial publishers, although these are usually behind a pay-wall•. In addition, Google Scholar collects together 'versions' of the same paper so that, even if you don't have access to a paid service version, there may be a pre-print version of the article also available for free. If there is no version available except a pay-for-access one, you can link Google Scholar to any university library that you have electronic access to: this is an incredibly useful service which gives you direct access to those articles found in Google Scholar that are included in your library subscriptions.

• A pay wall is an electronic way of protecting an electronic document.

Google Scholar can also help you access the so-called *grey literature*, which is the collection of information produced by organisations whose primary or commercial remit is not publishing, such as as academia, government bodies, or non-publishing businesses and industries. It includes pre-publication and non-peer-reviewed articles, theses and dissertations, research and committee reports, government reports, conference papers, accounts of ongoing research, etc.

Google Scholar is an amazing resource for the researcher.

Activity: Connecting Google Scholar to your library services #38

Investigate whether your library provides the facility to integrate Google Scholar alongside their proprietary search engines.

Discussion

Our university library provides some instructions on how to set up Google Scholar to connect to the databases the library subscribes to, so that direct links to the full body articles appear as part of the results of a Google Scholar search.

A third way to get to specific articles which you can't access from your library or via Google Scholar, is to contact the authors directly: academic authors are usually keen to have their work read and should be able to share pre-publication versions of their articles or even point you to other relevant publications which they have written. Contact details of academic authors can usually be found in the header of the articles they have published, or from their university's web pages. Alternatively, you may be able to contact them via professional networks, such as ResearchGate• or LinkedIn•.

• ResearchGate is an online network specifically created to connect researchers around the world. It currently has a community of over 20 million researchers which use ResearchGate to "connect, collaborate, and share their work."

• LinkedIn is the largest professional network worldwide, used to make professional connections

3.3.3 How to read an article

In this section, we'll be looking at how to read an academic paper. It may seem strange to think about trying• to read an academic article without having found any first! It's such an important skill, however, that it needs introducing early, and in a way that we can coach you through it the first time. Honestly•, it's going to take some time to pick up this skill, but it's an investment worth making.

• Searching comes next, promise!

• And not just for your masters project. Reading the academic literature is a professional skill that not many professionals have.

The approach we introduce in this section is one that we have used many hundreds of times with our students and is based on an excellent paper “”How to read a paper” by Srinivasan Keshav (2007)•. Keshav suggests a practical workflow for reading an academic paper. The workflow has up to three ‘passes’, not all of which need to be used, with each having a specific aim:

• The version we are using was revised by the author in 2013.

- the first pass gives you a general idea of what the paper is saying. The first pass may take only 5 minutes and will allow you to disregard the paper if you find out it isn't relevant•.
- the second pass gives you a better grasp of the content in outline of a relevant paper. The second pass may take 20 minutes or so, and gives you the opportunity to annotate the paper• as you begin to understand it. You can stop after the second pass if you need to – perhaps you have a large pile of papers that you wish to sort for relevance.
- the third pass deepens your understanding of the paper to that point that you can reproduce its main arguments and conclusions – Keshav calls this “Virtually reimplementing the paper”! Clearly, this form of understanding is truly deep and can take many hours, days, months, or even years! You can read a paper over and over again in the third pass, and your annotation at the end may grow to be as big as the paper itself. There will be key papers in your Masters project that have this status but they will be few.

• You should still be adding it to your BMT, however, who knows when it might become relevant in future – even a long time after your masters studies are complete.

• We mean write your notes on it that capture your growing understanding.

Keshav's approach is summarised in Table 3.16.

Ok, now it's time to give you something to try Keshav's workflow on!

Activity: Applying Keshav's approach to Keshav's paper! #39

The paper you need to investigate is Kershaw's paper itself:
Keshav, S. (2007) ‘How to read a paper’, ACM SIGCOMM Computer Communication Review, 37(3), pp. 83–4.
Use Google Scholar to search the article's title and then download the paper[a].

Table 3.16: Summary of Keshav's approach — adapted from the 2013 revision of Keshav (2007)

#	Time	What to read or do	What you should know after the pass	Criteria for stopping at current pass
1	5–10 minutes	Title, abstract, introduction; Section and sub-heading; Glance at mathematical content (if any); Conclusions; Glance over references	Main contribution; Relation to other papers	Paper not in research area
2	1 hour	Jot down key points, comments, questions; Mark relevant unread references	Main thrust of the paper with supporting evidence	Paper of interest but not key to your research
3	>1hour	Virtually reimplement the paper; Identify/challenge assumptions	New knowledge contributed; Strong/weak points, implicit assumptions, missing citations, potential issues; Insight into complex arguments and presentation techniques; Jot down ideas for future work	

Start reading Keshav's paper using the guidance in Table 3.16.

Guidance

You should ensure you make appropriate annotations as you go along, then develop and include appropriate notes and summaries in your BMT.

[a] Remember to record it in your BMT.

Reading Keshav's paper using Keshav's workflow will give you a head start on the following• — something we've learned in the time Keshav's paper has been in use by our students.

• It's also satisfyingly recursive!

Firstly, the time suggested for each pass is only an approximation, and will depend on your own skills and previous experience of reading the academic literature, whether the subject matter or research design is new to you, or even that the article may be poorly written and difficult to follow. Secondly, three passes may not strictly be enough: for some articles, particularly the most critical to your research, the third may actually consist of multiple passes.

Vice-versa, not all papers require a third pass and you should be careful in deciding whether a particular paper should have one at any point in time: you should never totally disregard a paper – unless it is clearly out of scope – as the importance of understanding a paper may only become apparent later: it may be a highly cited paper that needs to be understood so that other papers become accessible, for instance.

Secondly, we've found the following to be very important: at each pass, Keshav stresses the importance of making annotations as you read. Whether you print the article or work to annotate an electronic copy•, effective annotations will help you identify, and access more easily later on, those elements of the paper which are of particular interest to you. In the second pass, your annotations should include comments or queries on elements you find particularly relevant, interesting, or unclear, while in the third pass, they may include ideas for future work which may provide some inspiration for your own research. Your annotations will then help you write up your own notes and summaries. Electronic copies of notes should, of course, also be stored in your BMT.

• A tablet of some form with appropriate note taking software is a great way of doing this.

Finally, Keshav suggests you should highlight references upon which the arguments of the paper rest and that you may like to read later on, and comment on possible relation to other articles you may have already read. This will help you contextualise the article in the wider literature you are reviewing.

We recommend you apply Keshav's workflow when reading the academic literature. But first, let's consider the literature review process as a whole.

3.3.4 How to review the literature

Reviewing the literature is a process of knowledge discovery•, and it is both iterative• and incremental•. Its core activities are summarised in Table 3.17 alongside the key skills required.

• To know where there are gaps in knowledge, you need to know what is already known – hence knowledge discovery. A poor literature review may leave you unable to claim a contribution to knowledge.

• Iterative = it never finishes – although it's better than it sounds: later iterations will typically make fewer changes than earlier ones

• Incremental = you'll add to it over time.

To conduct your literature review successfully, you will need to be able to select work which is relevant and should be included, assimilate and summarise relevant work of other researchers, synthesise and critically appraise ideas from different sources, establish links between studies and their findings, and draw on strengths and limitations of published research. In summary, in your literature review you will need to make use critically and creatively of the content of articles, books and other literature sources you have reviewed to demonstrate your knowledge of the subject, support your own arguments and justify your research. In this chapter and the next, this handbook will help you develop and apply these skills.

You will need to read extensively during your research and you will read a lot• more than your final selection of articles cited in your research proposal and dissertation. So, a natural question is "How do I

• When you write, you will focus only on the most relevant of the papers your search turned up.

Table 3.17: Key activities in reviewing the literature, including key skills required

Activity	Aim	Key skills	Outputs
Searching and gathering	To identify search terms, conduct bibliographical searches and collect articles for consideration	Applying effective search strategies; systematic searching bibliographical databases	Successfully applied search terms and related electronic (or paper) articles for further consideration
Processing	To establish the relevance of searched articles for follow-up in-depth analysis, and record them in a BMT	Skim reading, note taking, bibliographic management	Populated BMT, article annotations, notes, article ranking for follow-up in-depth analysis
Assimilating and analysing	To engage with the content of relevant articles, and keep track of them, establishing potential links, common themes and emerging knowledge gaps	Critical reading, including identifying key arguments, findings, strengths and weaknesses; critical thinking, including comparing articles and identifying relationships and gaps; further note taking	Detailed article annotations, notes, short summaries, tables, diagrams, etc. leading to understanding
Synthesising	To consolidate and summarise what you have learnt in well-formed academic arguments and a well structured narrative, able to justify your proposed research on the basis of the identified knowledge gaps	Critical thinking and academic writing, including making academic arguments and organising your summary narrative	Sound academic arguments and well-structured narrative, constituting a substantial draft of your literature review

know when I have read enough and have the references I need?" Your final selection, simply, will be sufficient to convince the examiner that you have identified a gap in knowledge.

You might like to think of identifying a knowledge gap as trying to locate a particular rock pool• starting from a map of your country. For places extremely far away from the rock pool, you don't need any description at all, other than mentioning the country. But, as you get closer, you might want to pick out a particular town to give an approximate location. Then, you need to give more and more precise descriptions as your reader gets closer and closer to the rock pool, finally giving them a really precise description so they can lock onto it.

• Might not be a good metaphor:)

In detail, you want your literature to identify the area in which your contribution to knowledge is going to be made, and to support your arguments in relation to your choice of research problem and the potential contribution to knowledge of your research with reference to the state-of-the-art.

Given this, if there are significant points which are not linked to the relevant literature, and not supported by other evidence otherwise, then you don't have enough references; conversely, if there are references which don't relate to any significant point, then they may well be superfluous. You can apply this rule of thumb at each stage of your research to assess whether you have done enough to progress to the next stage.

There is a caveat. A literature review is never really finished because as as you gain insights from the literature, those insights will in turn point you toward other reading; once you have answered a question, new questions arise, and so on. It is a process you will go through till your final dissertation submission, and even then you will have new insights to follow-up or unanswered questions to address. But that's good, as it simply points to the fact that more can come from your work that other researchers may well pick up and so can contribute to your conclusions and further work, which examiners always like to see.

It's now time for your first literature search!

3.3.4.1 Searching and gathering

At this stage of your project, the main objective of your literature review is to demonstrate sufficient understanding of the topic you have chosen to be able to justify why your chosen research problem is worth investigating, i.e., why it will lead to new knowledge. In particular, your literature review should help you consider its wider significance beyond your personal or professional interest.

It is not surprising, therefore, that this handbook recommends you start from your research problem to plan how you will go about searching and gathering articles for review. In the course of your project, your research problem may well be refined, so that your literature review will need adjusting accordingly•.

- This is yet another reason for putting as much effort as you can into your research problem, so that downstream activities, such as the literature review, will change as little as possible as you progress.

What to read The gold standard of academic publications are peer-reviewed articles, that is articles which have been rigorously scrutinised by academic experts in the field (the 'peers') to ensure high scientific quality. Peer-review is a practice unique• to academia and it reflects the critical need in the academic community to establish that work contributes new knowledge, that it is the work of those claiming it, and that the paper has been written to be accessible• to the community. Academic journal and conference articles are usually peer-reviewed•.

- Well, almost unique.
- This doesn't necessarily mean it will be easy to read!
- The peer review process may be more or less stringent, so you need to take care when selecting articles and you should treat each publication on its own merits. You can check through your university library if an article is peer–reviewed or not.

Most references in your literature review should be peer-reviewed, therefore this handbook recommends you start with those. However, there may be some scope for using other non-academic sources – the grey literature. For instance, articles that are professionally relevant could be helpful, even if not peer-reviewed. Equally, you may reference government and other official reports: although non peer-reviewed, they may have undergone some level of public scrutiny and still contain reliable information. Books and even websites could also be used sparingly, but they are unlikely to have been peer-reviewed or scrutinised, so you should treat their claims to be new or definitive knowledge with appropriate caution.

Identifying search terms The number of peer-reviewed academic articles was estimated to have passed 50 million way back in 2010. So even without the grey literature, focussing on the most relevant articles for your research could be a challenge, if not approached systematically.

A good place to start is to brainstorm a set of search terms• that bear a relationship to each of the elements of your research problem. As we've explained, a research problem has the following elements: a context including some phenomena of interest, a knowledge gap in relation to those phenomena, and a justification in terms of who the stakeholders are and the reasons why the problem matters to them. Your quest for knowledge about each of them will drive your literature search.

• A search term is a word or a combination of words that you can key into a search engine.

Let's see how this could be done on an example.

Search terms from a research problem

Let us consider the following research problem:
"To evaluate the effectiveness of techniques to test embedded safety-critical software while the hardware is still unavailable. Full software testing can only occur once the software is embedded in its hardware. However, in many safety-critical avionics systems, this can happen very late in the development process, leading to expensive re-design if errors are found. Early software testing while the hardware is still unavailable could reduce such late occurrence of errors and expensive re-design."
We can take each problem element in turn to identify possible search terms. In doing so, we have come up with those in the table below. This initial set should be sufficient to perform our initial search.

Problem element	From problem statement	Our brainstormed search terms
Context	Avionics systems development	Avionic systems; system development
Phenomena	Embedded software; safety-critical applications; testing approaches	Embedded software; safety-critical systems; software testing
Knowledge gap	To evaluate the effectiveness of testing techniques when the hardware is not available	Testing techniques; effectiveness
Stakeholders	Software developers, safety engineers within the context	Software developers; software engineers
Reasons	Early software testing while the hardware is still unavailable could reduce the late occurrence of errors and expensive re-design.	Late errors; re-design

Activity: Search terms brainstorming #40

Using your research problem, fill in a table similar to that in the example, indicating few search terms you have brainstormed for each research problem element.

Guidance

The aim of this activity is to arrive at an initial set of search terms you can use to start your own literature search. You should start by words in your problem descriptions, but you could also include synonyms, particularly if you are not sure which technical terms are used in the literature.

You shouldn't worry too much if you have come up with too many or too few in relation to each element: you will have an opportunity to review and refine your choices later as this, too, is an iterative and incremental process.

Your brainstormed search terms will provide a starting point for searching the literature. Initially, you should be prepared for the fact that very large numbers of articles might be returned with many of them irrelevant to your final goal of understanding your chosen topic. Therefore, you are likely to need to refine your search terms and also come up with ways to narrow down your search results to manageable set of relevant articles.

Search terms are often used in combination to create more complex search terms which may increase the likelihood of finding articles which are close to your topic of interest. Basic Boolean operators, as those described in Table 3.18, are used for this purpose.

Table 3.18: Boolean operators for search terms

Boolean operator	Effect of the search
"Term 1" AND "Term 2"	Materials containing both Term 1 and 2 will be returned. This is used to narrow down a search.
"Term 1" OR "Term 2"	Materials containing only Term 1 or only Term 2 or both will be returned. This is used to expand a search.
NOT "Term 1"	Materials not containing Term 1 will be returned. This is used to narrow down a search.

Activity: Your first literature search #41

Conduct a search in Google Scholar from the search terms you brainstormed out of your research problem elements, combining them using the operators above if appropriate.
For each, record both the combination you have used and how many articles Google Scholar returns as hits. Reflect on how using different terms and operators may change the number of hits and how that may inform ways to widen or narrow down your searches.

Guidance

In combining your search terms, you could start by using the AND operator, then repeat the search trying different combinations of search terms, different operators, adding and removing terms, or even using synonyms of your search terms.
You should ensure you record both the combinations you've used and the resulting number of hits.

Discussion

Using the search terms from our example, we have conducted the following searches.
Firstly, we typed in:
"safety critical systems" AND "software testing"
to Google Scholar and this returned 5310 results: that's a lot of papers to read, so we knew that we needed to narrow the search down.
We therefore added another term and typed in:
"safety critical systems" AND "software testing" AND "avionics systems"
which returned 389 results: more manageable, but still a very large number.
To narrow the search further, we typed in:
"safety critical systems" AND "software testing" AND "avionics systems" AND "testing techniques"
and found 90 results.
We then tried:
"embedded software" AND "testing techniques" OR "testing methods" AND "avionics systems"
Which returned 35 results.
In this example, adding "avionics systems" helped us narrow down the search, presumably because only avionics applications were returned, rather than any kind of safety critical system; similarly, adding "testing techniques" presumably helped the search engine focus on techniques rather than, say testing processes or other. However, when we added "testing methods" using the OR operator, the hit list got even smaller, which was surprising. This demonstrate that search engines do not always behave as we would expect, so that it is important to try different approaches to arrive at a desirable outcome.

As you may have gathered from this activity, to a large extent your initial search will be a trial-and-error process• and you may end up iterating several times. It's not wasted effort, though. You can make the most of the time spent by:

• Be sure to be systematic and record which search terms you have used: this will save a lot of pain later when you're trying to remember which search term you used to pick a particular article!

- Using Boolean combinations of search terms wisely to narrow or widen your searches
- Particularly if only few hits are returned, replacing your search terms with new terms – often synonyms for existing ones.

Finally, although in this section we have focussed on Google Scholar, the same techniques apply to most bibliographical database search engines, so you could repeat the activities on subscription databases you can access through your Library.

What if there are still too many hits? Even if you spend your search time wisely, you may still end up with a large number of hits to consider. An important thing to recognise, is that not all of the hits returned will be relevant, so you will need to make an initial assessment of what to exclude from further consideration. When the number of search hits is high, this will take time, so you will need to select which articles to look at first.

We recommend you start by considering recent review articles. Review articles, also known as surveys, are academic articles which summarise the current understanding of a specific topic or phenomenon. They are usually the result of analysing and synthesising academic literature or bringing together findings from several studies. Any recent review articles that appear in your search offer a very easy way to start your literature review: not only do they collect together recent relevant papers, but they may have an overview or a precis of each.

If no review articles are included in your hits, you could repeat your search by adding AND "Review" or AND "Survey" to the end of your search term. Alternatively, you could ask your supervisor if they can suggest a review article you can start with. It's a great question to ask at an early meeting with them. Your supervisor may also suggest other seminal papers for you to look at.

By 'recent' we mean within 2 to 5 years, particularly for fast changing disciplines, such as Computing. For slow changing disciplines, the time frame of publication may be less important. Reducing the timeframe of publication is an effective way to cut down the returns considerably. Google Scholar allows you to select articles within a specified timeframe, and similar facilities are available in most bibliographical database search engines.

Second thing to recognise is that not all hits may be accurate – they may have the wrong date on them for instance – so care is warranted. Repeating the search on different bibliographical databases may help you identify erroneous entries.

Activity: Narrowing down your hit list #42

Consider the outcome of one of your searches. Identify any recent review paper which may be included. If necessary, revise your search term by including AND "Review" or AND "Survey" and try again, or set a specific timeframe to reduce the number of outputs.

Discussion

We conducted a search for Clara's problem using the search term:
"engineering plant" AND "planning" AND "forecasting" AND "accuracy" AND "production cost"

which returned 78 hits.
By considering the last 5 years as timeframe for publication, these were reduced to 17 hits. Among them, we found 3 articles which included some form of review.

3.3.4.2 Processing

Once your search has returned a manageable set of articles for further consideration, say up to 20, you should begin processing them to decide whether they could be relevant and, hence, considered further.

Although you will need to read all of the papers that you find potentially relevant, fortunately you won't need to read all of a paper to find out if that's the case! Sometimes it may sufficient to read what accompanies the paper on a search service•. Otherwise, clicking on the link to the paper will reveal its abstract, which you can quickly skim to check whether the paper might be relevant. If so, add it to your BMT as something for further consideration.

• Google Scholar, for instance, includes an extract from the paper that caused it to match your search term.

Don't be too picky at this point: it's better to include something in your database that you don't use later, than to discard something that you find later might have been relevant.

How will I know something is potentially relevant? Understanding the relevance of articles is an important skill that develops with the practice of reading the academic literature. Relevant articles will help you in a number of ways, including: to develop a deeper understanding of the context of your research, its stakeholders and beneficiaries; to raise your awareness of the significance of the contribution to knowledge you intend to make and any inherent difficulties in doing so; to show you different ways of thinking about your problem; to illustrate possible approaches or techniques you could apply to your problem.

During processing you need an efficient way to decide which of the papers in your search hits are potentially relevant, before investing considerable time and effort into assimilating and analysing their content.

You'll know a paper is potentially relevant if the phenomena that are mentioned in its abstract bear some relation to those of your research problem. Therefore, focusing on such phenomena is what we recommend you do at this point.

You should keep an open mind at this point, as it is likely the articles you are considering will use a different terminology from yours. Nevertheless, you should be able to judge whether they are close enough to elements of your own research problem, particularly the knowledge gap and its context.

It is important to acknowledge that there is no standard way of referring to phenomena, so having an open mind – at least initially – as to what could constitute them would be good. Remember, phenomena were defined very generally as observables. In a paper, phenomena, as observables, can be referred to in many ways, including:

LR – this, till the end of the sub-section, needs work; for Jon to do

- Directly: statements such as "the prices of software services were *observable* in this study" – the observables are the prices of software services.
- Indirectly: statement such as "the prices of software services were *not directly observable* in this study, so we used the proxy of hours worked accumulated across the team of developers" – the observables are the number of hours worked.
- As measurable: statements such as "the number of bugs in the software were given through the collection of bug reports" – the observables are the bugs in the software.
- As inferences from other phenomena: statements such as "the number of bugs in the software were estimated from the number of bug reports" – the observables are the number of bugs reported.

Going back to our example of safety-critical development...

...one of the review articles we found in our search is:
garousi2018testing
Its abstract reads[a]:
"**Context** Embedded systems have overwhelming penetration around the world. Innovations are increasingly triggered by software embedded in automotive, transportation, medical-equipment, communication, energy, and many other types of systems. To test embedded software in an effective and efficient manner, a large number of test techniques, approaches, tools and frameworks have been proposed by both practitioners and researchers in the last several decades.

Objective However, reviewing and getting an overview of the entire state-of-the-art and the – practice in this area is challenging for a practitioner or a (new) researcher. Also unfortunately, as a result, we often see that many companies reinvent the wheel (by designing a test approach new to them, but existing in the domain) due to not having an adequate overview of what already exists in this area.

Method To address the above need, we conducted and report in this paper a systematic literature review (SLR) in the form of a systematic literature mapping (SLM) in this area. After compiling an initial pool of 588 papers, a systematic voting about inclusion/exclusion of the papers was conducted among the authors, and our final pool included 312 technical papers.

Results Among the various aspects that we aim at covering, our review covers the types of testing topics studied, types of testing activity, types of test artifacts generated (e.g., test inputs or test code), and the types of industries in which studies have focused on, e.g., automotive and home appliances. Furthermore, we assess the benefits of this review by asking several active test engineers in the Turkish embedded software industry to review its findings and provide feedbacks as to how this review has benefitted them.

Conclusion The results of this review paper have already benefitted several of our industry partners in choosing the right test techniques/approaches for their embedded software testing challenges. We believe that it will also be useful for the large world-wide community of software engineers and testers in the embedded software industry, by serving as an "index" to the vast body of knowledge in this important area. Our results will also benefit researchers in observing the latest trends in this area and for identifying the topics which need further investigations." (**garousi2018testing**)

[a] Increasingly, and very helpfully, many journals and conferences research articles are beginning to use *structured abstracts*, such as the one in this article. A structured abstract has sections which bring out the context, objectives, results and other information.

Activity: the relevance of early hits to your search terms #43

For five of the hits to the search you conducted in Activity ??, fill in the relevancy matrix below, and score them for relevance.

Type	**Comment**	**Score**
Direct	TBD	TBD
Indirect		
Measurable		

Inferences
Complete this...

Discussion

TBD

What to do when you find a potentially relevant paper First thing you should do is to record it in your BMT. You should record it with the search term that you used to find it so that you can rerun the search to:

- Find similar papers that might later have added relevance to your work
- Find new papers that have been added to the literature since you last looked

In the latter case, you should also record the date• that you found it so you can check.

• Many bibliographic management tools will do this for you. Check whether yours does, perhaps even by reading the manual...

What if none of the hits are relevant? This is a point where you need to iterate back to searching bibliographical databases for new hits, using different search terms to widen the scope of your search. Also useful on these occasions is to ask your supervisors for advice: they should be able to point to seminal or review papers you should start from, or indicate which authors have made core contributions to your topic.

What if too few hits appear relevant? In this case too you will need to iterate back to searching bibliographical databases for new hits. In such cases, however, the few hits you have identified can also help you find other potentially relevant work. This is because articles cite other related articles, and in turn they are cited by other others in their papers.

Citation searching is the process of looking backwards and forwards to track citations, starting from an article of interest. Specifically, backward searching looks through the articles cited by a paper, while forward searching looks through the articles which cite that paper.

Looking backward is straightforward: all you have to do is go through the reference list at the end of the article. Looking forward, instead, will require you to make use of Google Scholar which, for every hit, provides a list of the articles that cite that paper•.

• Similar features are available in many other bibliographical databases, like the Web of Science.

Activity: Using Google Scholar 'Cited by...' feature #44

Conduct a Google Scholar search for Keshav's paper, and examine the information returned. At the bottom, you should see a number of links, included by a 'Cited by...' link which indicates how many articles cite the paper. Click on the link and examine the related list of articles.

Discussion

At the time of writing, the 'Cited by...' list included 211 articles: there were all the papers citing Keshav's work at the time. That number may be greater now.

Alongside, the 'Cited by...' link, Google Scholar also provides a 'Related articles' link, where you can find yet another list of articles, some of which may be relevant to your work.

Activity: Using Google Scholar 'Related articles' feature #45

Return to your Google Scholar search for Keshav's paper and click on the 'Related articles' link. Compare this list of articles with those at the 'Cited by...' link. What's their main difference?

Discussion

The 'Cited by...' list includes articles which cite Keshav's work. As such they may addressing very different topics and may belong to different disciplines. On the other hand, the 'Related articles' includes paper which address the same topic as Keshav, including various approaches to reviewing the literature.

You should make good use of such facilities as they can speed up considerably your search for relevant work to review. They are equally valuable at the beginning of your literature review process while you are trying to identify an initial set of articles to read, and later on, when you wish to expand your literature review on specific topics.

3.3.4.3 Assimilating and analysing

It's time to engage with the content of the articles you've identified as potentially relevant during processing. For this, you need to refer back to the Keshav's workflow you practiced in Section 3.3.3.

To understand an academic paper is to understand the contribution to knowledge that it makes. While you won't have to understand in depth everything you read, there will be some articles which are so fundamental to your research that you will need to study them carefully. This will require a substantial investment of your time and can be very challenging: even the most experienced researcher is unlikely to be able to read an academic paper once and immediately understand it in its entirety.

As your collection of articles grows, Keshav's approach will help you separate efficiently which are the most important papers, deserving several passes, from those where only a first pass may be sufficient, perhaps because they are not all that relevant ofter all.

As the number of papers you read grows, it will also be increasingly difficult for you to keep track of what each article is about without, without having to refer back to your annotations. Even more difficult will be to compare and contrast quickly key concepts you have encountered in different articles.

Therefore, alongside Keshav's approach, you will also need techniques, introduced in this section, to help you track and compare content, establish relationships and identifying emerging themes.

Tracking content of academic articles A summary-comparison matrix• is a useful tool to track the content of academic articles in a way which also makes it easier to compare the articles you have read.

• This term is used in Sastry and Mohammed (2013), although another term used online is 'literature matrix.'

A summary-comparison matrix is a table which includes a row for each article you have reviewed, and a number of columns corresponding to key aspects of the article you wish to summarise and compare with other articles, such as the research problem or question addressed, contextual facts known at start of the reported study, key contributions made, research methods applied, etc. The exact form of the matrix can vary, but we recommend you include at least the following columns in your matrix•:

• Feel free to adapt it to your own needs, for instance by changing the columns or adding new ones.

- Reference: either the full reference or a link to your BMT, to help you locate the article quickly
- Research problem/question: your understanding of the research problem or question(s) the reported research aimed to address
- Research methods/approach: how the authors conducted their study. Don't worry if you don't understand all the details at this point: we will return to research methods in Stage 2

- Known facts/assumptions/definitions/gaps at start: these are the premises of the study, that is arguments or evidence on which it relies upon
- Key findings/contribution made: what the study has contributed in terms of advancing knowledge in the field of study
- Notes in relation to own research: these are your own notes on how the content of the article is relevant to, or could be used in your own project

Activity: Using a summary-comparison matrix for the Keshav's paper #46

Create a summary-comparison matrix with the columns recommended above, and fill in its first entry in relation to the Keshav's paper you considered in Section 3.3.3.

Guidance

You can use a spreadsheet to create the matrix. To fill in the entry, you will need to go back to your notes on the article, and possibly skim through the article again to extract relevant points.

Discussion

This is our attempt. Yours may differ slightly.

Reference	**Research problem/ question**	**Research methods/ approach**	**Known facts/assumptions/ definitions/gaps at start**	**Key findings/ contribution made**	**Notes in relation to own research**

Keshav, S. (2007) 'How to read a paper', ACM SIGCOMM Computer Communication Review, 37(3), pp. 83-84. Revised in 2013.	to define an approach to reading and assimilating academic articles	the approach is explained and exemplified; no formal evaluation is presented	research requires spending a significant amount of time and effort reading academic papers; particularly novice researchers lack the skills to do so effectively, leading to wasted effort; such skills are rarely taught	a practical approach to help researchers engage with the content of an academic articles effectively and efficiently; an outlined process for reviewing the literature based on the approach	it seems a simple, yet effective approach, well worth applying when working on my literature

What to include in your summary-comparison matrix is, of course, a matter of judgement, so there is an element of subjective interpretation of each article content. This is expected, so that the column headings we have chosen should help you be consistent and systematic across different articles. It is also up to you to choose the level of detail for each entry: while you should try to be succinct, it is important that you include enough information to use the matrix without having to continually refer back to your notes and articles. These may result in quite a bit of text included in the matrix, as shown in the next example, which we will use to illustrate the techniques introduced in this section.

An example of summary-comparison matrix

We are interested in reviewing the literature in relation to the following research problem:
How to leverage curriculum data effectively in Higher Education Institutions (HEIs) to augment curricular decision making capability. This matters to HEIs because, while they collect vast amount of curriculum data, how to harness effectively remains an open question. An effective use of such data may lead to better curriculum benefiting both HEIs and their students.
We conducted a literature search, out of which we identified eleven potentially relevant articles. We constructed a summary-comparison matrix, whose first three entries are illustrated in Figure 3.1. It is not necessary for you to read it through, but you may notices that our entries are quite detailed.

Reference	Research problem/question	Research methods/approach	Known facts/assumptions/ definitions/gaps at start	Key findings/contribution made	Notes in relation to own research
Hilliger, I., Miranda, C., Celis, S. and Pérez-Sanagustín, M., (2023). Curriculum analytics adoption in higher education: A multiple case study engaging stakeholders in different phases of design. British Journal of Educational Technology. 00,1–17	to understand how stakeholders can contribute effectively to the design process and adoption strategies of learning analytical tools	Cross-analysis of quantitative and qualitative evidence from three case studies in the context of multiple Latin American universities. The case studies focussed on the development of analytics tools to support continuous curriculum improvement (both student learning and programme quality)	data researchers/tech developers generally lack awareness of how learning analytics tools can provide meaningful and actionable information for everyday use stakeholder engagement could ensure the successful development and adoption of learning analytics current studies indicate that stakeholders are often only engaged at start, while participatory human-centred design could provide stakeholders with the opportunity to influence the whole of development and increase acceptance and adoption post-deployment barriers to adoption stem from tools not addressing stakeholders' needs or requiring unwelcome changes to processes/tasks	some mechanisms for engaging stakeholders at various CA tool development stages, from requirements to design to deployment some success factors for CA adoption	The findings are very generic and a bit weak in the sense that they could have been inferred from the literature on software development in general: there is very little (if anything) which is specific to curriculum analytics. However, the empirical evidence provided contextualises such knowledge from SE to this particular educational context.
McEneaney, J., & Morsink, P. (2022). Curriculum Modelling and Learner Simulation as a Tool in Curriculum (Re) Design. Journal of Learning Analytics, 9(2), 161-178	to develop a simulation method to explore the possible causal effects of curriculum design before implementation	Construction and evaluation of Coloured Petri Nets simulations based on curriculum and learners characteristics, in relation to learning outcomes, curriculum sequencing and learning progression	a key risk in curriculum re-design is that effects on learning cannot be empirically tested until after deployment, when significant resources have already been used it is desirable for stakeholders to be able to explore the possible causal effects of curriculum design before implementation existing learning analytics focus primarily on historical data and probabilistic prediction, so have limited applicability to the above problem simulations could be used to investigate envisaged interventions, but no research to date achieves this at a programme level	proof-of-concept simulation method to be used alongside other practices intended to support curriculum designer, from scholarship around learning and curriculum design, to applying learning analytics to historic data identified benefits: - high stakeholder engagement in a collaborative programme improvement - stakeholders able to see the (potential) effects of curriculum sequencing and timing on student learning - can support iterative testing of different design choices - is transparent in its rule and algorithmic base, hence open to inspection and adjustments identified limitations: - based on simplified assumptions of human learning - early stages in its development	An interesting alternative to more traditional curriculum analytics approaches. A clear demonstration of how certain curriculum and learning data could be put to use to inform curriculum design/re-design. Quite technically focussed: it would be interesting to know how easy would be to reproduce it for different programmes

Figure 3.1: Example of summary-comparison matrix

Activity: Building your own summary-comparison matrix #47

Create a summary-comparison matrix for your own project, based on your reading of the articles you have identified as potentially relevant during processing.

Guidance

You should apply the Keshav's approach to read and assimilate the content of each article. It is worth including in the matrix only articles which you deem as definitely relevant after a first pass, as those are the articles you're likely to return to over and over again in writing up your literature review.

Identifying concepts of interest Once you have a number of entries in your summary-comparison matrix, you can start analysing them in order to identify concepts — facts, ideas, questions, etc. — relevant to your research problem. You are looking for concepts that can help you address the following questions in relation to your research problem:

Questions	Contribute to
* When, where and why does the problem occur?	Articulating the problem in its context
* Whom does it affect? * How serious is it? * What are the benefits of addressing it?	Establishing its significance, stakeholders and beneficiaries
* What has been done so far to address it? * What else could be done to address it?	Establishing knowledge gaps and the potential contribution to knowledge

To this end, we recommend you highlight concepts of interest within your summary-comparison matrix, then collect them in a *concept matrix*. This is yet another table, with one concept per row and one article per column, and a tick at their intersection to indicate whether the concept appears in the article. Some concepts will recur across several articles, and the concept matrix is a useful visual tool to identify those recurring concepts.

That some concepts recur in papers in your chosen area might suggest to you that they are important concepts, which have attracted the attention of several researchers•. On the other hand, new concepts may are introduced in very recent work, which are yet to be established across the literature: it may be good to make a special note of those, as they might reveal current hot research areas or research paths that are still to be trodden.

• Of course, forming a judgement on this is something you will have to do, perhaps with the help of your supervisor.

Recurring concepts may also point to relationships and parallels which may be drawn between the work of diverse authors. This will help you in your critical summaries, where you will need to bring together and compare and contrast ideas from different authors and articles.

An example of concept matrix

Carrying on with our example, we have highlighted a number of concepts in our summary-comparison matrix, as shown in Figure 3.2, from which we have constructed a concept matrix, a small extract of which is given in Figure 3.3 In our example, we have applied the following heuristics to each article, to decide which concepts to include:

- an indication of the research problem/question
- facts contributing to a characterisation of the problem context
- key contributions made
- any specific tool/technique/technology developed or adopted to address the problem

We have, however, avoided details about research design and methods at this point, as our focus is to characterise and justify our research problem. Research design is, of course, very important, and something we will consider later on in the research process.

Activity: Building your own concept matrix #48

Create a concept matrix for your own project, derived from your summary-comparison matrix through the identification of concepts of interest.

Guidance

We could start by applying the heuristics from the example to identify and highlight concepts in your summary-comparison matrix, but do not be constrained by them, and feel free to come out with other heuristics to guide your choices. Expect to go over each entry a number of times before reaching the set of concepts you wish to focus on.

Reference	Research problem/question	Research methods/approach	Known facts/assumptions/ definitions/gaps at start	Key findings/contribution made
Hilliger, I., Miranda, C., Celis, S. and Pérez-Sanagustín, M., (2023). Curriculum analytics adoption in higher education: A multiple case study engaging stakeholders in different phases of design. British Journal of Educational Technology. 00,1–17	to understand how stakeholders can contribute effectively to the design process and adoption strategies of learning analytical tools	Cross-analysis of quantitative and qualitative evidence from three case studies in the context of multiple Latin American universities. The case studies focussed on the development of analytics tools to support continuous curriculum improvement (both student learning and programme quality)	data researchers/tech developers generally lack awareness of how learning analytics tools can provide meaningful and actionable information for everyday use stakeholder engagement could ensure the successful development and adoption of learning analytics current studies indicate that stakeholders are often only engaged at start, while participatory human-centred design could provide stakeholders with the opportunity to influence the whole of development and increase acceptance and adoption post-deployment barriers to adoption stem from tools not addressing stakeholders' needs or requiring unwelcome changes to processes/tasks	some mechanisms for engaging stakeholders at various CA tool development stages, from requirements to design to deployment some success factors for CA adoption
McEneaney, J., & Morsink, P. (2022). Curriculum Modelling and Learner Simulation as a Tool in Curriculum (Re) Design. Journal of Learning Analytics, 9(2), 161-178	to develop a simulation method to explore the possible causal effects of curriculum design before implementation	Construction and evaluation of Coloured Petri Nets simulations based on curriculum and learners characteristics, in relation to learning outcomes, curriculum sequencing and learning progression	a key risk in curriculum re-design is that effects on curriculum cannot be empirically tested until after deployment, when significant resources have already been used it is desirable for stakeholders to be able to explore the possible causal effects of curriculum Text design before implementation existing learning analytics focus primarily on historical data and probabilistic prediction, so have limited applicability to the above problem simulations could be used to investigate envisaged interventions, but no research to date achieves this at a programme level	proof-of-concept simulation method to be used alongside other practices intended to support curriculum designer, from scholarship around learning and curriculum design, to applying learning analytics to historic data identified benefits: - high stakeholder engagement in a collaborative programme improvement - stakeholders able to see the (potential) effects of curriculum sequencing and timing on student learning - can support iterative testing of different design choices - is transparent in its rule and algorithmic base, hence open to inspection and adjustments identified limitations: - based on simplified assumptions of human learning - early stages in its development

Figure 3.2: Example of highlighted concepts

concept vs reference	Hilliger, I., Miranda, C., Celis, S. and Pérez-Sanagustín, M., (2023). Curriculum analytics adoption in higher education: A multiple case study engaging stakeholders in different phases of design. British Journal of Educational Technology. 00,1–17	McEneaney, J., & Morsink, P. (2022). Curriculum Modelling and Learner Simulation as a Tool in Curriculum (Re) Design. Journal of Learning Analytics, 9(2), 161-178	Hilliger, I., Aguirre, C., Miranda, C., Celis, S., & Pérez-Sanagustín, M. (2022). Lessons learned from designing a curriculum analytics tool for improving student learning and program quality. Journal of computing in higher education, 34(3), 633-657	Ochoa, X. (2016, April). Simple metrics for curricular analytics. In Proceedings of the 1st learning analytics for curriculum and program quality improvement workshop, CEUR Workshop Proceedings (Vol. 1590, pp. 20-26).	Dennehy, D., Conboy, K., & Babu, J. (2023). Adopting learning analytics to inform postgraduate curriculum design: Recommendation s and research agenda. Information Systems Frontiers, 25(4), 1315-1331	Greer, J. E., Thompson, C., Banow, R., & Frost, S. (2016). Data-Driven Programmatic Change at Universities: What Works and How. In proceedings of PCLA @ LAK, 32-35	Molinaro, M., Steinwachs, M., Li, Q., & Guzman-Alvarez, A. (2016). Promoting Instructor and Department Action via Simple, Actionable Tools and Analyses. In PCLA@ LAK, pp. 36-40
how stakeholders can contribute effectively to the design process and adoption strategies	yes	yes	yes				
analytics tools to support continuous curriculum improvement	yes						
mechanisms for engaging stakeholders at various CA tool development stages	yes						
success factors for CA adoption	yes						

Figure 3.3: Example of concept matrix

3.3.4.4 Synthesising

The next step is to analyse both recurrent concepts and concept relationships to work out whether they contribute to wider common themes. This is a step of synthesis and abstraction: synthesis in the sense of bringing together different ideas; abstraction in the sense of deciding whether specific concepts may be instances of more abstract ones. Let's look at what we mean through our example.

What we mean by common themes

In our review, we found that many concepts we have identify point to some sort of modelling of students' study pathways through study programmes. While both modelling techniques and the purpose of it may vary from articles to articles, they all shared this common theme. By recognising 'modelling study pathway' as an emerging theme, we can both abstract and bring together research from different authors, making it easier for us to write a summary which compare and contrast their work.

Developing a concept map To find common themes you will need to exercise both judgement and creativity, and the tool we recommend you use is a *concept map*: this is a diagram or graphical tool where you can represent visually concepts and their relationship. To produce your map you could use a drawing package, or a physical board. What matters is that the tool you use should allow you to 'move things around' to explore different ways to relate and group your concepts.

In constructing your concept map, we recommend you follow the following process:

Step 1 reproduce on the map all the concepts from your concept matrix, linking them to the articles they came from. For a recurring concept, only include the concept once, but clearly link it to all the articles in which it appears.

Step 2 colour-code concepts so that concepts you think are related share the same colour; name the themes corresponding to each colour

Step 3 re-arrange the concepts, grouping them by colour; make sure the link between concepts and articles are transferred to the groups

Note that it is unlikely you will reach your final grouping in one pass: this is yet another iterative process, so you should expect to go back and forth between steps!

Figure 3.4 illustrates the outcomes of applying the three steps in our example: in the map, concepts are in plain text, and references are within yellow stickers; a legend was used to relate the identified themes to their colours. You can, of course, choose different visual representations to achieve similar outcomes.

Although we only illustrate the final outcome at each step, we should stress that it did take us several attempts to identify a set of themes we were happy with. Note how some groups are larger than others: the group 'size' provides an indication of which themes feature more prominently in the articles reviewed. For instance, in our example, lots of content is dedicated to "modelling student trajectories" and the "benefits of CA tools", while only one article deals with the 'student voice'. This is also useful as a measure of which themes you have already addressed comprehensively and which may deserve further consideration through further literature search, reading and assimilating.

Activity: Building your own concept map #49

Create a concept map for your own project, in order to identify any emerging theme.

Guidance

You should start from your concept matrix and apply the process outlined. There may be different themes, and groupings, emerging from your analysis, which you should explore in relation to the extent they help you characterise and justify your research problem.

Writing summaries It is now time to start writing! Each theme you have identified should include enough concepts and references for you to start summarising what you have found in the literature under that theme. Later on, you will be using these summaries as building blocks towards writing up your literature review draft.

Writing a summary for an identified theme

Among the themes of our example, 'modelling study pathways' is one of the most prominent. By considering the information we have collected in our summary-comparison matrix and concept map, we have produced the following summary:

> Several authors have considered modelling and analysing students' learning trajectory through a programme of study, in order to understand how students progress or otherwise

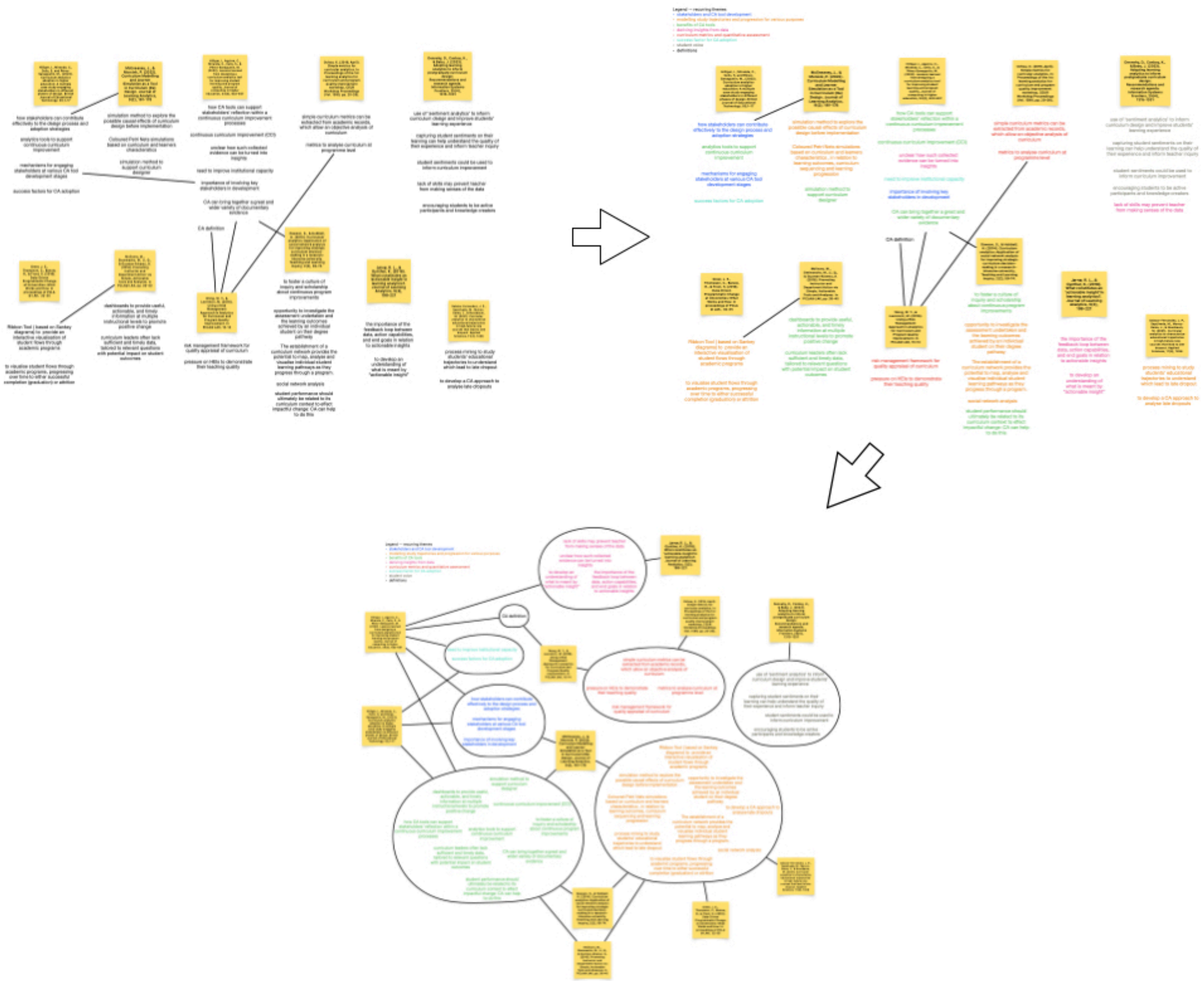

Figure 3.4: Example of constructing a concept map

through their study and the learning outcomes they achieve in doing so. Such an understanding can then be used to inform scholarship and reflection around curriculum and its design, and inform possible changes.

For instance, Dawson and Hubball (2014) deploy social network analysis techniques to identify and visualise the most common learning pathways followed by students within complex curriculum structures, in which many links may exist between the various curriculum components. They suggest that their proposed tool could be used by curriculum practitioners to study student progression and completion across different pathways, and the extent students acquired the expected learning outcomes, although their study does not evaluate the extent that might be the case.

Similarly, Salazar-Fernandez et al. (2021) use process mining to extract students' educational trajectories from historic data: in this case, their aim is to understand which trajectories are more likely to result in late dropouts. In their proof-of-concept tool evaluation over a specific data set, they achieve some positive results with the tool providing a strong indication that students taking a study break before resitting a failed module are most likely to drop out. Further research is needed to apply and evaluate their tool in other settings.

Somewhat distinct from these studies is the work of McEneaney and Morsink (2022), who propose a simulation tool, based on Coloured Petri Nets, to be used as a design tool to help curriculum practitioners to test the possible effect on learning of envisaged curriculum changes, such as including or removing modules or study pathways in an existing programme. As another proof-of-concept tool, the work still requires wider application and evaluation.

Finally, both Greer et al (2016) and Molinaro et al. (2016) focus on potentially useful visualisations for curriculum practitioners. In particular, Greer et al (2016) introduces the "Ribbon tool", based on Sankey diagrams, for visualising student flows through academic programmes, with interactive capabilities which allow practitioners to study and compare specific student demographics. The same tool is recommended by Molinaro et al. (2016), alongside other visualisation tools, based on both students and course data, to allow practitioners explore both curriculum features and students' attainment. Both articles are part of the proceedings of the very first Curriculum Analytics workshop, in 2016, which also explain why they contain primarily poof-of-concept work and suggestions for future research.

Overall, this collection of articles contains some interesting ideas as to how curriculum and student data could be combined and analysed through the application and development

> of bespoke Curriculum Analytics tools. They all appear, however, quite preliminary studies, which is also an indication that this remains a young field of study where much research is still needed.

This is already a sizeable summary, which makes good use of the articles we have reviewed, appropriately cited in the text. Note how we have structured the narrative by including: an opening paragraph introducing the theme; separate paragraphs for the relevant articles we have reviewed, highlighted the specific problem and contribution made in each; a concluding paragraph with an overall assessment of the work reviewed. We have also presented together articles with similar contributions, and highlighted those which are quite distinct from the others.

Activity: Writing you own theme summaries #50

Write up summaries for each of the common themes you have identified, making good use of the content of your summary-comparison matrix and concept map.

Guidance

As long as the entries in your summary-comparison matrix are sufficiently detailed and informative, you should be able to write your summaries without having to go back to the body of the articles, although be ready to do so on occasion. The concept map should tell you which articles to focus on for each of the themes.

3.4 Setting research aim and objectives

Exciting times! Now that you have a candidate research problem, and have conducted an initial review of the literature, you can start defining more precisely the scope of your project, but first it is important to revisit your candidate research problem in view of what you have learnt from the literature.

Curriculum Analytics

We left our Curriculum Analytics example with the following expression of our research problem:

> How to leverage curriculum data effectively in Higher Education Institutions (HEIs) to augment curricular decision making capability. This matters to HEIs because, while they collect vast amount of curriculum data, how to harness effectively remains an open question. An effective use of such data may lead to better curriculum benefiting both HEIs and their students.

The knowledge gap in this formulation ('to leverage curriculum data effectively in HEIs to augment curricular decision making capability') is quite broad: for instance, we may ask ourselves, which data to consider and in relation to which curriculum decisions. Our reading the literature has given us some concrete ideas. In particular using data about students' study choices and data about the structure of study program can help us model students' trajectories, and this has shown some promise in relation to supporting academic enquiry into student learning and curriculum design. The literature also supports the notion that published work is still preliminary and by and large untested, which affords further opportunities for research. As a result, we decided to narrow down the knowledge gap in our research problem to the following:

> How to leverage curriculum data effectively in Higher Education Institutions (HEIs) to model students' trajectories with a view to improve curriculum design and student learning.

Activity: Revisiting your research problem #51

Consider your current research problem statement and what you have learnt from the literature review you have conducted. Revise your problem statement accordingly.

Guidance

You should focus on the extent your literature review supports the knowledge gap in your problem, and can help you narrow down the scope of your research to address it. After this activity, you should have a clearer idea of the focus of your research.

3.4.1 Articulating your research aim

While your research problem highlights the knowledge gap you intend to address, your research aim should express the specific way that gap will be addressed by your project. The distinction is subtle but important: your aim should provide a clear indication of the focus of your work and the particular form the new knowledge generated will take. That you can provide such a description means that you have made some great progress!

Curriculum Analytics example, cont'd

Going back to our example, you may recall the latest formulation of our research problem as:

> How to leverage curriculum data effectively in Higher Education Institutions (HEIs) to model students' trajectories with a view to improve curriculum design and student learning.

From this, we could formulate our aim as:

> To apply techniques for modelling students' trajectories within a UK university, in order to evaluate their effectiveness in informing curriculum re-design.

which indicates that our research intends to test the effectiveness of a number of techniques in their application to curriculum data within a particular context, a UK university.

Activity: Drafting your research aim #52

Consider your current problem statement. Draft a possible related research aim.

Guidance

Your research aim formulation doesn't need to be perfect at this stage, and will evolve with your research problem as you progress through your project. However, it is important for you to think about what intended knowledge contribution your research will make, and expressing your research aim is a way to do so.

3.4.2 Choosing a title

With your chosen research problem and aim you should now have a good idea of what you are hoping your research will focus on – the need you will address in context – and deliver – the intended knowledge outcome. From this you can choose a representative title for your project. •

• The title is the first contribution you will have made to your dissertation! That first page is no longer blank. Congrats, you're on your way!

The title provides the first indication to your reader of what you propose to research. It may change as the research progresses, so it is important to review it from time to time to check its current relevance. At this stage, the title can only be your best attempt at anticipating later developments in your research, so don't agonise too much over it.

Here are some guidelines for you to follow:

- A good title should succinctly convey elements of both research problem and aim, specifically, the focus and intended outcome of your project
- A good title is around 8–20 words. Here are some examples•:
  - Integrated process improvement strategies in small/medium-sized manufacturing enterprises in the UK fabricated metals industry
  - Cost-effective greenhouse gas mitigation measures for the UK livestock industry – a risk assessment of the impact on water footprints
  - Critical Success Factors for enabling Packaged Software to realise the potential Business Benefits

• An experienced supervisor may have other examples too.

- Avoid titles that are very short and enigmatic, or titles that are long and rambling
- Do not include acronyms or obscure technical terms, except those which are likely to be widely understood (e.g., UK, USA, IT, or WWW)
- Do not pose a question in your title
- A title is not a sentence, so it does not require a full stop at the end.

Activity: Choosing a title #53

Use the guidelines above together with your research question and aim, to write down an appropriate title for your research proposal.

Guidance

You will have many opportunities to refine your title, so at this point, spend no more than 20 minutes on this.

3.4.3 Articulating your research objectives

Research objectives help you break down your aim into smaller targets that, together, achieve the aim.

Each objective should be expressed in a way which allows you to tell if you have achieved it by the end of your project. To this end, they are generally expressed using action verbs, like to identify, design, compare, explain, describe, evaluate, ..., which point to activities the effect of which can be observed and somehow measured. Objectives should also be achievable within your project constraints, that is the knowledge, skills, time and resources you have or can acquire within your project. As stepping stones towards reaching your aim, your research objectives should be sequenced in a way that meeting early objectives should enable subsequent ones.

While more specific than your aim, your research objectives can still be relatively broad at this point, in the sense that they are not meant to enumerate every little thing you are going to do. Usually 3 to 5 research objectives are sufficient: later on you will break them down into several specific tasks, but we are not there yet.

Let's go back to our example.

Curriculum Analytics example, cont'd

We left with our aim stated as:

> To apply techniques for modelling students trajectories within a UK university, in order to evaluate their effectiveness in informing curriculum re-design.

from which we could derive the following research objectives:

- Objective 1: To *identify* a set of techniques that can be used to model students' study trajectories
- Objective 2: To *apply* those techniques in the context of a UK university
- Objective 3: To *evaluate* the extent they can help curriculum stakeholders take design decision in relation to programmes of study

Objective 1 requires the identification of specific techniques that could be used in the project. An appropriate selection should take into consideration whether their use on the project is feasible in relation to available knowledge, time, resources.
Objective 2 concerns the application of the techniques selected in context of the target UK university. Feasibility may relate to the kind of data required and their availability with the target university.
Objective 3 concerns the evaluation of the techniques applied in relation to their use by curriculum stakeholders. Feasibility may concern the availability of such stakeholders to participate in the study.
Note how those objectives are expressed using action verbs and build on each other – if successfully completed, they will allow us to meet our overall research aim.

In this example, we have used an *identify-apply-evaluate* pattern to break down our aim into objectives. This is a useful patten, particularly when you intend to apply and evaluate something – a theory, a product, a new technology – within a real-world context, something very common in Masters research project. If your research is more formal, mathematical, clinical, or of some other form, other patterns may apply. For instance, a mathematical dissertation is likely to require you *to prove* formally that a particular theorem holds, while a clinical trial is likely to require you *to test* some statistical hypothesis•

• We haven't discussed hypotheses so far. In common language a hypothesis is a supposition for which supporting evidence is yet to be found, so it may be the starting point of an investigation. Statistical hypotheses are particularly types of hypothesis that can be tackled with statistical techniques. We will return to this in the next chapter.

Even if you apply a pattern, identifying the best form for your research objectives will require some creativity on your part, as there is no magic formula to do so. In all cases, you should discuss how to break down your aim into objectives with your supervisor.

At this point in your project your objectives are still speculative, expressing the intention of your research: they are likely to change during your project, so that you you will need to review them at each study stage.

Activity: Articulating your research objectives #54

Consider your current research aim. Write down 3 to 5 possible objectives, explaining how they relate to each other and how they contribute, if successfully completed, to meet your research aim.

Also comment on how specific and feasible they are, the latter in relation to your own knowledge, skills and resources, and your project time span.

Guidance

Your aim and objectives don't need to be perfect at this stage and will evolve with your research problem as you progress through your project. However, it is important for you to think about what concrete contribution your research will make: expressing aim and objectives is a way to do this.

3.5 Developing the research design

Developing a design for your research will help you summarise, explain, and justify how your research is conducted to your examiners and other readers of your dissertation. In addition, it will be a touchstone for you to refer to at times of difficulty and allow you to plot your progress against your objectives.

The research design will, like most other aspects of your project, evolve: at the start, it will be a collection of your initial ideas and intentions; by the end, it will be a detailed account of what you have actually done.

Your research design will depend on many factors, including the type of research problem you are trying to address, the intended outcome of your research, the sort of evidence you will need, the resources and expertise you have, accepted research methods applied by other researchers in your field•. As you are a key participant in your own research, your personal views and values will also affect the choices you make while developing your research design.

• And the philosophical beliefs which motivate them

Research design is also a field of study in its own right, one which has grown out of many diverse academic traditions and ways of thinking across academic disciplines and subject areas, and which is still evolving•. As such, it is not an easy topic to digest and is one of the most challenging aspects of doing academic research. It can be puzzling for students embarking on academic research for the first time.

• In this young research area, there is still a lot of post–rationalisation of a particular course of research as authors looks for generalisable themes.

For this reason, in Stage 1, we will not consider research design in detail — that will happen from Stage 2 instead. However, so that you can start to think about your research design, in this section, we introduce a range of topics which concern research design and should influence your follow-up work.

3.5.1 Types of evidence and data

The phenomena upon which your research will be based must be observed and this gives rise to data. Data can be interpreted to give information and evidence.

Thus, most academic research will be based on data and evidence. Data is the raw observations with no interpretation attached — anything you may collect, observe or gather in your research. Evidence is information interpreted to support (or otherwise!) your academic arguments. Indeed, data forms the basis of evidence, so the two concepts are closely linked and often used interchangeably. This section recalls briefly the main types of data and evidence used in academic research.

Quantitative data are data that can be quantified or measured, and be given numerical values. They include the following types:

- **Numerical** data are numbers•, such as the number of students registered on a module or the temperature in the UK in July. Simplifying a little, when numerical data has a whole-number value it is called discrete, otherwise it is continuous•. In either case, appropriate mathematical and statistical operations can be applied to them, values can be ordered, and the interval between two numbers can be calculated exactly.
- **Ordinal** data are non numerical data that can be arranged in an order. An example is the very widely used Likert scale• often used in questionnaires to elicit opinions. An example of a 5-point Likert scale is that ranging from 'Strongly disagree' to 'Strongly agree' with 'Disagree', 'Neither Disagree nor Agree', and 'Agree' in the middle. While these values can be arranged in order•, mathematical and statistical operations can only be applied in a limited way, for instance, taking the mean (or average) score of responses on a Likert scale. •
- **Interval** data are data which can be arranged on a scale, so that we can calculate the distance between any two data points. All numerical data are also interval data, but interval data may not be numerical. For instance, calendar dates are interval data as we can calculate the time interval between two given dates, e.g., the number of days in between.
- **Ratio** data are numerical data with an absolute zero considered as a point of origin, that is no negative values are possible. Examples include a person's high, weight or their wage from employment: none of these can take a meaningful value less than zero.

• Yes, they are!

• Given the fundamental nature of energy, and the vagaries of quantum physics, it may be that we're incorrect in stating that real–world temperature is actually a continuous variable. However, even if it isn't, its values lie on a continuous scale.

• Almost certainly, the most recent survey you completed would have used the 5–point Likert scale mentioned here.

• This might be done by giving 'Strongly disagree' the numerical value 1, 'Disagree' the numerical value 2, and so on.

• Read more about Likert scales use (and misuse) in **carifio2007ten**.

Qualitative data, on the other hand, are descriptive in nature and defy ordering. Sentences, images, sounds, etc., are all examples of qualitative data. An important subclass of qualitative data is **nominal** data commonly used to denote categories, for instance, Dog, Cat, Alligator, etc. These data cannot be ordered and mathematical operations and functions don't apply to them.

Note that in Statistics ordinal data and nominal data are called **categorical** data, exactly because they are used to denote categories, which may or may not be ordered. This also means that categorical data span the quantitative/qualitative divide.

Data and evidence are also classed as:

- **primary,** when newly generated or collected during research; or
- **secondary**, when already available from previous research, and re-used during new research.

The academic literature that will be at the core of your literature review• is secondary evidence, as are all other published academic and non academic documents, e.g., laws, policies and procedures, official reports, etc.

• A bit or a hint for the next Activity :)

Curriculum Analytics example, cont'd

In our example, to conduct our research we would need to make use of a range of curriculum data which are likely to include both quantitative (e.g., number of students, pass rates, etc.) and qualitative data (e.g., components of a programme of study, learning outcomes, etc.). These will be all secondary data, in the sense that they will be provided by the target university for us to apply a range of modelling techniques. In terms of outcomes of our research, we are envisaging some form of stakeholders' evaluation of the effectiveness of the techniques, so we are likely to generate, as primary evidence, mainly qualitative data.

Activity: Considering types of data and evidence in your project #55

List and justify the kinds of data and evidence your research will make use of or generate.

Guidance

Consider both existing data and evidence you will need and any new data/evidence your research may produce. Justify your answer in terms of the specific aim and objectives of your work.

3.5.2 Classes of research methods

Research methods are the means used in research to collect, analyse, synthesise or present data and evidence, and to derive findings from them. Their purpose is to help you conduct your research in a systematic, rigorous, repeatable and reliable fashion.

Research methods can be classes based on their purpose into:

- **data collection methods**, used to gather data and evidence
- **data analysis methods**, used to analyse data and evidence
- **modelling methods**, used to build models of complex real-world situations, where many interrelated phenomena are at play and a holistic understanding is needed.

Methods are also classed based on the type of data and evidence they handle into:

- **quantitative methods**, which – unsurprisingly – are used when dealing with qualitative data;
- **qualitative methods**, which – again unsurprisingly – are used for qualitative data.

Broadly speaking, quantitative methods are widely applied in the natural sciences, with their focus on measurement, natural phenomena and their simpler cause-and-effect relations, while qualitative methods are widely applied in the social sciences, with their focus on understanding human behaviour. In practice, however, this distinction is not as stark and often quantitative and qualitative methods are mixed in research, particularly when research spans several academic disciplines. Instead, modelling methods are often associated with design, computing, engineering and more generally the so-called 'sciences of the artificial' (Simon, 1969), which consider technology and its development in its wider social context, focusing on addressing complex, messy socio-technical problems.

Within these broad classes, you will encounter several methods from Stage 2 onwards.

Curriculum Analytics example, cont'd

In our example, we may need both quantitative and quantitative collection methods to extract relevant data sets from the data provided by the target university. In addition, modelling methods may be required in the application of the selected techniques to those data set. Qualitative data analysis methods should apply to stakeholders' evaluation data.

Activity: Considering research methods in your project	#56
List and justify the kinds of research methods you may apply in your research.	
Guidance	
You should relate your choices to the kind of data and evidence you have identified in the previous activity.	

3.5.3 Ethics and regulations

All research must be carried out legally and ethically•, so that it is essential you consider your proposed research and research design from these standpoints.

• People who carry out unethical and illegal research cannot share their results within the academic community without being called out. They cannot, therefore, be called researchers.

Your responsibilities as a researcher, many of which we will consider in this section, are to:

- Behave with integrity, i.e., respect the rights of all participants in your research, be open and honest about how you have conducted your research and about your results, including not committing plagiarism•, ensure validity and accuracy in the collection and reporting of data, and disclose any conflict of interest, e.g. personal interests or relations with research participants which may compromise your judgement.

• Briefly, plagiarism is the action of passing somebody else's work as your own. We will cover plagiarism in detail in Stage 2.

- Comply with ethical codes and standards for research, laid down by your own university, and possibly professional bodies in your field of study.
- Comply with legal requirements in relation to health and safety and the protection of personal data.
- Guard against all forms of bias in your research.

3.5.3.1 The rights of human participants in your research

In your project, you may call on other people to take part in your research, for instance people you intend to interview or observe, or who may complete questionnaires you design, or provide you with documentary evidence you require. These people have a number of rights you must respect, primarily:

- The right not to participate – no-one should be pressured to take part in your research
- The right to withdraw – they can change their mind at any point
- The right to give informed consent – they should be given sufficient information on your research and their role in it for them to decide whether they wish to participate or not
- The right to anonymity – their identity should not be disclosed unless they give you explicit permission to do so
- The right to confidentiality – the data/information you obtain from them should be kept private if they ask you not to disclose it
- The right to privacy – you should not intrude unnecessarily into their lives
- The right to protection from harm, i.e., you must take steps to minimise the risk of harm, either physical or psychological, to all participants.

Your university's guidelines for research with human participants #57

By asking your supervisor, searching on your university's intranet, or otherwise, find out which guidelines exist in relation to human participants in your research.

Discussion

Our university has a very comprehensive set of ethical guidelines and codes for research with human participants, covering expected behaviours and protocols, including the need for explicit approval from the university's ethical research committee to conduct the research, the use of personal data and how to safeguard the health and safety of all participants.

3.5.3.2 Personal data in research

In your research, you may wish to collect data about your human participants. The collection and use of this kind of data is usually regulated by law, although the specifics may change from country to country, and the university with which you're studying might add specific guidance too.

Within the European Union, the EU General Data Protection Regulation (GDPR) applies.• GDPR defines **personal data** as any information which may identify a living person, be that a name or a personal identification number, or a combination of physical characteristics, or cultural or social identities, and establishes rules for the use of such data.

• At the time of writing...

It also establishes particular legal protection or safeguards for **sensitive personal data**, that is, data which may reveal:

- racial or ethnic origin
- political, religious or philosophical beliefs
- trade union membership
- genetic or biometric data
- physical or mental health
- sex life or sexual orientation
- criminal convictions and offences.

Depending on your university or course regulations, you may not be allowed to handle sensitive personal data in your research, and you are likely to need to follow strict protocols when handling other personal data. You may even have to apply for permission from an ethical committee to conduct the research you wish to do.

Activity #58

By asking your supervisor, searching on your university's intranet, or otherwise, find out which guidelines you should follow in relation to personal data in research and whether you are allowed to handle sensitive personal data in your project.

Discussion

Our university upholds GDPR regulations, with which all research must comply. The use of personal data in a project must be declared and permission to proceed obtained from and academic board. At Masters level, research students are not allowed to make use of sensitive personal data in their projects.

Processing personal data This refers to any action involving personal data, including obtaining, recording, analysing, and/or destroying data from which a living individual can be identified.

The GDPR sets out six principles• that must be observed when processing personal data.

• Why not set a reminder in your diary to revisit these principles whenever your research design changes.

The first four principles refer to the collection and intended use of personal data. They are:

- Personal data processing must be lawful and fair
- The purposes of personal data processing must be specified, explicit and legitimate
- Personal data collected must be adequate, relevant and not excessive
- Personal data must be accurate and kept up to date

GDPR principles for processing personal data #59

Consider these four principles. Write down how you would ensure these principles apply when collecting personal data from your participants.

Discussion

This is what we recommend our students do:

- Explain to your participants the reason why you are collecting the data as part of your Masters project, and the use you will make of them, including giving assurance that the data will only be used for academic research and be kept confidential otherwise
- be specific as to which data you will collect and for which purpose
- explain how you will ensure the data collected will remain accurate

The two remaining principles concern the way personal data are stored and processed. They are:

- Personal data must not be kept for longer than is necessary
- Personal data must must be processed in a secure manner

GDPR principles for processing personal data, cont'd #60

Consider the two remaining principles. Write down how you would ensure these principles apply when storing and processing personal data you have collected from your participants.

Discussion

This is what we recommend our students do:

- Although GDPR does not set an explicit limit, personal data should not be kept much longer than the duration of your project and submission of your dissertation. If you wish to retain some of the data for longer, you should anonymise[a] them, so that personal information cannot be leaked accidentally

- Stored your data securely to prevent unauthorised access, accidental disclosure or corruption or loss of data. For physical data, this may require locking them in a secure, locked cabinet. For digital data, you could make use of encryption and secure repositories, ensuring appropriate back-ups of all digital files.

- If using online storage services for digital data, you must also ensure they comply with GDPR: you should avoid repositories kept in countries outside the EU which have weaker regulations and legal protection.

[a] This topic comes up next!

Even if you think GDPR will not apply to your research, we would still encourage you to apply those principles in your project, to guard against an improper use of personal data.

Anonymising personal data The six GDPR principles puts many constraints on the use of personal data as they are designed to protect the identity of the people they refer to. Sometimes this can be an hindrance, particularly in reporting and sharing your research where there may be a need to also share the data used your study – like in your dissertation.

As a result, techniques have been developed to allow the use of personal data without comprising the six principles. These generally anonymise the data, i.e., the data is processed so that any link, direct or indirect, to a living person is removed.

If you do need to work with personal data, it is worthwhile to understand which techniques exist for anonymising it, which we consider in the next activity.

Activity: Anonymising personal data #61

Do a web search to identify techniques to anonymise personal data. List and summarise the main techniques you have found.

Discussion

Among others, you may have encountered the following common approaches to anonymising personal data:

- hiding, which refers to removing personal data from a dataset, for instance, the name and address of participants in a study. Those categories are completely removed from the data set.
- masking, which refers to obfuscating personal data by replacing values with certain characters, for instance replacing all names and addresses with asterisks. As are result, the specific values are not visible, but their categories are retained in the data set.
- pseudonymisation, which refers to replacing identifying data with made-up identification data, for instance replacing names or addresses with fake ones.
- Generalisation, which refers to replacing certain data with more general equivalent, for instance, replacing an exact address with an area code.

Choosing a particular way of anonymising personal data will depend on how the data will be used and the level of information that needs preserving•.

Among the techniques mentioned in the activity, hiding is the most destructive one in the sense that removing personal data from the data set which will stop you tracking a participant in data collection over time. While this is good for anonymisation, it may be inappropriate for the research. In a clinical study, for instance, you might need to identify the outcomes of a series of tests with a particular individual. If you have removed all identifying information, this isn't possible.

• A supervisor that has conducted research in the area of your project may have used data anonymising techniques before. It's always worth checking with them what level of anonymisation is needed, and which techniques could be used to achieve this.

If you need to track participants through their data over time, pseudonymisation – in which, say, "Cruella Deville" is replaced by the made up identifier "Mario Rossi" allows you to track a named individual without giving any personal data away.

Generalisation, on the other hand, can be used when more specific data can be replaced by more general one without loss of accuracy. So, an exact address with an area code may be appropriate in a study where geographical areas are the focus, so that exact addresses are not needed.

It is therefore important that you consider carefully how personal data are to be used in your project when choosing an anonymisation technique.

3.5.3.3 Equity, Diversity and Inclusion in research

Equity, diversity, and inclusion (EDI for short) are important ethical considerations in research. Not only is EDI important for society, but good research EDI leads to better research as your and others' biases can be compensated for.

In the UK, national EDI definitions and principles have been established across the academic sector by UK Research and Innovation, which is a government body that brings together all UK research councils responsible for supporting research and knowledge exchange in UK higher education institutions. In your own country, similar guidance may also exist.

As stated by the UKRI EDI guidance•, "research and innovation should be 'by everyone, for everyone' – a dynamic, diverse and inclusive research and innovation system in the UK is an integral part of society and should give everyone the opportunity to participate and to benefit." And also that "By valuing all, we recognise that a diversity of ideas, opinions, knowledge and people enriches our work and enlarges our knowledge economy."

• https://www.ukri.org/manage-your-award/good-research-resource-hub/guidance-for-equality-diversity-and-inclusion/

Equity•, Diversity and Inclusion are as follows:

• It is worth noting that both equity and equality are often used in the literature as the 'E' in EDI. There is, however, a difference: equality refers to treating everybody in the same way, while equity acknowledges specific barriers or obstacles which affect certain individuals or groups of individuals, and seeks to remove them. The latter is now considered the better definition of the two.

- **Equity,** which relates to fairness and justice, in the sense of removing barriers or bias which may prevent individuals, or groups of individuals, from having equality of access, opportunity or outcomes.
- **Diversity**, which refers to the full spectrum of differences and similarities between individuals, whether socio-demographic, such as age, gender, race, ethnicity, etc., or in terms of beliefs and values, life experiences or personal preferences.
- **Inclusion**, which concerns ensuring that all individuals feel welcome, valued and confident to be treated fairly and respectfully. Inclusion is often paraphrased as 'diversity becoming normal'.

Your university is likely to have policies that guide research towards good EDI, with which you should become familiar.

Your university's EDI guidelines #62

By asking your supervisor, searching on your university's intranet, or otherwise, find out which EDI guidelines you should follow in your project.

Discussion

Our university complies with the UKRI EDI guidance mentioned above. In fact, it has a broad approach to EDI, which requires the embedding of EDI principles within its whole operation, including research, teaching, and the hiring and professional development of all staff.

It is important to embed EDI principles within all research project. Failing to do so may lead to studies whose results are not applicable, or are even detrimental, to particular groups of people. For instance, medical trials in which some groups are under-represented may lead to treatments which are not effective for those groups. Clearly, a medical trial is beyond the scope of Masters research! However, taking an EDI stand can also inform your project, as we discuss in the next activity.

Activity: Considering EDI in research activities #63

Write down how taking an EDI lens may influence the following research activities:

- Framing your research problem
- Inviting people to take part in your research project
- Collecting data to use in your research
- Designing a novel artefact as a main deliverable of your research

Write down your answers.

Discussion

Your answer may include some of the following:

- When framing your research problem, you should consult with a diversity of stakeholders and ensure you take differing views into consideration. This will help you validate that the problem is felt across a wider community of stakeholders who my be affected by your research, and will also mitigate any personal bias[a] or pre-conception you may have.
- When inviting research participants, you should consider their diversity to ensure they form a representative sample of the population under study, so that your results are more likely to be generalisable to that population.
- When collecting data to use in your research you should ensured they are not biased against specific groups[b], for instance, by gender or race, which could lead to results which are not applicable or even unfair for those groups.
- When designing a novel artefact, you should take end-users diversity into account, so not to disadvantage some groups of individuals, for instance in terms of accessibility, which could lead to less equity.

[a] We address bias in Section XX.
[b] This is currently a hot topic given the recent rise of Artificial Intelligence and Machine Learning algorithms, which have started to replace human decision making: bias in the data often leads to unfavourable outcomes for those groups.

3.5.3.4 Research involving animals

Although it is rarely the case at Masters level, research may involve animals, something which is regulated in many countries. For instance, the EU has issued a Directive 'On the Protection of Animals Used for Scientific Purposes•', while in the UK all research involving animals must comply with the Animal Welfare Act 2006• and the Wildlife and Countryside Act 1981•.

As argued by Mancini and Nannoni (2022), the ethical dilemma about involving animals in research stems from "a recognition that they are capable of suffering while being incapable of consenting to procedures that

• https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32010L0063

• www.legislation.gov.uk/ukpga/2006/45

• www.legislation.gov.uk/ukpga/1981/69

can harm them," which motivated two researchers, Russell and Burch, back in 1959, to propose three core principles for humane animal research. They are known as the 3R principles and concern:

- the *replacement* of the use of animals with alternative techniques, possibly avoiding using animals altogether
- the *reduction* of the number of animals used to a minimum, by deploying ways to obtain the same or more information from fewer animals
- the *refinement* of experimental procedures to limit animal suffering, including improving animal welfare and minimising pain.

Your university is likely to have specific guidelines on conducting research involving animals, which you should take into consideration.

Your university's guidelines on research involving animals #64

By asking your supervisor, searching on your university's intranet, or otherwise, find out which guidelines apply for research involving animals. In particular, you should check whether you are allowed to conduct this kind of research for your Masters project.

Discussion

At our university, all research involving animals is tightly regulated: all proposals are subject to rigorous ethical scrutiny and it necessary to obtain a special licence to practice it. Masters research students are not allowed to conduct research involving animals.

3.5.3.5 Intellectual property

Intellectual property (IP) is the owned property• created through intellect, such as an invention, an artwork, a formula for some chemical compounds, etc.

Some IP gives rise to specific rights which are protected by law. For instance, the UK UK Intellectual Property Act 2014 • defines a number of IP rights, establishing whom they belong to and what they allow the owner to do.

• In this definition 'property' has the legal meaning of a collection of rights applying to the things which have been created, rather than the things themselves. If you find this confusing, think about a house or a car you may own. In legal terms, you have the property of that house or car, which gives you certain rights in law. However, in common language you may refer to your house or car as your own property. The two meanings are often confused in the wider literature on intellec-

Activity: Types of IP rights #65

Conduct a web search to identify way of protecting intellectual property. For each, write down a definition and comment on whether they may arise from academic research.

Discussion

Your answer may include the following:

- Copyrights — A copyright is an IP right that applies to any original work that is expressed in a tangible form, say a poem or a painting. It gives legal right to its creator(s) to reproduce, publish and distribute the IP, and to transfer it to a new owner. A creator acquires copyright automatically. A research dissertation, and any part within, gives rise to copyrights.

- Patents — A patent is an IP that prevents anybody by the owner from making, using, or selling an invention for a limited period of time. Patents are usually associated with products and processes, e.g., a microchip in a mobile device, or the process to engineer bacteria that digest plastic. For the owner's rights to be protected in law, a patent must be registered with a patent office, and different regulations apply in different counties. Academic research can generate patents, but the protection is not automatic: it requires appropriate registration to take effect.

- Trademarks — A trademark applies to something which can be used to distinguish commercial products and services of a trader from all others within the same market, e.g., the 'apple' used on all products by Apple inc. A trademark must be registered, but there is no time limit to the protection it provides. Academic research may lead to new products or services which could be protected by registered trademarks.

- Trade secrets — A trade secret, according to the Merriam Webster dictionary, is something which has economic value to a business because it is not generally known or easily discoverable by observation and for which efforts have been made to maintain secrecy. In other worlds, a trade secret is confidential business information which provides some competitive edge: the famous CocaCola formula is a trade secret. Trade secrets are used instead of patents when the owner doesn't wish to disclose the information publicly, something required by a patent. Academic research may lead to trade secrets, under certain circumstances, for instance if the research is entirely financed by industry and protected by a non-disclosure agreement.

This is not an exhaustive list and different countries' legislation may include different forms of IP. For instance, the UK IP Act mentioned above includes 'design' as a form of IP, which relates to the appearance, shape or configuration of a product, rather than the product itself (as the case for patents).

Your university is likely to have an IP policy which establishes, among others, which IP applies in the context of academic research and Masters studies, defining both ownership and related rights.

Activity: Understanding your university's IP policy #66

Using your university's intranet look up any IP policy you university has. Write a brief summary of what you have found out in relation to possible rights which apply to your Masters project work.

Discussion

At The Open University in the UK, the IP policy establishes rights in relation to the ownership, development, protection and exploitation of IP arising from all types of research and scholarship carried out in the institution. Although the policy changes depending on the type of invention, in relation to Masters research projects which are part of a taught course of studies, our university assigns the IP to the student, as long as they have paid their university fees. However, in case of fee waivers or bursary from the university, the IP will belong to the university.

3.5.3.6 Use of generative AI in research

Generative Artificial Intelligence (GenAI) is an emerging digital technology able to generate new content automatically in response to prompts from the user. Its current capabilities include the automatic generation of text, images, videos, music or computer code.

It relies on algorithms trained on vast amounts of digital data, from which they learn recurrent patterns and structures, which they then apply to generate original content. For instance, a GenAI system trained on English text will learn patterns related to the English grammar alongside structures and expressions commonly used in writing, and frequent combinations and sequences of words and phrases. Such patterns and structures are then used to generate original English text in response to a user's query: often such responses are indistinguishable from those of a human English writer.

Learning and originality have a specific meaning in GenAI. Learning is the process followed by the algorithm to build an abstract model from the data used in training, which can then be used to generate content similar to those data, be that text, images, sounds, or other. Originality refers to the fact that the particular content generated is not copied from an existing repository, but constructed by the algorithm based on its abstract model combined with the vast repository of information it has access to: as a result no two answers to the same user's query are exactly the same.

Activity: Investigating GenAI systems #67

Conduct a web search on GenAI systems. List the ones you have found and indicate their use.

Discussion

At the time of writing, these are among the most used GenAI systems:

- ChatGPT and Bard: these are conversational systems in that they allow users to conduct conversations in written natural language. They can be used to answer specific questions, for language translation and even creative writing.
- DALL E: this is an image and art generation system. It can be used to produce images from a text description, or to edit or enhance existing images.
- AIVA: this a system to generate music. It can generate new songs in a great variety of styles and genres.
- Copilot: this is a system to generate code in a variety of programming languages. It can assist a software developer by suggesting new code, completing code being written or generating documentation.

Impressive as it may be, GenAI has a number of pitfalls you should be aware of. Firstly, the content generated depends heavily on the data set used to train the algorithm, so that any intrinsic bias in the data set will also be present in the new content generated. For instance, if discriminatory language is present in the training data, the same will be the case in the content generated by the algorithm.

Secondly, the technology is designed to fill in any gap there may be in their knowledge base with plausible, but made-up information, so that what is generated may not be true or reliable. The term 'hallucination' is used to denote such behaviour, although fabrication would probably be a more accurate term! So, for instance, if you ask the AI to provide a summary of a particular topic including a list of references on which the summary is based, more often than not, those references will include completely made-up entries, although constructed in a way which makes them look perfectly legitimate (by applying the pattern learnt for references from academic papers used in the training process). Hallucination means that you can't necessarily rely on the veracity of the content generated, and any significant use of it in your research is only possibly after you have double checked both accuracy and authenticity, and, ideally where it comes from.

Another important consideration is that not being copied from somewhere else doesn't mean novelty: although originally expressed, the content is still pieced together from what is already known, so there is no new knowledge contribution or creative invention. Equally, the algorithm has no understanding or critical insight of what is generated: it is just very clever at putting the puzzle together from existing pieces and rules learnt. As a result, you should not expect deep or critical accounts of a topic of interest, but you may still obtain good factual summaries or descriptions.

Even with these drawbacks, GenAI can be a useful tool in research, particular to get you started on specific tasks, like gathering some initial information on a particular topic, identifying some initial articles to read, or even summarising certain literature, as long as you then put your own effort and work to generate your own content which is both authentic, unbiased and creative.

A final consideration is that the content generated by the AI is not your own work, so it should be treated as any other secondary source you use, and clearly identified and distinguished from your work, to avoid any accusation of plagiarism. In fact, you should be open and transparent in your use of GenAI in all aspects of your research.

GenAI is a fascinating subject, which is generating, as it may be expected, much controversy. At the extremes are those who focus solely on the risks or the opportunities it affords, often overestimating what the technology can actually do. The state-of-the-art is somewhere in the middle: yes, there are both risks and opportunities, but as often with technology, the issue is what people choose to do with it.

Because of this, organisations, and particularly academic institutions, are developing their own rules and regulations on the use of GenAI by staff and students. If you are considering using GenAI in your project, you should become familiar with your university' position on what you can and can't do

Activity: Understanding your university's guidelines on generative AI #68

Using your university's intranet look up any policy or guideline related to the use of generative AI. Write a brief summary of what you have found out which may be relevant to your Masters project work.

Discussion

Our university explicitly states some admissible and not admissible uses of GenAI. In particular, it considers inadmissible, and a form of plagiarism, to copy and paste content generated by an AI system without proper attribution. On the other hand, admissible uses include:

- to make materials more accessible, for instance by auto-generating transcripts of audio or image captions,
- to help with spelling and grammar in written text, and generally to help your improve your writing skills,
- to prompt you to develop new ideas,
- to revise basic knowledge on a particular topic.

3.5.3.7 Bias in research

Bias is a tendency to support or oppose particular ideas or things based on personal preferences rather than objective evidence. Cognitive bias, in particular, prevents people from processing information objectively due to limited processing capabilities of our mind or due to emotional responses or social norms and conditioning.

Bias is problematic when it leads to the unfair treatment of others, particularly as a result of preconceptions or prejudice. Bias is subtle. We are all affected by it. It is easy to see in others, but extremely difficult to see in oneself.

Bias can damage research findings, leading to outcomes which are unreliable, and casting doubt on the claimed knowledge contribution. To be a good researcher you should assume that you are affected by many different forms of bias and work to eliminate them from your work. The upside is that you will be a better researcher for doing this.

Several forms of bias have been recognised in research: you can do some preliminary work on identifying general biases that might affect you by looking on the web.

Activity: Bias in research #69

Conduct a web search on types of bias affecting research and ways to mitigate them. List and summarise the main kinds you find, and their counter-measures. Make sure you include bias which relate to the use of data[a].

Discussion

Among others, you may have encountered the following:

- Confirmation bias, which is the tendency to favour the selection, analysis and interpretation of data which support the researcher's prior beliefs. A way to counteract it is to consider your own beliefs and actively look for reasons why you might be wrong. Another way is to ask colleagues and/or your peers to review your work, including your arguments and results.
- Observation bias[b], which is the tendency of participants being observed during a study to change their behaviour, possibly to please the researcher or provide the answers they think the research is seeking. A way to counteract it is to complement your observation with other kinds of data collection and compare the outcomes – this is called triangulation.
- Selection bias, which occurs when data is selected subjectively, leading to samples which are not representative of the population under study. A common way to avoid selection bias is randomisation.
- Recall bias, which is the tendency of people to recall certain types of events more vividly than others, and can affect the outcomes of research which relies on participants' memories of the past. Reducing the recall period, for instance by interviewing participant soon after the fact, or asking then to keep detailed diaries of their experience are ways to mitigating it.
- Algorithmic bias, particularly in relation to AI applications, which occurs when an algorithm produces outcomes systematically and repeatably which disadvantage one group of individuals over others. Counteracting algorithmic bias effectively is a hot research topic, and much remains unknown. Involving domain experts alongside data scientists in the detailed consideration of both

the data used by an algorithm and its outputs is one approach, alongside ensuring that the working of the algorithm are transparent to its users, and its behaviour can be explained.

[a] Data bias is becoming more and more topical with the rise of AI algorithms which may replace human decision makers.
[b] Observation bias is also known as the Hawthorne effect. You can read about the original Hawthorne experiment here: \url{https://en.wikipedia.org/wiki/Hawthorne_effect}

All bias can damage your research. However, confirmation bias is very easy to fall into, can be very disruptive, and can arise when you have too personal a stake in the research beyond the project itself. For example, you may be the manager of a process you are seeking to improve. This means that you will have a stake in the research subject beyond meeting your Masters academic requirements. Although this can be a strength, in that, since you already have an interest in, and knowledge of, the research subject and context, you are likely to have insights into the causes of problems and the factors that have an impact on them, it can also be a weakness in that it may lead you to focus on evidence that confirms any existing beliefs that you might have about how the process should improve, while dismissing evidence that does not support them•. This may result in a lack of objectivity, and a tendency to make subjective judgements instead of an evaluation based on sound evidence.

• In the worst case, you might find that your current approach to improvement is wrong which might be visible to others within your organisation. If you find yourself in this situation and, in our experience, it does happen, it can be very hard to deal with this sort of bias.

Another effect of confirmation bias is that you clearly see a problem where no-one in your readership does. So much so that you don't feel you have to explain the problem or convince others that it exists.

In our experience, both of these can hamper progress. The latter is especially pernicious: that you see a problem is great, but can you find sufficient evidence in the academic literature?

3.6 Managing risk

"What could possibly go wrong in a flourishing concern like the Brixleigh Bank•? My dear, you are too fond of conjuring up imaginary evils." – Matilda Mary Pollard's *Cora: Three Years of a Girl's Life*, 1882

• Later in the book, Brixleigh's Bank is shown to be a Ponsi scheme – a gigantic fraud – which fails.

Pollard's imaginary evils are now called risks. They are no longer seen as imaginary evils, but as things that need managing.

Risk captures the likelihood of something going wrong combined with the impact that will have on your project, both on time, resources and outcome. In theory, both positive and negative impacts should be considered, but very often the focus is on what can affect your project in a bad way, letting the good stuff roll.

The management of risk is an important discipline in its own right – you do not need all of the tools that that discipline offers.

So, in analysing risk for your project, you should focus on the following dimensions:

- Specific risks: What sort of things can go wrong? For example, you may not be able to recruit sufficient respondents to a survey to gain direct access to key evidence.
- Impact: What are the consequences if things do go badly? How severe might those be? For instance, not obtaining key evidence will invalidate your all research, so this would be very severe in terms of your project outcome.
- Likelihood•: How likely is it that things will go wrong?
- Mitigation/contingency: What can you do to reduce likelihood or impact? For example, you may have lined up a secondary source of evidence, which may not be as authoritative or useful as what you had in mind originally, but would be easier to access and still allow you to derive some interesting results.

• Some approaches to risk ignore likelihood, assuming Murphy's Law, i.e., that anything that can go wrong will go wrong. This makes risk

3.6.1 Research project risk

In a research project there will be risk which is very specific to what you intend to do, but there are also risk categories which are common to all projects, which we consider in this section.

3.6.1.1 Technical skills

Your intended project may require you to apply expert technical skills, for instance, coding or advanced statistical analysis. Early on in your research project, it may be possible that the details of precisely which technical skills you will need are unclear. Nevertheless, you should start thinking about technical skills you may need and what might happen if they are not sufficiently developed.

For instance, will conducting a survey require sophisticated statistical skills? Your risk analysis should recognise this by considering:

- Specific risks: whether your current statistical skills level may be insufficient;

- Impact: whether a lack of appropriate skills might mean that you are not able to analyse your data as well as you would like, losing their value;
- Likelihood: how likely it is that skills that you don't possess will be needed;
- Mitigation/contingency: to reduce the impact (to manage the risk), which course of action you could take to help you enhance your skills to the level you will need. This is an item that you can include in your project plan.

Activity: Risk in relation to technical skills #70

Consider whether there are bespoke technical skills which are essential to your intended research. Perform a risk analysis in relation to your whether your possess those skills and write down the outcome.

Guidance

As shown in the example, you should record the specific risks, their likelihood, impact, and any mitigation/contingency.
On mitigation: if you don't think you can develop all necessary technical skills in good time, then you should consider whether you have made the right choice of project – this is also a way of managing risk! At Masters level, it is a lot safer to focus on research which makes good use of technical skills you already possess and employ your limited time wisely to conduct your research.

3.6.1.2 Study time

Consider the time which is required for your project — you may have to go back to your estimates from Chapter 2. To succeed in your Masters project it is essential you sustain a continuous effort throughout, with little scope for making time up when you are not able to, or for taking long breaks. The key question, therefore is whether any other commitments, professional or personal, may get in the way and what you could do about it.

Activity: Risk in relation to study time #71

Consider your current personal and professional commitments, and study practices. Perform a risk analysis on whether you will be able to dedicate sufficient time to your project on a regular basis and write down the outcome.

Guidance

You should focus on the extent your current study practices are appropriate for your project, or whether there may me changes in your professional or personal circumstances which may have a negative impact on the time you will have for your project.
Under mitigation/contingency, you should include any adjustments you may need to make in your life and your studies. If these are substantial, however, you will need to assess very carefully how feasible it is for you to make them.

3.6.1.3 Resources

Depending on your chosen research problem and aim, you may need access to participants, organisational information, third-party data, industrial case studies, etc., or you may need to acquire specialised software or hardware.

It is important for you to assess how likely it is that you will be able to gain access to or acquire such resources and, should there be any cost involved, whether you can afford it.

If conducting research with your current employer, you should also consider the extent the data or information you require from them are confidential and non disclosable, as well as the possibility of changing jobs, and the extent you may be able to retain access or make alternative arrangements if that's the case.

Activity: Risk in relation to resources #72

Consider resources you are likely to need to conduct your research. Perform a risk assessment in relation to your access to those resources for the duration of your project and write down the outcome.

Guidance

You consider both access to those resources, the extent circumstances may change which might prevent

you from accessing them at any point in your project, and possible alternatives.
If you don't think you will be able to guarantee access to all necessary resources or appropriate alternatives, then you should consider refocusing your project, so that you can make best use of resources you already have or will find easier to access.

3.6.1.4 Ethics and regulations

Under research design in Section 3.5, you have encountered a wide range of ethical and regulatory issues which may be pertinent to your research project. Here you are asked to consider any related risk.

Activity: Risk in relation to ethics and regulations #73

Consider the ethical and regulatory issues from Section 3.5, and write down those which are most pertinent to your project. For each, perform a risk analysis and write down the outcome.

Guidance

You should pay particular attention to your university's regulations in regard to those topics, in particular if your project is likely to involve human participants and the handling of personal data, and to assess risk around possible bias.
It is also essential you identify any regulations which may limit what you can do in your project, for instance working with animals, and you should double-check with your supervisor that what you are proposing is acceptable.

3.6.2 Summarising your project risk

It is time to summarise the outcome of your risk analysis. To do so, you could use a risk table similar to Table 3.22. Note that the table encourages you to consider also risk specific to your project which may not fall within the categories we have already considered.

Table 3.22: Risk table

Category	Specific risks	Likelihood	Impact	Mitigation/contingency
Technical skills				
Study time				
Resources				
Ethics and regulations				
Other (specific to your project)				

Activity: Risk assessment for your project #74

Complete your project risk assessment by filling in the entries in Table 3.22.

Guidance

You should already have most of the required content from your previous activities.
You should ensure you consider carefully any specific risk to your project which is not covered by the generic risk categories we have included in the table.

3.7 Reflecting

You might be thinking: "Why, if I've finished a task, should I cause myself grief by reflecting on it – in the best case nothing will change. In the worst case, I'll have to do it again."

We feel exactly the same – reflecting on what you've written causes a lot of grief, especially when you realise that it's not as good as it could have been• and there are very good reasons to improve it.

At the same time, we've learned a lot from that reflection. For instance, we've been able to split up complex issues into more digestible chunks; we've identified new links between topics that we hadn't thought about before; we've read more about what the students we have worked with to understand more precisely their contributions; we've taken apart the materials we have written to ensure their validity in the Master's research context; and, last but not least, we've been able to generalise much of what we know of this topic

• We‘ve reflected on the materials for this book many many times... That's meant redrafting, adding extra and – hurtfully – having to remove stuff that just wasn‘t good enough. It's changed – for the better we hope – because of it. You are free to disagree, and we'd welcome your reflection on it too.

to be more applicable across the board, while at the same time realising that there are special topics that will affect only a small part of our readership.

We feel exactly the same – reflecting on what you've written causes a lot of grief, especially when you realise that it's not as good as it could have been• and there are very good reasons to improve it.

• We've reflected on the materials for this book many many times... that's meant redrafting, adding extra and – hurtfully – having to remove stuff that just wasn't good enough. It's changed – for the better we hope – because of it. You are free to disagree, and we'd welcome your reflection on it too.

Reflection is also the thinking of radical thoughts. There is a context into which all research fits that colours the knowledge that is its primary contribution, making it less valuable, less distinct, less out there. That context is a hegemony of received wisdom, of 'common sense thinking', of uncritical investigation, none of which are necessarily knowledge. Reflection – "the voluntary disobedience of thought and reasoned undocility" according to Foucault (1985) – is your way of breaking that mould, of stepping out of conventionalism and of shaking up the world.

Reflecting on your learning and practice #75

In this activity you are asked to stand back and reflect deeply on what you have leant and done, the wider context of your work and your own attitude to it. Specifically, you are asked to think deeply about each of the following:

- Think about your study this far – using this book and anything you've done for your project in parallel – as a journey. How has your view of academic research changed from when you started? In which ways has it help you think as a researcher? Which things have surprised you or challenged your initial beliefs? How have your original research goals changed as a result?

- Think about the way you work. Are you tidy and systematic, or let things happen organically? For instance, how does your desktop (physical and digital) look? Think about how your way of working affects the way you do your research. Are you systematically keeping your references, notes and summaries in your BMT? How successful were you at reviewing the literature systematically and extracting relevant themes for your research? Has your approach to work changed since you started your project?

- Think about the context of your research. What motivated you to do your project? Are there pressure, professional or otherwise, on you to succeed? Professional pressures could come in many forms: financial – there's a promotion for you at the end of it; peer – your colleagues know that you are studying will have good expectations of your result and you'll want to prove them right[a]. Are you sponsored by your employer? Will you be able to report a negative outcomes to your research, for instance, that there is no solution to your problem using the current technology stack? A negative result is a very good research outcome, even if it tends to satisfy fewer non-academics than a positive result. Which family pressures do you feel? It's not unusual that you will have given up a paying role to study, moving the responsibility to provide onto another member of your family, or given up aspects of your family life to make space for your study. What are their expectations? How are you standing up to those pressure?

- Think about your feelings about your project. What's that thought nagging at the back of your mind? Is it "How will I start?" Or "Will I be able to dedicate enough time to this?" Or "Can I really do this?". Or "Is "shouldn't I be bringing in a wage rather than studying?" You may be one of the lucky ones that doesn't have such negative thoughts, but negative thoughts are a very natural part of steps into the unknown. And research is precisely that, a step into the unknown. Being aware of the doubts you naturally have, will help you manage them. Think of how to make visible and celebrate even the tiniest of steps forward in your research. Think of tools that may help you. For instance, if you have concerns about managing your time, start using one of the many tools out there that break time up into manageable units and help manage it for you. If your concerns are about how to organise your thoughts, look into mind maps, lists, todo lists.

Guidance

This activity has four parts, each prompting you to reflect on different aspects of your thinking and practice: you should give proper consideration to each of them, as together they will help you reflect deeply on your experience overall.

Thinking early and often through reflection is a powerful way of doing better. Do it well and you will be a better researcher, and your final report will be better than you will have expected.

It's worth saying that, at the end of what could be an exhausting journey, you will not fully appreciate your achievements. That realisation may have to wait until you are rested, graduated, or some distant time later. But it will come.

[a] Or wrong, depending on the colleague!

3.8 Reporting

It may not feel like it, but you're now ready to write a substantial contribution to your research project: your full research proposal.

We recommend that you write a report at the end of each stage of our framework to consolidate the work you have carried out, regardless of whether your course may require to do so. Writing such reports will help you develop your dissertation incrementally, and provide good practice to improve your academic writing skills as you go along.

3.8.1 Putting your research proposal together

Here, in Stage 1, your report will consist of your full research proposal, which we recommend you structure as indicated in Table 3.23• — subsequent reports will build on this structure by adding further elements. Although not all what you write here will end up in your actual dissertation, substantial parts of it will. You're definitely started now and that has to feel good!

• Unless your course requires a different structure, which you should apply instead.

Activity: Putting your report together	#76
Using your word processor of choice, create a report with the structured indicated in Table 3.23, and fill it in by following the guidance provided in the table, making good use of your notes and summaries from, and reflection on, all related activities you have carried out so far.	
Guidance	
In this first pass at putting together your report you should focus primarily on completeness, ensuring that each section includes at least a draft of the main points you wish to make.	

3.8.2 Assessing and Iterating

After you have filled in your report with as much material as you can, you should review and revise it until you are happy with your account, and ready to move on. This may take more than one iteration, but you should ensure you do not delay your work for the follow-up stage.

In the next activity, you will use Table 3.25 to assess whether your report is of good standard.

Table 3.23: Recommended structure of your research proposal

Report template	Guidance
Proposed title	Your title should capture succinctly your research problem and aim. You should refer back to Section 3.4.2 for more guidance.
Sect 1 - Introduction 1.1 Background to the research 1.2 Justification for the research 1.3 Fitness of the research	This section should provide an introduction to your research topic in its wider context (as background) and your justification of why the research is worth pursuing. Its purpose is to introduce and justify your intended research in overview, before entering the detailed work of the subsequent sections. It should be well argued and supported by appropriate citations. In this section, you should also argue how the research fits within the scope of your qualification, and meets any other personal, professional or organisational criteria. Revising Section 3.2.1 should help you with this task.
Sect 2 - Literature review 2.1 Draft review of relevant knowledge 2.2 Planned further literature review	This section should be based on the theme summaries you constructed towards the end of Section 3.3.4. You will build on this content in Stage 2 to write an extensive, well-argued literature review to demonstrate your in-depth engagement with the academic (and other) relevant literature. Your planned review should identify further reading you may still have to undertake in Stage 2, although the expectation is that the bulk of your reading has taken place in Stage 1, so that you can focus on synthesising your knowledge and understanding in the next stage.
Sect 3 - Research definition 3.1 Problem statement 3.2 Aim and objectives 3.3 Knowledge contribution	You should ensure that your research problem is well articulated, that your aim and objectives are consistent with the research problem, and that the intended knowledge contribution of your research is clearly argued. You should refer back to the activities you conducted in Sections 3.2.2 and 3.4, but also to the theme summaries you produced at the end of Section 3.3.4, particularly those which highlight knowledge gaps of interest.
Sect 4 - Research design 4.1 Evidence and data 4.2 Research methods 4.3 Ethics and regulations	This section should demonstrate your initial engagement with research design, particularly that you have thought about the kind of evidence and methods you may need, appropriately justified in relation to your research problem, aim and objectives. It should also demonstrate your careful consideration of ethics and regulations, and that your research will comply with your course and university requirements. You should refer back to Section 3.5 to develop the content of this section.
Sect 5 - Work planning and risk assessment 5.1 Statement of progress 5.2 Key priorities in follow-up stage 5.3 Risk assessment	In this section you should reflect on the progress you have made in Stage 1 in relation to your initial work plan and establish your priorities for the next stage. For this, you should refer back to Section 3.1 and revise your initial plan accordingly. You should also summarise the outcome of your project risk assessment (see Section 3.6).
References	You should keep your references in good order and ensure you apply the required

Table 3.25: Criteria for reviewing your research proposal

Criteria	Prompts
Completeness	Are all sections included and their content complete? What is missing?
Academic writing	Have you applied good academic writing practices throughout? Which main issues do you still have to address?
Logical structure and flow	Have you structured your writing appropriately to ensure a logical flow of arguments? Which restructuring may be needed?
Supporting evidence	Are your key arguments supported by appropriate references or other evidence? Which further evidence is needed?
Citation and reference style	Do all your citations and references comply with the required bibliographical style?
Avoiding plagiarism	Have you acknowledged the work of others and distinguished it from your own appropriately?
Grammar and spelling	Have you proof-read your report carefully to remove all typos and grammatical errors?

Activity: Reviewing your report #77

Apply the criteria in Table 3.25 to review and reflect on your current report, what is good, what is weak and what is yet to do, and write up a summary of your assessment. For work still do do, decide whether to complete it within Stage 1 or carry it over to Stage 2.

Guidance

For each criteria, consider the related prompts to help you assess your report overall, and write down any further work needed: some will be minor and may be done at another pass at editing your report; other may point to substantial work you will need to do in Stage 2, and should be included in your work plan.

Writing up your report is an excellent way to communicate to consolidated the work you have completed and are still planning to do, and is something tangible you can share with your supervisor for comment and other formative feedback.

3.9 Takeaways

- a research problem can be framed by identifying its key elements, that is, context, knowledge gap, phenomena of interest, stakeholders and their reasons
- there are different kinds of research problem, including descriptive, exploratory, explanatory, predictive, evaluative and design problems
- candidate research problems for Masters research should be assessed in terms of their generality, complexity and volatility
- bibliographical databases and Google Scholar are key online tools to access the academic literature
- Keshav's approach is an effective way to assimilate the content of an academic article
- a summary-comparison matrix can be used to keep track of the content of articles reviewed, also making it easier to compare them
- a concept matrix and a concept map can be used to identify themes emerging from the literature reviewed
- while a research problem highlights a knowledge gap, a research aim indicates a particular way the knowledge gap is to be addressed
- several kinds of data, evidence and methods are used in research
- research is subject to a wide range of ethical and regulatory frameworks
- project risk in research arises due to many factors, including lack of technical skills, time or resources, as well as ethics and regulations
- Gannt charts can be used in combination with the 5-stage framework guidance to outline your project work plan
- reflection can help you become a better researcher
- the template provided can help you structure your Stage 1 report

Chapter 4

Stage 2: Compiling your literature review and understanding research design

We now move onto Stage 2 of our 5-stage framework. Stage 2 assumes you have completed your work at Stage 1 and have discussed it with your supervisor, who will have helped you assess whether it is appropriate for your course.• Stage 2 also assumes you have now a fair idea of how the research process works, having been through one iteration in Stage 1, and that you have gained sufficient basic research skills to be able to carry on your research somewhat more independently, albeit with your supervisor's support.

• If the scope of your project is still unclear at this point, then you should spend more time in defining it before moving on.

The good news• is that this assumption means that there is less to read in Stage 2 and we will not take you through the research process step by detailed step, but focus on *additional* knowledge and skills you'll need to progress.

• The bad news is that if you haven't picked up everything, you may need to refer back to Stage 1. We will leave breadcrumbs throughout the chapter to help you do this if you need to.

The research activities which are in focus in Stage 2 are shown in Table 4.1, which also provides some guidelines for your interaction with your supervisor during this stage. As you can see, the focus of this stage is on completing your literature review and developing your understanding of the basic blocks of research design.

Activity: Understanding the effort needed in this stage #78

Consider Table 4.1 carefully, taking notice of the entries in the 'Effort' column. Make a note of the activities which will be the most time consuming in this stage and what is expected – the suggested focus – for each. Update your work plan accordingly.

Table 4.1: Research activities addressed in Stage 2 (15% of project length)

Research process activities	Deliverables	Learning Outcomes: by the end of this stage you will:	Effort	Suggested focus of your interaction with your supervisor
Identifying the research problem	Research problem statement, refined as needed	be able to express a research problem	3%	
Reviewing the literature	Substantial draft of your literature review	know key skills and practices in academic writing, and the elements of an academic argument; be able to write academic arguments, to structure the narrative of your literature review and to assess and improve your current draft	25%	Suitability of literature review scope, structure and narrative, including appropriate logical argumentation, and demonstration of critical thinking
Setting your aim and objectives	Aim and objectives, refined as needed	be able to express aim and objectives which relate to your research problem	2%	
Developing the research design	Candidate research strategies and methods for your project	know the building blocks of research design, and common research strategies and methods; be able to understand research strategies and methods applied in articles you have reviewed	40%	Suitability of candidate research strategies and methods
Reflecting and reporting	Stage 2 report	be able to assess your research progress and to write up a substantial report	25%	Any further improvements required, particularly in relation to critical thinking and academic writing
Planning work and managing risk	Updated risk and work plan	be able to assess risk and draw a work plan	5%	Any major adjustment required to address deficiencies or manage risk

Discussion

As 40% of your study time, developing the research design will constitute your major effort in this stage. There are two other research activities at 25%

- Reviewing the literature, which will get to an almost complete form; and
- Reporting, critical reflection and conclusions, which will complete Stage 2.

To update your work plan, you should use the effort percentages to estimate the actual study time you will need to dedicate to each.

4.1 Writing a full draft of your literature review

In Stage 2, you will build on your Stage 1 work to write a substantial draft of your literature review. Although it won't be in its final form, this draft will be close to complete – as you work through later stages, you might find a few more papers• to consider, but you'll probably be able to count them on one hand.

While in Stage 1 your main focus was on gathering and assimilating relevant articles, understanding their relationships and emerging themes, in Stage 2 your focus will be on consolidating all that you have learnt into a coherent, well-structured and critical review.

This is the essence of *synthesis* – the act of bringing ideas together into a cogent whole. That cogent whole is the spell-binding story you create to convince your readers• that *you have a contribution to knowledge to make*, based on the literature you have read and the knowledge gaps that you have found there.

Given the number of articles you'll have to read, and the complexity of the relationships that exist between them, there's a long (and sometimes winding) road from the literature to your dissertation. The knowledge, process and techniques you acquired and applied in Stage 1 will still be relevant•: you can make best use of the time you spend reading the literature by using the Keshav workflow•, iterating quickly between papers, and keeping notes that refine what you have as your understanding develops, and will eventually turn into text you can use for your dissertation, too. However, once you have selected, read and understood• a good number of relevant articles, and identified and summarised relevant emerging themes, you can also start develop the narrative to include in your literature review.

• Depending on how thorough you've been, of course.

• Eventually, your examiners, first your supervisor, family, friends, anyone else that will read it...

• If needed, refresh your understanding by rereading Section 3.3 in the previous chapter.

• Introduced in Section 3.3.3.

• At this point, you may have only a rudimentary understanding, but that will develop as you bring your synthesis together.

For this you will need further synthesis skills and techniques, which we consider in this section.

While we present them in the context of writing your literature review, these synthesis skills and techniques apply more widely to any form of academic writing, so they will be essential when you write your narrative across your whole dissertation – creating the spell-binding story to convince your readers that *you have made a contribution* to knowledge.

4.1.1 Key skills for synthesising

There are key skills you will be able to demonstrate through your synthesis of the literature. They are:

Critical thinking The first important skill is critical thinking, that is, that you have maintained an objective position by weighing up all sides of an argument, evaluating its strengths and weaknesses, and testing how sound the claims made and their supporting evidence are.

At its essence, critical thinking is the skill of systematically asking questions that get you "under the hood" of the research – perhaps into the hidden crevices into which no one has looked before. Part of this is searching for a lack of evidence or poor reasoning behind an argument, evidence or the application of other research tools, instead of accepting what you read 'at face value.'

Critical thinking develops with time and practice. The trick is a balance of scepticism: choosing the arguments or evidence to take issue with – those that are less solid – and leaving the rest.

As an academic author, critical thinking will benefit your ability to build stronger arguments, avoid bias and link your claims to appropriate supporting evidence, so it is well worth picking it up as a skill.

Establishing connections The second skill you must demonstrate is that of being able to draw links between the articles that you have found, a process you started in Stage 1 by constructing a summary-comparison matrix• and identifying emerging themes.

• Refer back to Section 3.3.4.3 if necessary.

As you have experienced in Stage 1, this is more than summarising each article in turn: it is about identifying the things that two articles agree on and disagree on, then do the same for three, then four, etc., and begin grouping articles together under the various different themes that you have found, those themes being relevant to your research problem.

At some point, you'll arrive at a collection of more or less definitive unifying themes to which you can assign the papers you are reading. At this point, you'll have moved on from an article-based process to a theme-based process and your synthesis will be really coming together. So much so that, perhaps•, the

• We're getting a little ahead of ourselves here – you won't have a complete literature review at this point, but you may start to feel that you can see how, eventually, it could come together...

themes that you have found could be used as the titles of sections of your literature review. Your thematic critical reflection on the literature will then be the content of those sections, which will continue to grow and grow into the completed literature review.

Critical writing Many authors of fiction use descriptive writing to give vivid, detailed descriptions of their characters in the hope you will feel some empathy for them. Being able to write descriptively is a great skill for a fiction author to have.

Descriptive writing is also an essential part of academic writing, but its use is very different: in academic writing descriptive writing is used to set the context and to provide any existing evidence behind an argument you are developing. The key word hereis *existing*: your descriptive writing should not change the sense of what someone else has written.

This does not mean that you shouldn't interpret or reinterpret what someone else has written if your additions add value to what someone else has written. That's the key to analysis, synthesis, and evaluation, skills in which are good things to demonstrate!

A certain amount of description is therefore necessary in any academic writing. But to present new knowledge, your examiner will be looking for something more than description – they will be looking for a critical approach, by which you will build• new arguments using what has gone before by, for instance, analysing, synthesising, and evaluating.

• You will be able to add in your generated evidence too, of course.

A perfect critique of an article will have the following components:

- your introduction to the paper, by saying what is involved, where it takes place, or under which circumstances.

  The perfect critique – introduction

  Kirlappos and Sasse (2012) discuss the implications of users visiting fake websites, concluding that trying to get them to stop doing so could prove difficult without appropriate user awareness training. [. . .]

- your analysis, which gives your perspective on the paper, perhaps highlighting how the paper comments on your focus in reading, including its strengths and weaknesses from the perspective of the topic.

> **[...] analysis**
>
> This training should be automated, involving 'fake' phishing e-mails being sent to users in order for them to compare the fake e-mail to a legitimate e-mail and understand the differences. [...]

- your synthesis, which explains how the parts fit into your research context, giving reasons, making comparisons, and highlighting relationships with other papers.

> **[...] synthesis**
>
> This can be contrasted with San Nicolas-Rocca& Olfman (2013, p.84) who state that users should be trained on understanding laws and regulations as well as organisational policies and guidelines which define their specific responsibilities. [...]

- your evaluation of the strengths and weaknesses of the paper from your perspective, the implications that can be made for your purposes, and the impact and value to your research.

> **[...] evaluation**
>
> This false dichotomy is in danger of losing something, however, in that training can be both instructive on the nature of 'fake' emails and on the formal understanding of users' responsibilities in regards to cyber breaches.

The boundary between these critique elements can sometimes be fuzzy, of course, in the sense that in-depth descriptions may well start to be analytical and synthetic, and some analysis and synthesis may include a level of evaluation. Table 4.2 provides some practical examples which may help you distinguish between description, analysis, synthesis and evaluation in academic writing.

Table 4.2: Types of academic writing (adapted from **Cottrell2005**.)

Descriptive	**Analytic**	**Synthetic**	**Evaluative**
What happens or what something is like		Makes comparisons	Identifies significance
Tells a story or the order in which things occur	Explain why things work the way they do		Demonstrate relevance
Explains how to do something		Gives reasons for choices	Draws conclusions
What a theory says or how something works		Structures information based on established criteria	Weighs pieces of information against one another
Lists things, alternatives and options, etc.	Shows relations between pieces of information, parts of a system		Highlights strengths and weaknesses
Describes a system or its components	Demonstrates how a theory works		Considers wider implications

Revisiting the academic writing in our theme summary

In Stage 1, we produced the following summary around the theme of modelling learning trajectories with curriculum analytics. This summary uses a mix of all the kinds of academic writing indicated in Table 4.2. You will consider the details in the next activity.

> Several authors have considered modelling and analysing students' learning trajectory through a programme of study, in order to understand how students progress or otherwise through their study and the learning outcomes they achieve in doing so. Such an understanding can then be used to inform scholarship and reflection around curriculum and its design, and inform possible changes.
>
> For instance, Dawson and Hubball (2014) deploy social network analysis techniques to identify and visualise the most common learning pathways followed by students within complex curriculum structures, in which many links may exist between the various curriculum components. They suggest that their proposed tool could be used by curriculum practitioners to study student progression and completion across different pathways, and the extent students acquired the expected learning outcomes, although their study does not evaluate the extent that might be the case.

Similarly, Salazar-Fernandez et al. (2021) use process mining to extract students' educational trajectories from historic data: in this case, their aim is to understand which trajectories are more likely to result in late dropouts. In their proof-of-concept tool evaluation over a specific data set, they achieve some positive results with the tool providing a strong indication that students taking a study break before resitting a failed module are most likely to drop out. Further research is needed to apply and evaluate their tool in other settings.

Somewhat distinct from these studies is the work of McEneaney and Morsink (2022), who propose a simulation tool, based on Coloured Petri Nets, to be used as a design tool to help curriculum practitioners to test the possible effect on learning of envisaged curriculum changes, such as including or removing modules or study pathways in an existing programme. As another proof-of-concept tool, the work still requires wider application and evaluation.

Finally, both Greer et al (2016) and Molinaro et al. (2016) focus on potentially useful visualisations for curriculum practitioners. In particular, Greer et al (2016) introduces the "Ribbon tool", based on Sankey diagrams, for visualising student flows through academic programmes, with interactive capabilities which allow practitioners to study and compare specific student demographics. The same tool is recommended by Molinaro et al. (2016), alongside other visualisation tools, based on both students and course data, to allow practitioners explore both curriculum features and students' attainment. Both articles are part of the proceedings of the very first Curriculum Analytics workshop, in 2016, which also explain why they contain primarily poof-of-concept work and suggestions for future research.

Overall, this collection of articles contains some interesting ideas as to how curriculum and student data could be combined and analysed through the application and development of bespoke Curriculum Analytics tools. They all appear, however, quite preliminary studies, which is also an indication that this remains a young field of study where much research is still needed.

Activity: Distinguishing between different types of academic writing #79

Consider the summary above. Write down examples of each kind of academic writing you can find with reference to Table 4.2.

Discussion

We've picked the following examples:

- descriptive: "Dawson and Hubball (2014) deploy social network analysis techniques to identify and visualise the most common learning pathways followed by students within complex curriculum structures, in which many links may exist between the various curriculum components". This simply summarises what those authors do.

- analytic: "Several authors have considered modelling and analysing students' learning trajectory through a programme of study, in order to understand how students progress or otherwise through their study and the learning outcomes they achieve in doing so. Such an understanding can then be used to inform scholarship and reflection around curriculum and its design, and inform possible changes." This highlights the connections between modelling, understanding and scholarship across the different articles.

- synthetic: "both Greer et al (2016) and Molinaro et al. (2016) focus on potentially useful visualisations for curriculum practitioners. [...] Both articles are part of the proceedings of the very first Curriculum Analytics workshop, in 2016, which also explain why they contain primarily poof-of-concept work and suggestions for future research." This brings together work which shows strong similarities.

- evaluative: " Overall, this collection of articles contains some interesting ideas as to how curriculum and student data could be combined and analysed through the application and development of bespoke Curriculum Analytics tools. They all appear, however, quite preliminary studies, which is also an indication that this remains a young field of study where much research is still needed.". This expresses a judgement on the maturity of the work summarised and more widely its field of study.

You should do a similar analysis of something you have written.

Activity: Types of academic writing in your summaries #80

Consider a couple of theme summaries you have written. Which kinds of academic writing have you used?

Guidance

If you find primarily descriptive writing, you should consider having another go at your summaries to improve the balance between description, analysis, synthesis and evaluation.

Having mastered these key skills, your completed literature review will be a self-contained piece of academic writing, which shows your critical thinking and mastery of academic writing skills, and through which you:

- demonstrate your understanding of key ideas and their significance to your research, particularly to framing and justifying your research problem
- relate different ideas to each other, including arguments and counter-arguments,
- reason through the evidence to argue the possible contribution to knowledge your research can make.

In this way, a completed literature review demonstrates your ability to synthesise from the academic literature.

4.1.2 Core practice for academic writing

Academic writing has certain core practices that you should be aware of and apply consistently in your project work. They are:

Use critical rather than descriptive language Your writing should be based on well-formed arguments, i.e., on claims that are supported by evidence•, on comparing and evaluating alternative arguments, and on forming judgements on the basis of that evidence. Your writing will therefore favour analysis, synthesis and evaluation over descriptions.

In your descriptions you should also focus on essential details and keep general background information to a minimum.

• Either that of others or that you have discovered yourself. We look at academic arguments in detail in Section 4.1.3.

Be clear and precise Your writing must make it easy for the reader to follow your arguments and grasp the points you are trying to make. You should:

- avoid long, over-complicated, poorly punctuated sentences;
- be accurate in what you report;
- be precise; avoid ambiguity and vagueness;
- clearly define terms and concepts that may be open to more than one interpretation to avoid misunderstanding;
- keep your audience in mind: avoid jargon and, when using technical terms•, explain any that your readers are unlikely to be familiar with.

• If there are a lot of technical terms, you might consider keeping a glossary.

Order you topics appropriately You need to consider carefully which information your readers need to read first to make best sense of the topics you will introduce•. Start with less complex• topics and build on them towards more complex ones. Later topics may depend on earlier ones, and this can give a hint to their presentational order, too.

• We get to how to structure an argument later in this stage

• You will have experienced which are the simpler and which are the more complex topics in your reading so you will already know in which order to place them.

You can make your reader's life easier if similar topics are grouped together in your writing – otherwise, they may get the impression that you are repeating yourself, or they may miss important connections between them. So, group similar topics together.

Signpost your narrative Another way of making your reader's life easier is to *signpost* your writing, i.e., provide explicit clues to avoids the reader getting lost while reading your work. It applies both to the overall structure of your document and to individual arguments within each of its sections.

Common signposting practices at chapter, section or document level are:

- careful choice of headings and sub-headings
- 'setting the scene'• at the start of a chapter or major section to provide a roadmap of what comes next
- summarising key points at the end of a section/chapter.

• Journalists will often structure their narrative in the following way: they will
  - tell you what they're going to tell you
  - tell you
  - tell you what they've told you.

  This is signposting at is best.

Another form of signposting is at the level of an individual argument, when appropriate words or phrases (see Table 4.3) are used to help the reader understand where they are in an argument.

Table 4.3: 'Signal words' used in academic writing, inspired by **Cottrell2017**

Function	**Possible word or phrase to use**
introducing an argument, a description, a section or a chapter	first, firstly, first of all, to begin with, initially
reinforcing similarities/arguments	similarly, equally, in the same way, also, for example
adding further evidence/arguments	furthermore, moreover, in addition
introducing alternative evidence/arguments	alternatively, however, on the other hand, differently
highlighting choices	either/or, neither/nor
contrasting ideas/arguments	instead, by contrast, conversely, on the one hand [...] on the other
drawing conclusions	therefore, as a result, as a consequence, in conclusion, consequently, because of this

Activity: Signposting in our theme summary #81

Consider, once again, our summary on modelling students' learning trajectories. Write down any form of signposting you can identify.

Discussion

This is what we have noted:

- there is an opening statement to set the scene
- 'For instance' is used to introduce a specific example which illustrates a point previously made
- 'Similarly' is used to introduce work with a similar aim as the previous work mentioned
- 'Finally' introduces the remaining work reviewed
- 'Overall' opens the concluding statement, which offers some summary observations

You can do the same for your own summaries.

Activity: Signposting in your summaries #82

Consider a couple of theme summaries you have written. Which forms of signposting have you used?

Guidance

Consider whether your signposting could be improved by applying the guidance in this section.

Write good, grammatical text This is an essential characteristic of all written work you are expected to produce. You should therefore proofread carefully all your writing before submission to remove as many grammatical errors and typos as possible.

With modern tools, producing good grammatical text isn't difficult and your examiner will appreciate good grammatical writing. In fact, given the availability of good tools•, they will, most likely, expect you to write perfect natural language prose.

• Misquoting Star Wars: "Use the tools, Luke, use the tools."

Use an appropriate format You should be sure to understand the required final format for your dissertation. For instance, all your citations and references should comply with the bibliographical style required. Your dissertation pages should be numbered, and all your figures and tables should also be numbered and accompanied by appropriate captions.

Dissertation format requirements #83

Check the requirements your course places on the final form of your dissertation then answer these questions[a]:

1. How many words should your dissertation be?
2. What font size should you use?
3. What should the line spacing and margins be?
4. How should you number your dissertation pages?

5. How should you number figures and tables?
6. Are there any stylistic requirements on headings and sub-headings?
7. Are you allowed to include additional material in appendices?
8. How should references and citations be formatted?
9. Is there specific information that you should include in your dissertation title page?

Discussion

Our university has no single format for all Masters courses. However, looking at one specific capstone project guidelines, we have found the following:

1. The dissertation should be between 10,000 and 15,000 words, excluding references and appendices
2. The font used should be 11 or 12-point Times New Roman, with 11 points recommended
3. 1.5 line spacing should be used and margins should be approximately 2cm
4. Pages should be numbered, including references and appendices. Lower-case Roman numerals – iii, iv, v, etc., should be used on the preliminary pages, and Arabic numerals starting from page 1 should be used from the beginning of Chapter 1
5. All figures and tables should be numbered, with sequential numbering within each chapter, for instance, the figures in Chapter 2 would be Figures 2.1, 2.2, 2.3, etc. Also, they should have descriptive captions: below them for figures and above them for tables
6. Headings and sub-headings should be numbered with sequential numbering within each chapter, for instance, in Chapter 3, you could have sections 3.1, 3.2, etc. each with sub-sections, say, 3.1.1, 3.1.2, etc. You should avoid sub-subsections
7. Appendices are allowed and should be used to provide extra materials in support of the dissertation body. Appendices are not assessed and should be used sparingly
8. References and citations should use the Harvard bibliographical style

9. The title page should include:

    - the full title of the dissertation
    - your full name
    - your university identifier
    - the degree for which it is submitted
    - the date (consisting of month and year) of your submission
    - the total word count.

    In addition, there should be a short statement declaring that no part of the dissertation has been submitted for a degree or other qualification.

[a] It may be that you can't answer these questions because they are not part of the requirements. In this case, we've suggested an answer for you.

Avoid plagiarism like the plague! In describing your research, you will need to distinguish it clearly from the work of others.

Part of this is to identify clearly the new contribution to knowledge your work makes: you can't make a new contribution to knowledge that someone else has already made•.

• Duh!

Another part of this relates to behaving ethically in acknowledging all sources you have used. This is known as attribution and its role is to give credit where credit is due, avoiding any possible accusation of plagiarism, that is passing off the work of others as if it were your own. In a dissertation, the correct form of attribution is through referencing, and there are two common ways to report cited work:

- Paraphrasing. This refers to rephrasing in your own words what an article says, still ensuring that the article is appropriately cited.
- Using quotation marks. You can use quotation marks to identify text reproduced without change from a cited article. In this case you can use the words of the article *verbatim*, as long as they are enclosed within quotation marks.

Both can be used, but an excessive use of quotations may interrupt the flow of the narrative making it harder for the reader. As a rule of thumb, you should use quotations in your literature review if the wording used by the authors of the article really matters, perhaps because they introduce a significant new term or concept or use particularly suggestive language. Otherwise, we recommend paraphrasing, which may help you convey the essence of what you have read more concisely or even more clearly.

If you follow these simple practices consistently, you will avoid most unintentional plagiarism and your work is more likely to comply with your course requirements and expectations.

Ways to report cited content #84

Consider the following statements:
"A summary-comparison matrix, introduced by **Sastry2013**, can be used as an efficient tool to keep track and compare the content of articles reviewed. Similar information is recorded for each paper, such as the research aim, research methods or key findings, organised in a matrix form which facilitates their comparison."
and
"**Sastry2013** define a summary-comparison matrix as 'a data organizer that helps students to extract relevant information from research papers, categorize those extractions and visualize how these disparate extractions are related to each other' "
Write down how they differ in the way they report the cited work.

Discussion

The former uses paraphrasing; the latter includes a verbatim quotation from the article.

A third part is to avoid *accidental* plagiarism, which may result from not keeping tabs on where ideas/arguments/logic/processes/etc. came from, and what your knowledge contribution to those is. This is to show that while intentional plagiarism is a deliberate attempt to deceive, something that both universities and publishers take very seriously and may have severe consequences, plagiarism doesn't need to be intentional to be classed as plagiarism. Accidental plagiarism is usually the result of poor organisation or sloppy review practices, and can be avoided by being careful and systematic when reading articles, and writing and organising your notes and summaries.

The final part is to avoid self-plagiarism, which is where you re-use already existing material that you yourself have published, without clear attribution•.

• Clearly, this is not relevant if you haven't published before.

Tip

The guidance we give above is much easier to implement at the time of creation, not at the end of the writing up process. Imagine not knowing where a quote on page 35 came from when you're writing up and the difficulty you could have in trying to find it retrospectively.
Given the importance academics place on plagiarism, the risks of not being proactive in avoiding it are very high. Universities take plagiarism very seriously. You should too.

ACTIVITY: Looking up your University's plagiarism policy #85

Look up your university policy on plagiarism and any disciplinary processes related to it.

Discussion

Our university has strict policy on plagiarism. Intentional plagiarism can lead to severe disciplinary actions, from failing study modules to be expelled from a course. Early on in study, poor academic practices can be addressed by providing extra study support. Repeated offences will incur in disciplinary action, decided on by an Academic Conduct Officer, including failure.

4.1.3 Develop your arguments!

The development and presentation of academic arguments forms the core of academic writing. But what exactly is an academic argument? To answer this question, we look at the model proposed by Booth, Colomb and Williams in **Booth1995**: we will refer to this as the BCW model.

4.1.3.1 The BCW model

In the BCW model, an academic argument has at least 2 parts – the *claim* and the *evidence* – and might, in more complex arguments, have up to 3 other parts – called the *reason*, the *warrant* and any *qualifications*.

Their model is shown in Figure 4.1, and the parts are:

1. The *claim*, which is a point of view and needs support with...
2. ... *evidence*, which provides the grounds on which the claim is made, and ...
3. ...the *reason*, which is why we believe the claim to be true.
4. The *warrant* explains how the reason is relevant to the claim.
5. The *qualifications* are concessions which may limit what is being claimed, for instance by acknowledging objections, alternatives, etc.

In dealing with qualifications, you might need to make further arguments, in which case the process of building an argument may become recursive and so much more complex to develop and present.

A fully developed BCW argument is a beautiful thing. Here's a short example•

• Adapted from **BCW1995**.

The need for a TV 'watershed'

Claim
showing violence on TV should be allowed only after the 9pm

Reason
TV violence can have harmful psychological effects on children

Evidence
Smith (1997)**Smith1997** found that children ages 5–7 who watched more than three hours of violent television each day were 25 percent points more likely to say that what they saw on television was "really happening"

Warrant
If children are protected from watching violence on TV they will be less likely to see violence as a normal part of day-to-day life

Qualifications
The following are qualifications that I have considered:

- that a child interprets something on TV as "really happening" does not necessarily mean that they will try to emulate it.

Figure 4.1: The five elements of an academic argument, adapted from Booth et al., 1995.

LR: Needs redrawing as it is currently a merger from a couple of illustrations in that book - also needs to bring out which parts are mandatory.

- Not all children are impressionable.
- Violence *is* a normal part of day to day life.

Qualifications can improve a claim – reducing its scope, for instance, making it more acceptable – but may also require further arguments to be made. For instance, a rebuttal to “Violence is a normal part of day to day life” might be the counterclaim that “To reduce violence in day to day life, we should insulate children from it so that the next generation isn’t so likely to see violence as a justified response to problems.” and so to other arguments. These might be structured the same way until all qualifications are discharged to your satisfaction.

Activity: Differentiating between reason and evidence #86

Think about the example above, write down what you think the difference between reason and evidence is.

Discussion

According to Booth, Colomb and Williams (1995), reasons are things we think up in our mind, while evidence is somewhat "out there" for everybody to see and examine. While in everyday casual conversation, we can often support a claim with just a reason, that should not be the case in academic research where reasons should be backed up by evidence, as your research audience is unlikely to accept your reasons at face value.

4.1.3.2 Arguments and narrative

In your literature review, and your dissertation as a whole, your arguments won't be presented in the BCW form above, of course: the model is only a useful device to help you distinguish between the essential elements of an academic argument. Your dissertation presentation will be in the form of a continuous narrative instead. However, it is essential that there is a strong connection between your narrative and your academic arguments. In this section, we consider ways the BCW model can help you write narrative which allows your arguments to shine.

We can start for the theme summaries from Stage 1. Let's look at an example.

Finding the academic argument in our theme summary

Let's consider once again our summary around the theme of modelling learning trajectories with curriculum analytics. Let's 'extract' from the narrative the argument made using the BCW model. It goes like this:

Claim

modelling and analysing students' learning trajectories can inform scholarship and reflection around curriculum, its design, and possible improvements.

Reason
: such modelling and analysis helps us understand how students progress or otherwise through their study and the learning outcomes they achieve in doing so

Evidence
: the works cited demonstrates how this can be done

Warrant
: if we understand which curriculum characteristics prevent students from succeeding on programme of study, then we could re-design the curriculum to address the problem

Qualifications
: All cited work is based on limited case studies, so that we have no evidence of wider applicability or generality; also some of that work is little more than a proof-of-concept aimed at suggesting new avenues for research rather than proposing a mature approach.

In this example, by matching our summary narrative to the BCW structure, we can check that all necessary elements of the argument we were trying to make, particularly its claim and evidence, are in place. In the example, our argument was complete with respect to the BCW model, in that all elements were present. Should that not be the case, however, the BCW model would have helped us identify how the argument could be developed further.

It's now time for you to have a go. To do so, you can start from the theme summaries you have already written:

Activity: Constructing your academic arguments #87

Consider your current theme summaries. Extract and write down their academic arguments according the BCW model. Identify those which are already well developed and those which require further work, indicating what is still needed.

Guidance

Don't worry if you can't include all the five elements for each argument, but try to capture both your claim and any reasons and evidence in support in all cases. It is possible that your summaries contain more than one academic argument each: in such case, ensure you apply the BCW model to each of them.

Constructing academic arguments is a fundamental skill which becomes easier with practice. Therefore we suggest you spend up to 2 hours on this activity.

You have seen how, given some narrative you have written, it should be possible to clearly identify all the elements of the argument you were trying to convey. Vice versa, given an argument based on the BCW model, the real skill of writing it down is to find a form of narrative that combines all components together in prose that is easily digestible•. If you find this conversion difficult, you could start with the following template• for creating a narrative around a BCW model argument:

• Meaning that your reader – cough, examiner, cough – can easily engage with it.

• Adapted from Figure 4.1

I claim that *my claim*, because *my reasons*, based on *this evidence*. The warrant that allows me to connect my reason and claim is *my warrant*. I acknowledge the following qualifications to my claim (which I deal with later):

- *qualification 1*
- *qualification 2*
- ...

Activity: Beginning an evidence narrative #88

Put the example TV violence argument into the BCW narrative form based on the template.

Discussion

You should have something like:
" I claim that showing violence on TV should be allowed only after the 9pm, because TV violence can have harmful psychological effects on children, based on Smith (1997)**Smith1997** found that children ages 5–7 who watched more than three hours of violent television each day were 25 percent points more likely to say that what they saw on television was "really happening". The warrant that allows me to connect my reason and claim is If children are protected from watching violence on TV they will be less likely to see violence as a normal part of day-to-day life. I acknowledge the following qualifications to my claim (which I deal with later):

- that a child interprets something on TV as "really happening" does not necessarily mean that they will try to emulate it.

- Not all children are impressionable.
- Violence *is* a normal part of day to day life.

"

As you can see, the model gets close to a narrative, but there are some grammatical errors – "... based on **Smith1997** found that ..." – which need smoothing out, and it could get very repetitive if each and every argument you present has this form.

There are many techniques for improving your narrative. One of the most powerful is to read what you have out loud to a live listener and have them try to follow your argument.

Activity: A willing audience #89

Read the result in its raw form – **as written** – to a willing family member/friend/colleague and ask for their opinions on it. Reflect on both their reactions to your reading and the feedback they provide.

Guidance

In your reflection you could consider the following questions. Was your audience engaged or did they fall asleep? Did their feedback help you understand how the narrative should improve? Will they come back and help with future versions? Did the template work for you?

It's unlikely that your first cut at creating a narrative using the template will result in something you can use directly in your dissertation. Instead, you should iterate to make it more compelling, using the feedback from your 'critical friends' to help you to do so.

4.1.3.3 Logical fallacies and cognitive bias

The BCW model is a useful device to help you structure your academic arguments. In making you think deeply and critically about what you are trying to claim and why, you have a better chance to write good argument. There are, however, things you still need to guard against.

Firstly, there may be logical fallacies in your arguments: these are errors of reasoning that can undermine your claim. The most common ones are•:

• Many more exist – you may like to do a web search to find out more.

- circular reasoning•, in which the supporting evidence is just a restating of the claim.
- hasty generalisation, in which a claim is made based on insufficient evidence.
- sweeping generalisation, in which a claim obtained from evidence within a specific situation or contest is assumed to be true in other situations/contexts.
- *post hoc ergo propter hoc*•, which claims a causal relation between two phenomena because one happens after the other.
- false dichotomy•, in which an either–or claim is constructed which assumes two phenomena are mutually exclusive where that's not the case.

• A.k.a. begging the question or begging the claim.

• This is a Latin phrase meaning "after this, therefore because of this". [More explanation here of why this is bad...]

• AKA black and white fallacy or false dilemma.

Activity: Logical fallacies #90

Think of each definition above and write down a possible example.

Guidance

If you struggle to think of appropriate examples, do a web search to get some inspiration. However, you should still try and come up with your own examples too.

Discussion

This is what we have come up with:

- circular reasoning: collecting quality data is difficult (claim) because quality data are difficult to collect (evidence, restating the claim)
- hasty generalisation: camomile tea cures insomnia (claim) because when I drink camomile tea in the evening I sleep well (insufficient evidence).
- sweeping generalisation: universities don't generate quality student data (claim) because I have observed this is the case in my university (evidence from a specific context)
- *post hoc ergo propter hoc*: I should not watch Italy playing rugby (claim), because every time I watch them they loose (assumed causal relationship).

- false dichotomy: during a pandemic we either save lives or preserve the economy (claimed false dichotomy), because to save lives we must shut all economic activities down.

Secondly, everybody is susceptible to cognitive bias, which prevents people from processing information objectively due to limited capabilities of our mind, or due to emotional responses or social norms and conditioning. You have already encountered cognitive bias in Section 3.5.3.7, alongside examples of various forms of bias. Among them, confirmation bias is particularly relevant to the construction of academic arguments.

Activity: Revisiting confirmation bias #91

Go back to Section 3.5.3.7 and revisit the definition of confirmation bias. Write down ways in which it may affect you when constructing your academic arguments.

Discussion

Confirmation bias may result in cherry-picking information which agrees most with our beliefs, opinions or preconceptions, and ignoring that which may support opposite views. This can lead us, as researchers, to conduct selective searches, actively looking for articles whose positions is in alignment with ours, or recall and interpret evidence in a way which reinforces our position, rather than maintaining an objective stance by weighing and contrasting available evidence.

4.1.4 Developing your literature review from your theme summaries

You should now have a collection of summaries based on the themes you have identified from the literature. You will have also revised those summaries to ensure that the academic arguments within are well-formed in relation to the BCW model. Congratulations! You now have some basic building blocks to put together your very first literature review draft.

4.1.4.1 Developing the main body of your literature review

In piecing together your literature review it is important you consider the order in which different topics are introduced. You main goal in doing so is to ensure that the reader of your dissertation will find it easy to follow the 'story' you are trying to tell — one which provides sufficient context and justification for your research.

In doing so, you should think of your literature review as made of three distinct parts:

- an introduction, which gives the reader, in outline, a sense of the detailed review you have conducted
- a main body, which provides a detailed account of such review, and
- a summary conclusion, which provides the academic argument in support of your research, based on the evidence you have presented in the main body.

Your theme summaries are your starting point to populate the main body of your literature review. In doing so, we suggest you take the following steps•:

• You should have both your theme summaries and concept map (see Section 3.3.4.4) at hand

- list all the themes you have identified in no particular order

Listing the themes

In our Stage 1 review of the Curriculum Analytics (CA) literature we identified the following themes:

1. stakeholders and CA tool development
2. modelling study trajectories and progression
3. benefits of CA tools
4. deriving insights from data
5. curriculum metrics and quantitative assessment
6. success factors for CA adoption
7. capturing student voice
8. CA definitions

- consider whether there are themes whose concepts overlap, and could be merged. If so, merge their themes summaries into a wider theme

Merging themes

We found that stakeholders were prominent both in the development and adoption of CA, so we merged those two themes; we also found that the 'capturing student voice' could be seen as a particular instance of the 'benefits of CA tools', so we merged those two themes as well. As a result, we ended up with the following (changes in bold, also illustrated in Figure 4.2) :

1. **importance of stakeholders in CA development and adoption**
2. modelling study trajectories and progression
3. **benefits of CA tools, including capturing student voice**
4. deriving insights from data
5. curriculum metrics and quantitative assessment
6. CA definitions

- consider whether there are themes which rely on concepts introduced by other themes. If so, the latter should come first, and the former could follow closely. You should re-order your themes accordingly

Identifying dependencies between themes

All themes assumes an understanding of what CA are, so that CA definitions should come first. Also, 'deriving insights from data' expands on some issues around stakeholders and CA adoption, so it should follow soon after that theme. This led to the following (changes in bold, also illustrated in Figure 4.3):

1. **CA definitions**
2. importance of stakeholders in CA development and adoption
3. **deriving insights from data**

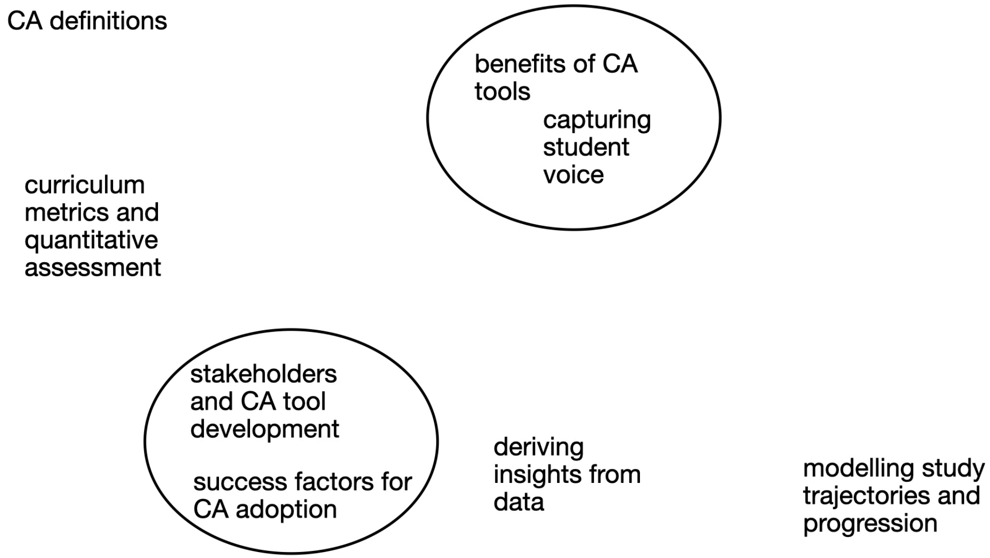

Figure 4.2: Merging themes

4. modelling study trajectories and progression
5. benefits of CA tools, including capturing student voice
6. curriculum metrics and quantitative assessment

- consider which themes may be broad and generic vs those which may be narrow and specific. Re-order the themes so that your narrative goes from the generic to the specific, while maintaining any dependencies you have already identified.

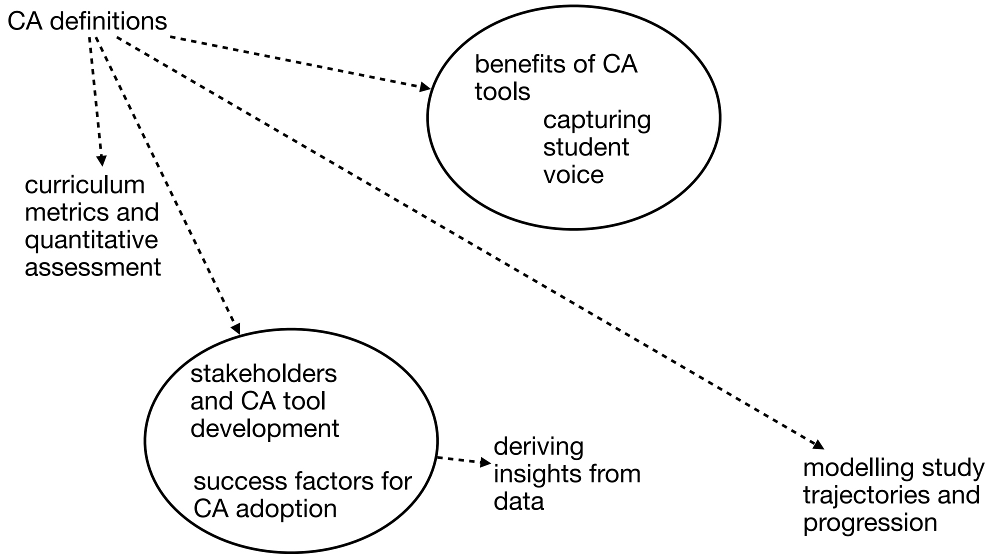

Figure 4.3: Theme dependencies

From generic to specific

Both CA benefits and metrics are quite generic theme, so that they could come early: this is illustrated in Figure 4.4, from more generic in top left to more specific in bottom right. Different re-ordering are possible. For instance:

1. CA definitions
2. **benefits of CA tools, including capturing student voice**
3. **curriculum metrics and quantitative assessment**
4. importance of stakeholders in CA development and adoption

5. deriving insights from data
6. modelling study trajectories and progression

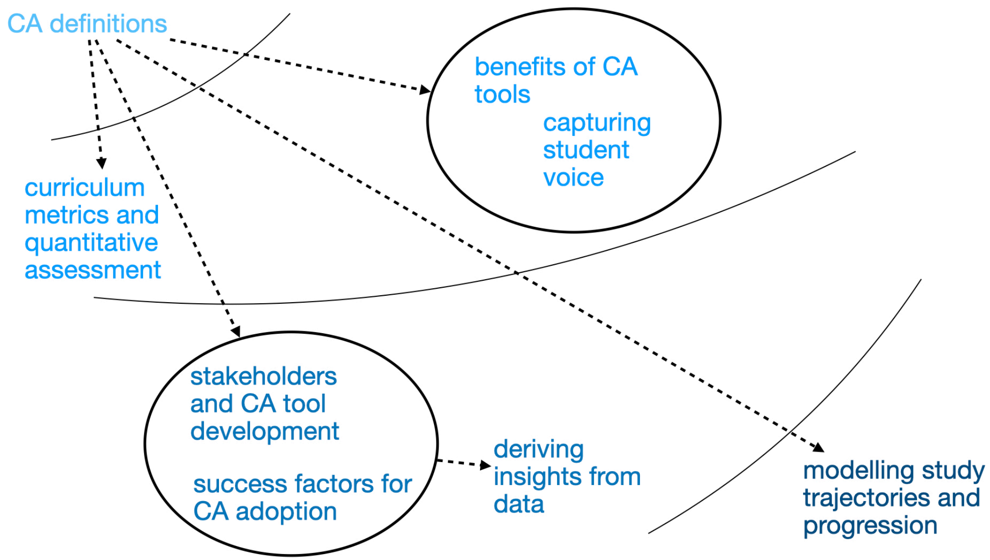

Figure 4.4: Theme generality

By the end of this process, you should have a structure for your literature review body: each of the themes in your list can be a sub-section which you can populate with the narrative from your summaries.

Activity: Structuring the body of your literature review #92

Consider your current theme summaries. Apply the above steps to arrive at a possible structure for the main body of your literature review. Once you are satisfied with the structure, populate it with your theme summaries and read it through. Make sure there is a good flow from one section to the next.

Guidance

You may have to re-apply the steps to improve both structure and narrative flow between sections. Being able to structure a narrative is yet another fundamental skill which becomes easier with practice and that will serve you well when writing up your whole dissertation. Therefore, you should tread this as a substantial activity which is likely to require you several hours if not days.

4.1.4.2 Choosing headings and sub-headings

You should now consider the headings of your review sections and sub-sections, to ensure they are appropriate. Your headings should:

- indicate, in outline, to the reader how the narrative develops from one section/sub-section to the next
- express clearly the purpose of each
- accurately reflect the content of each
- be concise

Activity: Improving your current headings #93

Consider your current draft of the main body of your literature review. Apply the guidelines above to improve its headings and sub-headings.

Guidance

You choice of headings and sub-headings should signpost to the reader where they are in your ‘story’, help them follow the thread of your arguments, and allow them to locate efficiently specific content they wish to return to.

4.1.4.3 Writing your review introduction and critical summary

Now that the main body of your literature review is in place, at least in draft form, you can top-and-tail it with a brief introduction at the beginning and a critical summary at the end.

Activity: Writing the introduction #94

Write a brief introduction to your literature review to introduce the topics you are going to cover in its main body, and their relevance in relation to your research problem.

Guidance

Your introduction should be brief and indicate in outline the main topics you are going to cover and why. This section should be straightforward to write now that the literature review main body is in place.

Activity: Writing the critical summary #95

Write the concluding section of your literature review which summarises the main findings from your reading in support of your proposed research.

Guidance

Your critical summary should take the form of an academic argument which supports your claim that there is a knowledge gap your research is going to address. You should skim through Section 4.1 to remind you of the key elements of an academic argument. Writing this section may take some time and require you to iterate until your argument is well-formed.

4.1.5 Assessing your literature review

It is time to assess whether you have done enough work on your literature review and can move on. If not, you will need to widen it to include what is currently missing – there may be topics which you haven't explored sufficiently, or even some you haven't address yet. This means iterating the literature review process by searching, gathering, assimilating and synthesising more published work.

The best person to assess your literature review is YOU•! The following activities will help you assess your progress and guide any further work required.

• Of course, others can help too, as we shall see.

4.1.5.1 Your own assessment

At this point, your literature review should be sufficient to describe the boundary of knowledge in the area of your research problem, including the knowledge gap you hope to fill.

Does your current review draft achieve this? To be able to answer this question, we recommend you apply the criteria in Table 4.4.

Table 4.4: Criteria for assessing your literature review

Criteria	**Prompts**
Research problem underpinning	To which extent does it demonstrate your understanding of different facets of your research problem?
Research problem justification	To which extent does it argue that the research problem is worth investigating?
Potential contribution to knowledge	How clearly does it expose what the knowledge gap? How clearly does it articulate why it is significant to address it?
Logical progression	Do sections and sub-sections structure the narrative appropriately? To which extent does it include a logical progression of arguments?
Critical writing	Are connections between ideas appropriately explored? Is there a good balance between description, analysis and evaluation?
Supporting references	To which extent are all key arguments supported by appropriate references?
Format and proof reading	Have you reviewed your writing carefully to remove typos and grammatical errors? Are all citations and references in correct bibliographical style?

Activity: Assessing your literature review #96

Assess your current draft of the literature review by applying the criteria in Table 4.4.

Guidance

For each criterium, use the prompts to write down your own assessment and to record what is still missing: the latter will help you identify further work you will need to carry out.

4.1.5.2 Getting others to help you

There are people around you that will be able to help. Gathering others' feedback will not only help you understand what still needs to be done, but it can also help you to find value in your work so far. Even if you feel the draft is scrappy•, for instance, others might be able to bring out things they like about it.

• It certainly won't be in its final form as yet.

Among them, the most important person to help you is your supervisor, as an experienced academic writer and topic expert.

ACTIVITY: Sharing your literature review with your supervisor #97

Before going further with your literature review, it would be wise to ask your supervisor for comments on what you have already achieved.
Share your current draft with them and ask them to find holes in your coverage and your arguments. Carefully gather any and all feedback you receive.

Guidance

As this point, it's unlikely that your supervisor will say "It's perfect!"[a] so be ready to hear one or more of the following comments[b]:

- "you should read/add the following papers to your review"
- "this section seems out of order, perhaps it would be better elsewhere"
- "you've missed this topic"
- "this argument would be better expressed this way"

- “Author X also made this argument”
- “other comments”
- “your conclusions are wrong because ...”
- “you might like to speak to this colleague about this issue”

Make sure you consider their feedback carefully and take notes of all remaining work needed to develop your literature review further.

[a] Although they may say “Well done!”, but don’t worry if they don’t:)
[b] Or something close.

Other help might come from family members/friends/colleague that you can talk to. Like you did in Activity **??**, read what you have out loud to a live listener and have them try to follow your arguments.

Activity: A willing audience #98

Read your current draft to a willing family member/friend/colleague and ask for their feedback on it. Take notes of improvements that may be needed.

Guidance

Write down their comments as they make them (but try not to interrupt the flow too much). What was their reactions? Were they engaged or did they fall asleep (again)? Will they come back and help for future versions? Make sure identify ways you could improve your draft for your readers.

4.1.6 Widening your literature review

Our 5-stage framework assumes you develop a comprehensive initial draft of your literature survey by the end of Stage 2, with the bulk of gathering and assimilating articles happening in Stage 1. However, even if you hit gold first time with your literature search, you are likely to require more than one iteration of the literature review process in order to develop a full draft to your own satisfaction and that of your supervisor.

Therefore, expect some iterations also in Stage 2. The focus of such iterations is to help you widen or deepen some aspects of your review — something you and your supervisor will have identified while assessing your current draft.

Activity: Widening your literature review #99

Select a number of topics or sub-topics for further exploration and iterate through the review process in order to gather further articles, assimilate and synthesise their content, and integrate it within your current literature review draft. Reassess the content at the end and iterate if necessary.

Guidance

The topics or sub-topics to investigate may include:

- those you identified while assessing your current draft
- those from suggestions and feedback from your supervisor
- themes or concepts currently under-explored in your concept map[a]
- interesting ideas or sub-topics you came across in previous reading, but yet to explore
- articles cited in work you have already reviewed, or that cite that work

At each iteration, make sure you apply the wide range of review techniques you have learnt in Stage 1 and 2. In particular, record all new entries in your BMT, alongside your notes and summaries; take good notes as you assimilate new content; update your summary-comparison and concept matrices, and your concept map; and produce appropriate theme summaries.

As you integrate new content within your current draft, you may have to amend your arguments, or even rethink the structure of your draft.

Alongside widening the content you should also improve your draft based on other feedback you have received, for instance improving the narrative flow or clarifying points your readers may have found obscure or poorly expressed.

Importantly, make sure you take your supervisor's comments seriously. We don't mean just taking note of what they say and implementing it, but – and this is a good habit to form – writing a response: thank them for each of their comments, and tell them how the literature review has changed because of their

input. Your response doesn't have to be long – the shortest response to a comment could be "Thank you, done!". Doing this will make them – or anyone that comments – feel really valued.
This is a substantial activity which, depending on how much material you still have to review, may take you several days, if not weeks.

[a] The concept map was introduced in Section 3.3.4.4.

4.2 Developing your understanding of research design

Your literature review has set you on the right course to begin your research – you now know that there's a hole in knowledge into which a contribution can be made.

While this tells you *what* you are going to research, your research design should tell *how* you are going to do it. As you learnt in Stage 1, your research design will summarise, explain and justify how your research is conducted, developing into a detailed account of what you have done by the end of your project. An appropriate research design is one which allows you to make your contribution to knowledge in a way which meets the expectations of researchers in your field of study.

In this section, we consider fundamental concepts in research design to help you develop your understanding and inform your project choices, and to prepare you for the detailed work in Stage 3 where you will apply your learning to your own project.

The basic building blocks of research design are research methods and research strategies. *Research methods* are standard ways to collect, analyse, synthesise and present data and evidence, and to derive findings. You can think of them as basic techniques and procedures that researchers have come up with over time to deal with different kinds of data and evidence. Instead, *research strategies* are ways to systematise how research methods can be used together. You can use them to guide you in selecting and combining research methods to address specific kinds of research problem. Both methods and strategies are therefore practical tools to do research. Those you will encounter in this section are summarised in Figure 4.5.

At a theoretical level, strategies and methods are motivated and justified by different sets of beliefs on the nature of what we can study, how knowledge can be generated, and what is of value in research, called *philosophical traditions*: although practically you could apply strategies and methods without referencing them, it is important for you as a researcher to be aware of the beliefs and values they embody, and the

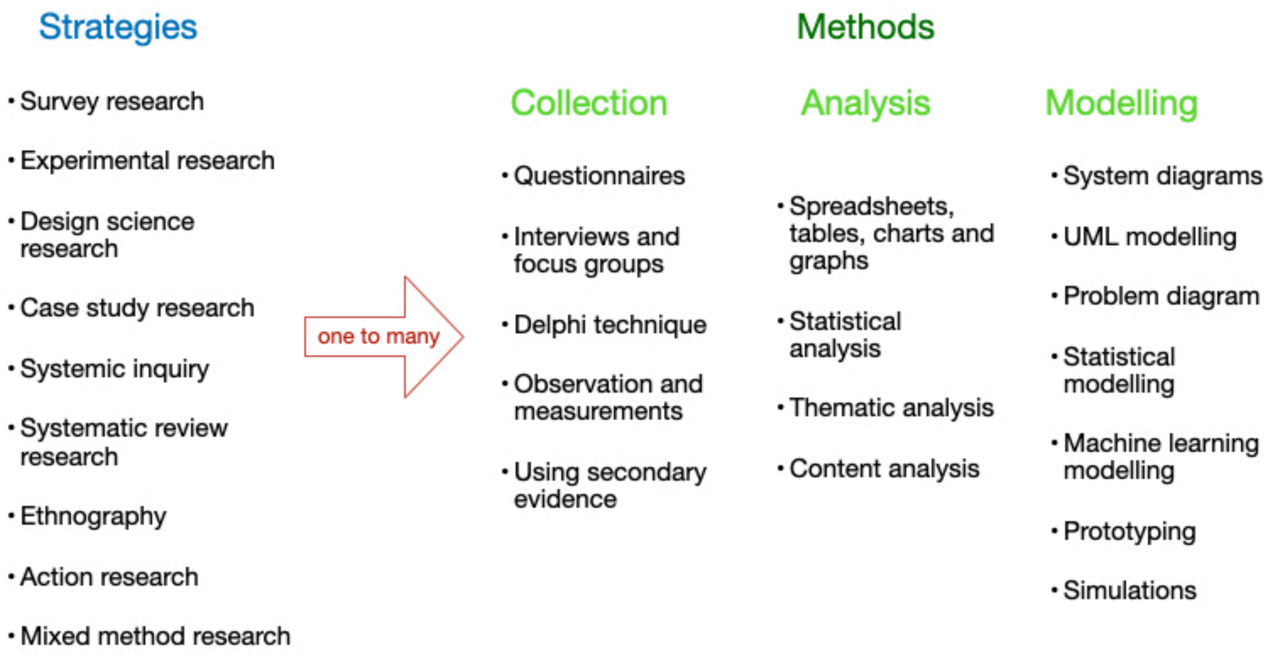

Figure 4.5: Research strategies and methods

extent they align to your own – something which may influence your own research design choices. In this section you will also read about the more prominent philosophical traditions.

4.2.1 Research methods

Research methods are the means used in research to collect, analyse, synthesise or present data and evidence, and to derive findings from them. They help you conduct your research in a systematic, rigorous, repeatable and reliable fashion. So, research methods are important because they underpin how sound• your research is.

• This is the topic of research *validity*, which will be covered in Stage 3.

Research methods are many and vary greatly, which can be confusing to the novice researcher — and even the seasoned one at times! One source of confusion is that the same term is often used to indicate both specific techniques and procedures, and broad research strategies combining many.

In this handbook we will use the term research method as a synonym for research technique/procedure, but be aware that you may encounter other meanings while reading the academic literature.

In this section, we recall a wide range of research methods commonly applied in research, particularly at Masters level. They are categorised as collection, analysis and modelling methods.

4.2.1.1 Data collection methods

These are methods that can be used to collect data and evidence, which might be qualitative, quantitative or both.

Questionnaires A questionnaire is a fixed set of questions organised in a particular order used to gather answers. It can be delivered face-to-face or distributed to respondents to gather their answers. The respondents' answers constitute the generated data that is subsequently analysed by the researcher.

Questionnaires are a data collection technique applicable when:

- you wish to obtain standardised data from many people
- you seek relatively brief information from your respondents
- you expect your respondents to be able to understand and interpret the questions in a straightforward manner.

Questionnaires can help collect both quantitative and qualitative data, depending on their questions. They can be *self-administered*, in the sense that the respondents complete the questionnaire without the researcher being present, or *researcher-administered*, in which case the researcher asks the questions and writes down the responses.

Interviews and focus groups An interview is a form of conversation between the researcher and one or more interviewees, designed by the researcher to gain insights and opinions on a specific topic. The researcher guides and controls the conversation and asks the questions. The interviewees' answers constitute the generated data that is subsequently analysed by the researcher.

An interview is a technique for data generation applicable when you wish to:

- obtain detailed information on a specific issue or topic
- ask open-ended, complex questions, which may be tackled or interpreted differently by different interviewees
- investigate sensitive issues or privileged information that interviewees may not be willing to commit to writing.

Interviews are primarily used to collect qualitative data. They can be one-on-one, between the researcher and one interviewee at a time, or can happen in a group, with several interviewees being interviewed together by the researcher. The latter is referred to as a focus group.

Interviews can be fully planned or quite open-ended. The former are termed *structured* and use pre-determined, identical questions with all the interviewees, while the latter are termed *unstructured* and typically start by introducing a topic but then let the interviewee talk freely around their ideas, experience and beliefs. Somewhere in between are *semi-structured* interviews, where the researcher selects some themes and related questions upfront, but then adapt them depending on how the conversation with the interviewee develops.

Delphi technique With the Delphi technique, a group of experts are consulted with a view of obtaining a consensus on a particular issue or topic. It involves an iterative process of collecting, synthesising and circulating anonymous judgements from those experts to eventually arrive at a consensual view. More precisely, each subject expert is initially consulted separately by the researcher, who then anonymises and collates the group responses and circulate them to the same group of experts. The process is repeated until a consensus is reached.

This technique is based on the idea that a group of people are more likely to arrive at an informed and valid position than an individual, with anonymity preventing interpersonal relationships from influencing the outcome. The judgements and consensus gathered constitute the generated data that is subsequently analysed by the researcher.

The Delphi technique is particularly suited to situations in which the researcher wishes to improve their understanding of an under-explored problem or issue in order to inform decision-making.

Observations and measurements Observations are used in research to find out what people actually do or what actually happens in a particular context, rather than what has been reported about it. Observations can be of people's behaviour or interactions, e.g., observing a formal meeting in an organisation, or of events and processes, for instance observing a queue at the post-office or a computer-controlled production plant. As such, observations can generate all kinds of data, qualitative and quantitative. Quantitative observations are often referred to as measurements, e.g., the length of time a particular customer has spent waiting in the queue at the post office.

There are two main types of research observation, *systematic* vs. *participant*. The former is when the researcher decides in advance what to observe, the schedule of observations and what to record. For example, the observation of a queue at the post office could be planned to take place over a certain week or month, and recordings may include time of arrival and departure of each customer, average and maximum length of the queue, average service time, etc.

In participant observations, the researcher participates directly in the situation under study and produces a rich description of what happens based on what they experience. For instance, in relation to the previous example, the researcher might join the queue at the post office and record their experience in great detail, or even join the staff in the post office to understand why queues are longer or shorter for certain tasks.

Use of secondary evidence The previous techniques can be used to generate primary evidence•.

• As defined in Section 3.5.1, primary evidences is newly generated during research, while secondary evidence is already available from previous research.

Academic research, however, can also use secondary evidence as its starting point. This can be represented by existing documents of many forms, from academic articles to documents found in organisations, e.g. laws, policies and procedures, reports, formal minutes of meetings, informal communications, etc. Similarly, there are plenty of publicly available data sets that can be used, created by academic communities or private and public organisations, such as business financial data or statistical data from the UK Office for National Statistics or data from social network platforms. As already noted, the academic literature at the core of your literature review is a form of secondary evidence.

4.2.1.2 Data analysis methods

These are methods that can be used to analyse data and evidence after collection.

Spreadsheets, tables, charts and graphs They are the bread and butter of data analysis, are applicable to all kinds of data, and can be used to summarise and visualise data, and identify interesting patterns. You should be already familiar with this topic from your previous studies, so that this is only a brief overview to refresh your knowledge.

A spreadsheet is a digital tool you can use to capture, display and manipulate data arranged in tables, that is arranged in rows and columns. Common spreadsheets include Microsoft Excel, Apple Numbers and Google Sheets. Spreadsheets are among the most used digital tools, so it is likely you are already familiar with at least their basic functionalities. Spreadsheets have become quite sophisticated tools, including all sort of charts and graphs, as well as programmatic capabilities which allow you to code quite complex data manipulation functions. Some of those advanced functionalities could be advantageous to your research, so it is worth spending some time considering what they can offer to your project. There are plenty of tutorials and other documentation online you can use to learn more.

Alongside spreadsheets a growing number of data analytics tools are also available: these are sophisticated digital tools which extend spreadsheet capabilities for collating and visualising data to include some degree of automated analysis, both statistical and based on Machine Learning algorithms. Tools like Tableau and Power BI are notable examples: both are available in free versions for community use and for study.

Statistical analysis This refers to a broad collection of techniques used to investigate trends, patterns, and relationships in quantitative data. It is a well established field of study with wide application across all kinds of research, and well developed tool support. In particular, both spreadsheets and data analytics tools include functionalities which allow you to calculate statistical measures on data, check statistical relationships between variables and data sets, and generate basic statistical models. Bespoke statistical tools also exist for more advanced statistical analysis and modelling, like IBM SSPS or Minitab, which are also available in free versions for students.

Should your project require advanced statistical analysis, then you will need to become proficient in good time to carry out your analysis and interpretation of findings in Stages 4 and 5 or your project.

Thematic analysis This is a way of analysing qualitative data, particularly texts, e.g., transcriptions of interviews or answers to questionnaires or existing text documents, in order to find out something about people's views, opinions, knowledge, etc.

At its core is the identification by the researcher of recurring themes, their definition and relationships: this relies on the researcher's judgement and it is quite subjective.

Content analysis This is used to identify patterns in non-numerical content used for communication, whether text, speech, images, videos, or other. For instance, in can be used to investigate certain words, themes, or concepts within that content.

It can be either quantitative, where the focus is, for instance, on counting occurrences, or qualitative, where the focus is on interpreting and understanding meaning and relationships. As such it can be used for many purposes, from discovering and understanding patterns, to looking at intentions behind what is expressed, or to highlighting differences of use in different contexts.

Discourse analysis It focuses on the use of language in conversations within their real-world context. In the analysis, it is essential to consider the influence of history, culture and power dynamics within that context.

Narrative analysis It focuses on stories which are told by people. The focus is on listening to such stories and how they are told to investigate their meaning, particularly how people make sense of reality.

4.2.1.3 Modelling methods

At its essence, a *model* is an abstraction or representation of something, be that a system, a structure or a behaviour. Modelling is used across many disciplines, so a vast repertoire of modelling techniques exist.

Possibly the most important thing you must remember about modelling is expressed by the following oft-cited aphorism•:

> *All models are wrong, some are useful* (Box, 1976)

which makes clear that a model should not be regarded as a faithful replication of some reality, but as a tool to investigate some aspects of that reality.

In this section, you will read about a small set of modelling techniques, which are particularly relevant in Master projects. A lot more can be found in the academic literature and beyond.

• Box, George E. P. (1976), "Science and statistics" (PDF), Journal of the American Statistical Association, 71 (356): 791–799.

Systems diagrams You can use systems diagrams to help you understand the structure of a situation of interest that can be rendered as a system. The term 'system' is meant in its widest possible meaning of a set of components interconnected for a purpose. This is a very general and versatile technique that you can apply to all sorts of real-world situations. If you have studied a systems thinking and practice module for your qualification, you will be already familiar with this technique.

There are many different kinds of systems diagrams•. For examples, *systems maps* allow you to sketch the structure of a system by identifying key components and sub-systems. They can be extended to show how those elements influence each other, in which case they are called *influence diagrams*. On the other hand, *causal loop diagrams* are used to capture cause-and-effect relations in a system, hence model certain dynamics of that system, particularly underlying feedback structures. They can be turned into *stock and flow diagrams* by adding quantitative information, so that this type of diagram is useful both for analysis and simulation of systems behaviour.

• You can find links to useful tutorials in Section **??**.

System diagrams have an accepted structure, format and notation but what you choose to describe and include within a system and its components will depend on your own viewpoint. Systems diagrams can be shared with others as learning devices to promote more understanding of a situation.

UML modelling UML (Unified Modeling Language) is a graphical language for visualising, specifying or documenting various artefacts in the process of developing software systems. If you have studied a software engineering module for your qualification, you may be already familiar with UML.

UML can be used as a 'sketching' language, to capture elements of systems informally, like you can do with systems diagrams, or as a 'blueprinting' language to specify precisely how elements of a software system will be developed. Different kinds of UML diagrams exist, so that you can model elements of software systems both in terms of their structures and behaviours, and their interactions with end-users.

In a Masters project, UML can be used to help you understand existing systems in context, or plan the development of new innovative artefacts.

Problem diagrams These have their roots in software requirements engineering as a diagrammatic technique to capture requirements in a real-world context to inform the specification of a new software system to satisfy them. They have been subsequently generalised for application to general engineering problems for which some novel solution artefact is to be developed in a real-world context, to guide design and ensure fitness-for-purpose. Problem diagrams span the problem-solution space divide by focusing on those phenomena that characterise a problem and constrain its solution.

In the context of Masters projects, problem diagrams can help you develop a good understanding of real-world requirements in context and explore both constraints and effects of designing new systems for that context.

Statistical modelling Many statistical modelling techniques exist. The most commonly applied include those used to model relations between variables, e.g., how crop yields relate to environmental factors, such as soil quality or meteorological conditions, or to model real-world processes, e.g., the spreading of a disease in a population. Once a statistical model is defined, it can then be used to make predictions of what might happen in the real world.

As per advanced statistical analysis, statistical modelling requires well developed statistical knowledge and skills, which you should already possess, or have the time to develop, if you are considering their use in your Masters project.

ML modelling Machine Learning (ML) models are computational programs which can identify patterns in large data sets and use them to perform a great variety of tasks usually associated with human cognition, like recognising images or language, classifying objects, or generating speech or texts, to name just a few current applications.

They are increasingly applied to all sort of data-rich problems, so that several ML models are readily available for use, embedded in computational library•.

• For instance, the *Scikit-Learn* library for the Python programming language.

ML modelling tools require highly developed technical knowledge and skills, which you should already possess, or have the time to develop, if you are considering their use in your Masters project.

Prototyping A prototype is an early version of an artefact, which can be used to test early design ideas or properties before implementation. As such they can present various degrees of fidelity in relation to the end artefact.

Prototypes are used in many contexts, particularly architecture, design, engineering or computing. In academic research, they can be useful to explore both problems and their intended solutions.

Data generated from prototyping can be either qualitative or quantitative, depending on the nature of the prototype and its intended use. For instance, the prototype of a digital app for a smart phone may be used to evaluate some usability properties with end users, which may generate qualitative data, or to measure computational speed and efficiency, which would generate quantitative data.

Simulations A simulation is something that mimics a situation, a process or the behaviour of system. They may be used to make predictions, for education and learning as well as for exploration and discovery. For instance, weather simulations are used to inform forecasts, while simulations of crisis scenarios, say a fire or an earthquake, can be used to train people.

Computer simulations are widely used in research, and many types exist. Among the most common are:

- *system dynamics*, which use continuous mathematical models to capture the dynamic behaviour of complex systems. Financial market simulations are often based on system dynamics.
- *agent-based*, which use collectives of interactive agents, whose behaviour can be programmed, to explore emergent properties of a system. Simulations of natural ecosystems are often based on multi agents, e.g., to study the balance between preys and predators over time, in which agents represent each the behaviour of ether a prey or a predator.
- *statistical simulations*, which apply statistical models to mimic a process or a system. The spread of diseases in a population, for instance, is often simulated statistically.

4.2.1.4 Summary of methods

We have covered quite a few methods in this section! Table 4.5 gives you a concise summary, including a brief description of each.

Before moving on, you should about which of these methods may find some application in your project.

ACTIVITY: Identify candidate research methods #100

Consider the methods in the table and which you may be able to use in your project. For each, write down what you would use them for and why.

Guidance

In considering candidate methods you should think of the sort of data and evidence your project may need, as well as the demands of each method in terms of access to people and other resources, and the level of expertise required to apply them. Their descriptions in the previous sections, which you may like to revisit, should be sufficient for you to carry on this activity. In Stage 3, you will return to some of those methods, to investigate how to apply them in detail within your project.

4.2.2 Research strategies

A research strategy• is a systematisation of a set of research methods, which can be applied together in order to address research problems of a particular kind. As such it can help you select and apply an appropriate mix of research methods. The term *methodology* is also sometimes used in the literature with a similar meaning•, although methodology also means the study of research methods, so it is an overloaded term this handbook will avoid.

This section provides an overview of some of the best known and most commonly applied research strategies.

- Our favourite take on *strategy* is: "The essence of strategy is choosing what not to do" from the economist *Michael Porter*. Your research strategy should do this – by giving you a focus – so choose carefully, and use its guidance wisely.
- And, confusingly, also as a synonym of 'method'...

Survey research This aims to gain insights which are valid across a target population, by collecting data from a predefined sample in a standardised and systematic way.

A typical application of survey research is to predict the outcome of an upcoming general election by polling data from a representative sample of voters.

Table 4.5: Research methods introduced in this section

Type	Name	Description
Data collection	**Questionnaires**	pre-defined set of questions used to gather answers from respondents
	Interviews and focus groups	form of conversation between researcher interviewee(s) to gain insights and opinions around a specific topic
	Delphi	iterative process of collecting and synthesising anonymous judgements from experts to arrive at a consensual view
	Observations/ measurements	direct observation/measurement of phenomena of interest
	Use of secondary evidence	reusing data/evidence from previous research
Data analysis	**Spreadsheets, tables, charts and graphs**	tools to summarise and visualise data in order to identify interesting patterns
	Statistical analysis	set of techniques to investigate trends, patterns, and relationships in quantitative data
	Thematic analysis	technique to identify recurring themes, their definition and relationships in qualitative data
	Content analysis	technique to investigate certain words, themes, or concepts in qualitative data
	Discourse analysis	technique to investigate how language is used in conversations
	Narrative analysis	technique to investigate meaning behind people's storytelling?
Modelling	**Systems diagrams**	representation of the structure of a situation of interest, rendered as a system
	UML modelling	graphical notation to visualise, specify or document software system-related artefacts
	Problem diagrams	graphical notation to capture requirements for to-be-designed artefacts, including software
	Statistical modelling	set of techniques to establish statistical relations between variables of interest
	ML modelling	computational programs able to identify patterns in large data sets and use them to perform cognitive tasks
	Prototyping	early version of an artefact used to test or investigate properties or early design ideas
	Simulations	something that mimics a situation, a process or the behaviour of

For your data collection, you need to identify upfront which data you will collect in a standardised matter, your target population and sample. So questionnaires or structured interviews are usually used for data collection.

In your data analysis, you seek patterns in the sample data collected to arrive at generalisations to the wider population. Statistical analysis is usually applied, possibly complemented by some thematic analysis, if open-ended questions are also included.

For survey research to be successful, you must be able to access an appropriate sample and generate a sufficient volume of data.

The advantages of this strategy are that it can produce a lot of data in a relatively short time, and you can replicate your data collection process on different samples or on the same sample at a later time. However, among its disadvantages are the depth in the data that can sometimes be lacking, its focus on what can be measured, the fact that it cannot reveal cause-and-effect relationships, and can only provide a snapshot at a particular time.

Experimental research This is used to investigate cause and effect relationships between factors by testing hypothesis or proving/disproving causal links.

For instance, you may run an experiment to test ways in which the use of mobile phones just before going to sleep affect people's sleeping patterns.

There are two main kinds of experiments: *laboratory experiments*, which are carried out in closed environments, such as a laboratory; and *field experiments*, which are conducted in the 'real world'. Laboratory experiments are often applied in engineering and computer science research, while field experiments are usually applied when people are involved.

Possibly the best known kind of field experiment are clinical trials, widely applied in medicine. However, field experiments are also very popular in research which investigates technology in its social context or application of use.

In experiments, first you would need to state the *hypothesis* to be tested: this is a tentative statement about the relationship between phenomena to be tested in the experiment. In the example above, a hypothesis to be tested might be that "the blue light emitted by a mobile phone reduces the production of melatonin." As melatonin is the hormone which controls a person's sleep-wake cycle, its reduction is likely to disrupt a person's sleeping pattern. After formulating the hypothesis, you would then make detailed observations and measurements of outcomes, e.g., the amount of melatonin released by the body, and any changes that take place when particular factors are introduced or removed, e.g., the length of exposure to the blue light.

In analysing your experimental data you seek to explain causal links between factors under study, looking at your observations and measurements under different experimental conditions. Statistical analysis is widely used for data analysis.

For experiments to be successful you must be able to control factors which can affect the outcome. This is possible in laboratory experiments, while the level of control in field experiments is diminished.

Experimental research has well established processes and protocols and is particularly well suited to the consideration of cause-and-effect relations. However, it has its pros and cons. Laboratory experiments are very reliable due to the high level of control, but can be very artificial, with little or no relation to a real-world context. The opposite is true for field experiments.

Design science research This seeks to generate new knowledge about a significant problem or its solution via the design of an artefact. It simultaneously generates knowledge about the problem, the artefact and the method used to design it. Artefact indicates anything made by humans, so this is a very broad definition, encompassing all that does not exist in nature.

Lots of research in Computing is an expression of design science, for instance designing new algorithms able to emulate human cognition.

More than data collection and analysis, in design science you need to follow a process of articulating the problem, and designing, constructing and evaluating a solution artefact. In doing so, you shed new insights on the problem, and argue how the solution and solution process contribute new knowledge. As a result, modelling techniques are widely applied, possibly informed by data collection techniques, like reviewing existing documents or interviews with stakeholders and experts. Prototyping is often used to produce proof-of-concept artefacts to test or demonstrate the design.

For design science research to be successful you must be able to argue that it is not 'normal' design, that is you are not simply re-implementing a solution to a well-known problem through a well-known development process.

An advantage of design science research is that it leads to tangible artefacts which fit real-world contexts, and it is particularly suited to emerging and rapidly changing technology-related fields of study, where new problems emerge all the time and known solutions are sparse or become rapidly obsolete. The latter is also a disadvantage, of course, as new solutions may be short-lived. Also, it may be difficult to generalise outcomes to different real-world settings. Depending on the nature of the artefact being designed, advanced technical skills may be required.

Case study research A case study can be used to investigate in great depth a notable instance of what is under study, in its real-world context. Case studies focus on the 'how?' and 'why?', and what you seek can span from exploring possible questions or hypotheses for follow-up research, to providing a detailed account of a phenomenon in its natural context, to explaining why certain outcomes or phenomena have occurred.

For instance, an example of case study could be a detailed investigation of the US Equifax social security breach of 2017, in which 143 million of their consumer records were stolen by hackers. This may be descriptive of the chain of events that took place or explicative of why things happened the way they did.

Case studies require you to collect data from a great variety of sources, and to focus on depth rather than breadth. Therefore, all data collection techniques which allow you to do so may be used, from interviews to observations to studying existing documents forensically. This will lead to much qualitative data, so that qualitative methods are often needed for the analysis of the evidence.

For a case study to be conducted successfully you must be able to analyse the chosen instance holistically and in its real-world context.

Case studies allow you to study a complex situation where several factors are at play, and to explore alternative meanings and explanations. However, case studies are time-consuming, difficult to perform rigorously and with limited generalisation beyond the particular instance under study.

Systemic inquiry This is used to explore complex, messy problematic situations involving multiple and often contrasting perspectives, with the aim of transforming the situation for social improvement. Systemic inquiry is based on concepts and principles of systems thinking and systems practice.

Situations for systemic inquiry can range from local to global. So, it may equally apply to exploring changes in practice within a local organisation, and to international responses to disruptive events such as climate change. Of course, it is highly unlikely that your Masters project will tackle a situation at a global scale!

In systemic inquiry, you must be able to articulate your personal stake in the situation, for example, a deeply felt interest or active involvement, rather than assuming and claiming unbiased passive 'neutral' observation. You must also keep your own journal during the course of your research inquiry, tracking changes in your own viewpoint and how you adapted your research as a result. In some sense, a systemic inquiry is a conceptualisation of your own learning system and how it adapts to change during the research. Therefore, a successful systemic inquiry should demonstrate **reflexivity** – reflecting on your own changing viewpoint and impact on the wider research situation. In fact, systemic inquiry emphasises reflexivity and building trust relationships with stakeholders, in order to make sense of complex situations of change and uncertainty.

To conduct your systemic inquiry you must articulate your research problem with reference to one or more systems which concern the problematic situation under study, and frame your research in terms of possible systems change. You must also have access to sources of different perspectives on the situation under study in order to generate your evidence. This may include both primary evidence from people involved or affected by the situation, and secondary evidence from official and grey literature• associated with the situation; your own research journal will also be a source of evidence. In terms of methods, a systemic inquiry is primarily a qualitative endeavour, so you can apply any methods that deal with qualitative data. Distinctively, you can complement them with other tools and techniques which you may have developed through your own experience and professional practice: this is known as *bricolage* research•.

- • As explained in from Section 3.3.2, grey literature refers to information produced by organisations other than commercial publishers, such as academia, government bodies, or non-publishing businesses and industries, and can include prepublication and non-peer-reviewed articles, theses and dissertations, research and committee reports, government reports, conference papers, accounts of ongoing research, etc.
- • Kincheloe, J. L. (2011). Describing the bricolage: Conceptualizing a new rigor in qualitative research. In Key works in critical pedagogy (pp. 177–189). Brill.

Systematic review research This is used to generate new insights from published work. A systematic review is a literature review linked to a clearly defined research problem or question. It uses a rigorous set of criteria to identify, select, and critically appraise relevant research from previously published studies in order to generate a scholarly synthesis of the evidence in relation to that problem or question. Such a synthesis is meant to advance a field of study.

For example, a systematic review of randomised controlled trials on the effectiveness of a specific medical treatment could be used to advance evidence-based medicine.

In a systematic review you only use secondary evidence from published studies. You must decide upfront your research problem/question and the set of criteria you will use to select, summarise and evaluate those studies. The type of analysis you will conduct will depend on the nature of the evidence you are considering and combining. In *narrative reviews*, a narrative synthesis is produced, while in *meta-analysis*, statistical techniques are used to analyse and combine results.

To be successful, a systematic review has to be both systematic and extensive, which requires the researcher to have a very good grasp of the subject area in order to establish appropriate criteria and make a novel contribution to knowledge.

Because of their explicit set of criteria, systematic reviews are considered transparent, reliable, and easy to replicate. However, they can be very time-consuming due to the large body of work to review. Also, in striving to piece together evidence from potentially very different studies, they may obscure important differences. Narrative reviews may also be subject to bias.

Ethnography This is used to study the culture of a group of people in their natural setting, and was originally developed within the discipline of anthropology.

It requires the researcher to characterise the culture being study by making detailed observations, gathering and recording detailed data, reflecting on what they have learnt, linking it to the existing literature.

The researcher is required to join the group in order to gain an insider's perspective by sharing what the group members' experience: the resulting cultural characterisation should therefore be one that the group members recognise and find familiar. This characterisation should be inclusive of various cultural facets, social and economical, rather than focusing on one specific aspect.

Ethnography can lead to rich descriptions of complex social settings. However, it is very time consuming and demanding in terms of quantity of evidence to produce. The dual observer-participant role of the researcher can also make it hard to maintain an unbiased stance. Also, while the characterisation produced may be very deep in representing a particular group culture, it may be difficult to generalise to other social groups or settings. Because of these characteristics, ethnography is seldom used at Masters research.

Action research This is used primarily to improve the researcher's own professional practice, focussing on practice change, and continuous learning and improvement via iterative 'plan-act-reflect' cycle. As such, it is often applied with the education discipline.

The researcher is an active participant in the research, rather than solely an observer, alongside other collaborating practitioners: in fact, reflection and collaboration are two key elements of this strategy.

The research outcomes should make both a contribution to knowledge *and* to practice. For instance, it is possible for new theories or methods to be outcomes of action research, which could be more generally applicable, alongside their direct implementation to improve practice within a specific professional setting.

Action research can bring immediate professional benefits, hence may have direct impact on practice. However, its application is constrained by the need to involve practitioners as collaborators in the research. Also, the researcher's own professional stake and involvement may increase the risk of personal bias distorting the research and its outcomes.

Mixed-methods research This combines quantitative and qualitative research to gain different perspectives on phenomena of interest, by exploring connections and contradictions between quantitative and qualitative data•.

For instance, in looking at acceptance of a new technology, mixed-methods research could consider both levels of adoption and demographics, and the reasons behind adoption or otherwise, possibly to inform further development of the technology.

• Mixed-method research should not be confused with *multi-method research*, which simply indicates the use of many methods, possibly all qualitative or quantitative.

Data collection and analysis will depend on the particular combination of methods selected. An important aspect is the consideration of how connections between findings are established, through comparing and contrasting data from the different methods applied. This is also referred to as *triangulation*.

The main advantage of mixed-methods research is that it can provide a more holistic understanding of the phenomena under study, and facilitate different avenues for exploration. It is particularly suited to situations in which neither quantitative nor qualitative methods alone can provide sufficient insights. However, mixed-methods make research design more complex and demanding in terms of execution time, skills required and data variety to handle and analyse.

4.2.2.1 Summary of research strategies

Table 4.6 provides a summary of research strategies introduced in this section. As you did for methods, in the next activity you should reflect on those which are most relevant to your project.

ACTIVITY: Identify candidate research strategies #101

Consider the strategies in the table and which you may be able to use in your project. For each, write down why you think they are applicable.

Guidance

In considering candidate strategies you should think about your research problem, aim and objectives. Their descriptions in the previous sections, which you may like to revisit, should be sufficient for you to carry out this activity. In Stage 3, you will return to some of those strategies, investigating them in greater depth and for their application to your project.

4.2.3 Philosophical traditions

Research methods and research strategies are strongly related to philosophical traditions•, which are world-views that inform how one should conduct research. Philosophical traditions may sound a bit esoteric, but they matter in that they make explicit assumptions behind research design choices, influencing what a researcher chooses to research and the way they may go about collecting evidence or interpreting findings.

• The term *research paradigm* is also used in the literature with a similar meaning.

Each philosophical tradition embodies a set of beliefs around three fundamental philosophical issues:

Table 4.6: Research strategies introduced in this section

Name	**Description**
Survey research	to gain insights which are valid across a target population, by collecting data from a predefined sample in a standardised and systematic way
Experimental research	to investigate cause and effect relationships between factors by testing hypothesis or proving/disproving causal links
Design science research	to generate new knowledge about a significant problem or its solution via the design of an artefact
Case study research	to investigate in great depth a notable instance of what is under study, in its real-world context
Systemic inquiry	to explore complex, messy problematic situations involving multiple and often contrasting perspectives, with the aim of transforming the situation for social improvement
Systematic review research	to generate new insights from published academic work
Ethnography	to study the culture of a group of people in their natural setting
Action research	to improve the researcher's own professional practice
Mixed-methods research	to combine quantitative and qualitative research to gain different perspectives on phenomena of interest

- The nature of our world, which relates to questions such as: What is there? What kind of categories do things belong to? How are those categories related? The part of philosophy dealing with these questions is called *ontology*. In research design, ontology determines which phenomena are there to be studied as part of the research, and underlies our experience of the world. Hence, ontology is closely connected with the kind of observations we make or evidence we gather.

- How knowledge is acquired, which relates to questions such as: What does it mean to know something? How can one claim to know something? What makes a belief justified? The part of philosophy dealing with these questions is called *epistemology*. In research design, epistemology is closely related to research methods for knowledge creation and validation.

- What are the values, especially in relation to ethics, which relates to questions such as: What is good or bad? What is right or wrong? Where do values come from? How do we justify our values? The part of philosophy dealing with these questions is called *axiology*. In research design, axiology is closely related to ethical considerations when planning or executing research.

In what follows, you will find a brief introduction to some of the better known and most often cited traditions. However, you should be aware that their definitions are not universal, their boundaries not clear-cut, and it is very rarely the case that a research design will fit a specific tradition neatly. You should, instead, consider each of these traditions as a 'wrapper' of convenience for a set of beliefs on research practice which have emerged from different disciplines and cultures, and also be aware that such beliefs have changed over time, and continue to do so.

Positivism This is perhaps the oldest tradition, with roots in the natural sciences. It sees the world as ordered and regular, with universal laws governing its functioning, and assumes it can be investigated objectively.

Specifically, positivism encompasses the following set of beliefs:

- There is a physical world which exists 'out there' and can be observed and measured. This also implies that all researchers will observe and measure the same phenomena in exactly the same way.
- Through observations and measurements, the researcher can produce models of how the world functions, which are 'true' explanations of the aspects of the world under study. This also implies that only one true explanation exists.
- Truths about the world are perfectively objective and independent of the researcher's values or beliefs. This means that all researchers will arrive at the same truth.
- Research is based on the empirical testing of theories or hypothesis, leading to either confirmation or rejection (a.k.a. 'refutation'). As there can only be one truth, either the theory or hypothesis tested is that truth, in which case all subsequent tests will confirm it, or it is not that truth, in which case at some point a test will reject it. The term refutation is used to indicate that a truth, albeit universal, is always tentative: it will be valid until somebody comes up with a test to reject it.
- Research seeks universal laws and irrefutable facts. This means that re-testing such laws or facts should always confirm them, if they are indeed truths.

For instance, starting with the hypothesis that 'all swans are white', a positivist researcher would set as a test to look for swans and observe their colour. If all swans are seen white, then the hypothesis would be confirmed, if not, then it would be rejected. If the hypothesis is confirmed, then the truth that 'all swans are white' is added to the body of knowledge and will remain so until another test will lead to a rejection — indeed that's what English people believed until they first spotted a black swan in Australia!

Activity: Summarising positivism #102

Given these beliefs, what does positivism assume of the nature of the world (ontology), how knowledge is acquired (epistemology), and what is of value in research (axiology)?

Discussion

Ontology: the world exists independently of the researcher, and can be observed and measured objectively.
Epistemology: there are universal truths, which can be acquired by empirical testing of theories and hypothesis. Tests can lead to either confirmation or rejection. Confirmed theories and hypothesis are added to the body of knowledge.
Axiology: positivism values objectivity above all, and dismisses individual's subjective views or experience.

Positivism has attracted criticism particularly from the social sciences, which consider some of its beliefs untenable, primarily that researchers are totally objective and not influenced by their own values and beliefs, or that knowledge is made of perfectly generalisable truths. This has led to other traditions, which we consider next.

Interpretivism/Constructivism With its roots in the social sciences, interpretivism seeks to identify, explore and explain phenomena in social settings, acknowledging that people perceive the world in different ways, mediated by their beliefs, attitudes and values.

Specifically, interpretivism encompasses the following set of beliefs:

- Different individuals, groups or cultures perceive the world differently and what people consider real is a construction of their mind — leading to the term *constructivism* also being used.

- The researcher is not neutral, and their perceptions of the world are influenced by their values or beliefs. This implies that different researchers can perceive the same phenomena in different ways, and there is no single truth or single explanation of the world.
- As there are different perceptions of reality, communication among groups of individuals is the only way of constructing some shared meaning or understanding, and this will change over time.
- As researchers are influenced by their own values and beliefs, they will arrive at different interpretations as a result of their observations. The strengths of their interpretations will depend on the strengths of the evidence and arguments their interpretations are based upon.
- Research is based on studying people and other phenomena in their 'natural' context. Such a context can be unique, so that interpretations based on observations may not be generalisable to other contexts.

Activity: Summarising interpretivism/constructivism #103

Given these beliefs, what does interpretivism assume of the nature of the world (ontology), how knowledge is acquired (epistemology), and what is of value in research (axiology)?

Discussion

Ontology: the researcher acknowledges that they perceive the world based on their belief, values and culture.
Epistemology: the researcher will offer interpretations based on observations in a social context. Different researchers may offer different interpretations. All knowledge is constructed and shared understanding is reached through communication. Interpretations in one context may not be generalisable to other social contexts.
Axiology: The researcher's values and beliefs matter. The strength of their interpretations will depend on the strengths of the evidence and arguments in support.

Critical theory Perhaps not as well established as the previous traditions, critical theory originated in the fields of sociology, philosophy and political theory.

Like interpretivism, it assumes multiple interpretations of reality in social contexts. However, it goes a step further by asserting that reality is shaped by those who are powerful, who legitimate particular ways of perceiving the world: 'truth' is inherently political, defined by those in charge to the disadvantage of many, and challenged by those who wish to promote equality.

As a result, critical researchers seek to challenge the status quo and perceive research as transformative at a social level, confronting ideology and trying to discover and challenge the mechanisms through which exploitation and disadvantage are perpetuated in society.

Activity: Summarising critical theory #104

Given these characteristics, what does critical theory assume of the nature of the world (ontology) , how knowledge is acquired (epistemology), and what is of value in research (axiology)?

Discussion

Ontology: reality is the product of power relations, shaped by those who are powerful and there are disadvantages for many.
Epistemology: the researcher confronts ideology and tries to discover the truth of exploitation and the mechanisms by which disadvantage is perpetuated to challenge the status quo and promote social justice and equality.
Axiology: The researcher has the moral responsibility to make things better in society.

Indigenous The traditions described so far are attracting increasing criticisms in that they are seen as Western-European centric and often imposed on other indigenous cultures as a result of colonialism.

In counterposition, an indigenous research tradition has emerged with a social and political agenda of decolonising indigenous societies. It emphasises the connection between the researcher and their own culture, in the sense that cultural practices and forms of expressions should be reflected in the way the research is conducted, including language, metaphors, oral traditions and knowledge systems. It also advocates an holistic approach which strives to reach a balance between different areas of life, integrating intellectual, social, political, economic, psychological and spiritual dimensions.

Activity: Summarising indigenous traditions #105

Given these characteristics, what does the indigenous tradition assume of the nature of the world (ontology), how knowledge is acquired (epistemology), and what is of value in research (axiology)?

Discussion

Ontology: reality is determined by the indigenous culture, to which the researcher is strongly connected.
Epistemology: this is determined by indigenous knowledge systems, cultural practices and forms of expressions.
Axiology: The researcher has a social and political agenda of decolonisation of indigenous societies.

4.2.4 Understanding research methods and strategies in articles you have reviewed

To ground what you have learnt so far on research methods and strategies, you should look back at some at the articles you have reviewed to see how they describe and use them. This may also give you some ideas on how to apply them within your own project. You should be aware, however, that terminology used in the literature may different from that of this handbook•.

• We have already noted how some terms are used differently by different authors.

Considering research methods and strategies in published work

Looking back to our curriculum analytics example, one of the papers we reviewed was:

> *Gray, G., Schalk, A. E., Cooke, G., Murnion, P., Rooney, P., & O'Rourke, K. C. (2022). Stakeholders' insights on learning analytics: Perspectives of students and staff. Computers & Education, 187, 104550.*

In this paper there is a 'Methodology' section which describes the study research design in detail. Specifically, it states that a mixed-methods strategy was used to collect and analyse qualitative and quantitative data. For data collection both questionnaires and a focus group were. For qualitative data analysis, thematic analysis was applied; for quantitative data analysis, tables and charts were used, including some calculation of differences in scores obtained from questionnaire answers.

The paper usefully includes some descriptions of the specific steps the researchers took to recruit participants and analyse the data, something that could be replicated in new studies.
We found differences in terminology:

- mixed-method 'approach' is used for what we call mixed-methods strategy, and
- 'survey' is used to mean a questionnaire: this is actually rather common in the literature, where the term survey is found to mean both.

Activity: Considering research methods and strategies in articles you have reviewed #106

Go back to two or three articles you have reviewed, perhaps those you have found most interesting or closest to the research you intend to do.
Look for research methods and strategies they use, and consider how these are presented and applied. Try to establish links to what you have learnt so far, including noting any differences in the terminology used. If appropriate, write down specific points which may help you apply them in your own project.

Guidance

Often articles include a 'Methodology' or 'Methods' section where research methods and strategies are discussed: that was the case in our example. That's the section you should start from. It may be, however, that more relevant content is described elsewhere, so also look for sections that summarise data or evidence collected and analysed.
You may want to skim through few articles before deciding which ones to consider in detail.

4.3 Reflecting and reporting in Stage 2

Well, you're reached the end of stage 2. You're really speeding along now.

Before carrying on, it's time to reflect and write up your Stage 2 report.

Activity: Reflecting on your learning and practice #107

As you did at the end of Stage 1, in this activity you are asked to stand back and reflect deeply on what you have leant and done, the wider context of your work and your own attitude to it. Specifically, you are asked to think deeply about each of the following:

- your study this far
- the way you work. Are you tidy and systematic, or let things happen organically? For instance, how does
- the context of your research
- your feelings about your project

You should also think of any significant changes with respect to your reflection in Stage 1

Guidance

You should refer back to the guidance to this activity in Stage 1, Section 3.7.

Your end-of-Stage 2 report will help you consolidate your work so far, and develop your dissertation incrementally. Its recommended structure and content is indicated in Table 4.8, which builds one that of your Stage 1 report.

Activity: Writing and assessing your report for Stage 2 #108

Using your word processor of choice, revise and expand your Stage 1 report by applying the structure and guidance in Table 4.8.
Assess your report by applying the criteria in Table 4.9. Revise and iterate until you are ready to move on.

Guidance

In completing your report, you should make good use of notes and summaries your wrote as part of the activities in this chapter. In evaluating your report, for each criteria, you should consider the related

Table 4.8: Report structure and guidance guidance

Report template	**Guidance**
Proposed title	Your title should continue to capture succinctly your research problem and aim. *It is likely this is the same as, or very similar to, that in Stage 1*
Sect 1 - Introduction 1.1 Background to the research 1.2 Justification for the research 1.3 Fitness of the research	This section should continue to provide an introduction to your research topic in its wider context (as background) and your justification of why the research is worth pursuing. Its purpose is to introduce and justify your intended research in overview, before entering the detailed work of the subsequent sections. It should be well argued and supported by appropriate citations. In this section, you should also argue how the research fits within the scope of your qualification, and meets any other personal, professional or organisational criteria. *You may review this section from Stage 1 to reflect your growing understanding of the topic in context derived from your literature review.*
Sect 2 - Literature review 2.1 Introduction 2.2 Main body 2.3 Critical summary	*This section should consist of your current literature review, developed in this stage by following the advice in Section 4.1.* At this point, it should be a substantial, almost complete, draft, well structured and articulated through solid academic arguments. It should demonstrate your understanding of the main literature which relates to your research problem, clearly identifying the knowledge gap your project will address.
Sect 3 - Research definition 3.1 Problem statement 3.2 Aim and objectives 3.3 Knowledge contribution	You should continue to ensure that your research problem is well articulated and appropriate for your course and your personal and professional circumstances, that your aim and objectives are consistent with research problem, and that the intended knowledge contribution of your research is clearly articulated. *You may revise this section from Stage 1 in view of your increasing understanding from your literature review.*
Sect 4 - Research design 4.1 Evidence and data 4.2 Research strategies and methods 4.3 Ethical, legal and EDI considerations	*This section should extend your Stage 1 work with your considerations of candidate research strategies and methods for your project, based on the guidance in Section 4.2.*
Sect 5 - Work planning and risk assessment 5.1 Statement of progress 5.2 Key priorities in follow-up stage 5.3 Risk assessment	In this section you should reflect on the progress you have made in Stage 2 and establish your priorities for the next stage. You should also review your risk assessment as appropriate.
References	You should keep your growing references in good order and ensure you apply the required bibliographical style consistently. Ideally, you should use a BMT to generate and integrate your references within your report
Appendix - Work schedule	You should include your revised work plan as an appendix
Appendix - Risk assessment table	You should include your updated risk table as an appendix

Table 4.9: Criteria for reviewing your research proposal

Criteria	Prompts
Completeness	Are all sections included and their content complete? What is missing?
Academic writing	Have you applied good academic writing practices throughout? Which main issues do you still have to address?
Logical structure and flow	Have you structured your writing appropriately to ensure a logical flow of arguments? Which restructuring may be needed?
Supporting evidence	Are your key arguments supported by appropriate references or other evidence? Which further evidence is needed?
Citation and reference style	Do all your citations and references comply with the required bibliographical style?
Avoiding plagiarism	Have you acknowledged the work of others and distinguished it from your own appropriately?
Grammar and spelling	Have you proof-read your report carefully to remove all typos and grammatical errors?

prompts, write down any further work needed for your next stage, and update your work plan and risk assessment table accordingly.

4.4 Takeaways

- the fundamental skills for synthesising the literature are critical thinking and writing, and the ability to establish connections between ideas and arguments
- academic writing requires you to observed a number of practices, which ensure your writing is clear, precise, logical and well-structured
- an academic argument is a structured argument whose key elements help you ensure your claims are carefully reasoned and supported
- your theme summarised from Stage 1 are your starting point when writing your literature review
- your literature review will be adequate if it contextualise and justify your research in the context of related academic literature, and is well structured and logically argued

- the building blocks of research design are research methods and strategies, together with their underlying philosophical traditions
- several research methods exist to help you collect and analyse data and evidence, or model real-world scenarios or systems and artefacts
- several research strategies exist to help you meet your research objectives
- philosophical traditions capture different ways of thinking about knowledge generation and values in research
- knowing the building blocks of research design helps you understand how research reported in academic articles was conducted
- the template provided can help you structure your Stage 2 report

Chapter 5

Stage 3: Developing your research design

By now you will have some mastery of the techniques and tools that you need to *do* research at masters level. You may also have ideas about what you still need to do in the next step•.

• If not, don't worry – we've got you covered with this chapter!

With the skills you have so far gained, you're developing into an independent researcher• and you may feel that this book holds nothing more for you.

• Being an independent researcher isn't one of the examined outcomes of masters research, but if you're feeling confident in your research that's a good thing.

Stay with us a little longer though: the next sections aren't as long as those that you've studied already – you'll be doing more yourself, honing the skills you've picked up as you go along – but they might help to keep you systematic and on the path to submission.

You won't be surprised to know that stage 3 comes next; there's another research increment coming.

5.1 Introducing stage 3

LR: update at the end

LR: to check all activity titles at the end

In Stage 3 you will focus on adding detail to both your aim and objectives and your research design. Stage 3 assumes that you have completed your Stage 2 work, and possibly discussed it with your supervisor•, particularly your research design choices.

• If your proposal still requires some 'remedial' work to fully satisfy your course requirements then you should carry that out before moving on.

With reference to our 5-stage framework, the activities which are in focus in Stage 3 are recalled in Table 5.1, which also provides some guidelines for your interaction with your supervisor during this stage.

Table 5.1: Stage 3 activities Update as necessary)

Research activity	**Effort within stage**	**Suggested supervisor focus**
Identifying the research problem		
Adjust, if needed	2%	
Reviewing the literature		
Adjust, if needed	3%	
Setting research aim and objectives		
finalise aim and objectives, and define tasks and deliverables	10%	Suitability of tasks and deliverables from objectives
Choosing the research design		
Complete research design, with detailed consideration of data and evidence, research strategy, research methods and procedures	20%	Suitability of research procedures
Gathering and analysing evidence		
Conduct pilot work to test aspects of your research design	35%	Scope of your pilot work
Interpreting and evaluating findings		
n/a	0%	
Reporting, critical reflection and conclusions		
Assess research progress and write up Stage 3 report	25%	Any further improvements required
Work planning and risk management		
At stage start, review work from previous stage and project risk; adjust plan as needed If you have received feedback from supervisor on your previous stage work, adjust plan to include any revision recommended	5%	Any major adjustment required

Activity: Understanding the effort needed in this stage #109

Consider Table 5.1 carefully, taking notice of the entries in the 'Effort within stage' column. Write down the most time-consuming activities in this stage and what is expected under each.

Discussion

Developing your research design further and conducting your pilot work will constitute your major effort in this stage (55% of the study time in total): your pilot work will be an initial test of some aspects of your research design, including a proof-of-concept application of some of your chosen methods.

5.2 Research design foundation

To make a contribution to knowledge we do research. Practically, to do research, we combine a number of research tasks into a framework. Designing such framework is what we term research design. The framework will depend on the research area, the type of knowledge contribution you wish to make, your mindset as a researcher, and the opportunities and difficulties you may face along the way.

A research framework has many levels. At its foundations are its "ontology", "epistemology", and "methodology":

Ontology is the philosophical study of the nature of existence and addresses the question: "What is the reality that I will research?". Practically, ontology translates to determining what *phenomena* exist in the context of your research, the *relations* that exist between them and how they group together into *categories*.

Epistemology is the philosophical study of knowledge and addresses the question: "How is knowledge generated and from what sources?". Practically, epistemology is about finding out "What people know?", "What does it mean to say that people know something?", and "How do people know that they know?".

Methodology is the system of principles and methods by which you conduct research, that is, investigate, measure, and analyse your research's aim and objectives. Methodology operationalises the "how" question of knowledge generation, so it is about devising concrete strategies to answer "How will I make my contribution to knowledge?".

As you might have guessed, given that the goal of research is to make a contribution to knowledge, epistemology and ontology are incredibly important in defining what knowledge is in any particular research context and what, in that context, can be known about. Once this choice is made, an appropriate methodology can be devised: hence, methodology depends on choices made in relation to ontology and epistemology.

Fortunately, many others have thought very deeply about ontology and epistemology• and, in most areas and for the vast majority of masters-level research, their thinking will suffice. If not, we'd be left in a situation in which even an ostensibly simply statement like "That hat is blue" becomes in need of complex debate (**steup2020epistemology**).

• For instance, if you're interested, you can find a fuller discussion of Ontology and Epistemology in the Stanford Encyclopedia of Philosophy.

Methodology, on the other hand, is something we will spend some time on, particularly how individual research methods combine to produce knowledge contributions through research strategies.

You should be aware that 'methodology' has many meanings in the literature, including the study of research methods, which questions the assumptions that underpin their creation and application. Wikipedia says•:

• It could almost be seen as a warning!

Quote

[...] A few theorists reject methodology as a discipline in general. For example, some argue that it is useless since methods should be used rather than studied. Others hold that it is harmful because it restricts the freedom and creativity of researchers. Methodologists often respond to these objections by claiming that a good methodology helps researchers arrive at reliable theories in an efficient way. The choice of method often matters since the same factual material can lead to different conclusions depending on one's method. Interest in methodology has risen in the 20th century due to the increased importance of interdisciplinary work and the obstacles hindering efficient cooperation.

These are not unimportant issues to consider. However, and as for ontology and epistemology, we will leave their discussion to others, content to stand on those giants' shoulders – we take an unapologetically practical approach to research methods, limiting our discussions to what, we feel, are their important characteristics for practice. This doesn't ignore philosophical issues, however: where there are important philosophical considerations to be considered, we address them. This includes questions as to how to choose a particular research method, and what an experienced reader will expect to be answered by it. You can then craft your dissertation to meet those expectations.

5.3 Researcher mindsets

Depending on your background, you may have begun your research studies with a particular mindset – that of a scientist, for instance, or as someone embedded within an organisation. This mindset will flavour your approach to research, but it shouldn't constrain it – there are many options for research and the right one for you might be outside of your current understanding.

Over time, researchers in different communities and disciplines have developed differing mindsets, which are known in the literature as research paradigms. You can think of a research paradigm as a philosophical way of thinking, a set of shared beliefs which shape a worldview.

[ADAPTED from https://proofed.com/writing-tips/the-four-types-of-research-paradigms-a-comprehensive-guide/]

A.k.a. philosophical traditions.

We briefly outline the prevalent ones in this section — there is a lot, lot more to be known around this topic, and this introduction only scratches the surface! We provide some references for you to start your own investigation into this fascinating and complex topic, should you wish to.

Each paradigm comes with its own ontological, epistemological and methodological choices. It is important for you to be aware of their existence as this may help you guide your research design choices, even if in practice you will mainly focus on methodological considerations.

5.3.1 Positivist and post-positivism

The Positivist research paradigm assumes that there is a single, objective reality that can be accurately known, described and explained.

Positivism contributes knowledge as explanations of this reality, constructed from hypotheses which are confirmed through observations and measurements, hence becoming universal laws or facts. As an example, think of Newton's explanation of the action of forces on matter that is encoded as his Three Laws of Motion: these are meant as universal objective truths which apply to the natural world forever.

In assuming a single, objectively knowable reality, positivism removes the researcher as a variable in the research equation: research is necessarily limited to data generation, analysis and interpretation from an objective viewpoint as the basis of knowledge. As such, it befits research where a single objective reality can be assumed, such as the natural sciences, the physical sciences, or whenever very large sample sizes can be used to infer characteristics of a population. It leads the researcher towards quantitative methods.

Positivism emerged in the late eighteenth and early nineteenth centuries in Western societies, fuelled by a growing optimism on the role and power of the natural sciences – as witnessed, for instance, by the universal acceptance of Newton's Three Laws, and their explanatory and predictive capabilities backed up by empirical observations. So much so, that it was the predominant paradigm for almost a century and a bulkhead against a growing number of worrying observations, including the movements of the planet Mercury•, which didn't reinforce – indeed appear to contradict – Newton's Laws. How could an established truth lead that way? Indeed, Einstein's insight into the intimate connection between space and time inspired a substantial move away from the established Newtonian "laws" and "facts", which were neither any longer **lakatos2014falsificationlaka**.

• See **enwiki:1193607156**, for instance.

The need to rethink positivist objective truths was something of a crisis in the positivist movement (see, for instance, **kuhn2012structure**), leading to post-positivism• which introduced the idea of falsification: any posited theory must make predictions which are testable, the currency of a theory being determined by whether or not it had yet been proven false•.

• Not the most creative name, you must admit.

• Note that falsifiable theories that have been tested and failed can still be useful, perhaps within a restricted context. For instance, Newton's Laws of motion provide a very good approximation at low energies.

So, both positivism and post-positivism accrete knowledge by formulating generalisations and cause-effect linkages, based on objective, verifiable observations and measurements, and expressed as theories and laws. However, post-positivism acknowledges some of the limitations in such observations and measurement, so that a theory or law will only remain true for as long as it is not falsified by new observations or measurements. There is therefore a shift from certainty (positivism) to probability (post-positivism), with post-positivist researchers encouraged to take multiple measurements and observations, including triangulating their data, to arrive at an objective truth. Thus you might take a post-positivist approach to establishing the linkage between a drug and the alleviation of symptoms: once a generalisation or cause-effect linkage is established, it applies for as long as it remains un-falsified.

Both positivism and post-positivism assume an objective reality and do not admit that the researcher's own mindset and values may influence true knowledge: in being objective and verifiable, different researchers must necessarily arrive at the same truth, as long as the research process is reliable•, that is different researchers can follow the same process to arrive at the same conclusions.

• We will discuss reliability in the next section

This denial of the researcher's influence on the research is often levelled as a criticism of these paradigms, particularly by social scientists, and has led to new paradigms.

5.3.2 Anti-positivist (interpretivism)

The shift from positivism to post-positivism still preserves the absolute objectivity of reality. In contrast, anti-positivism asserts that different people experience and understand reality in different ways: while there may be only "one" reality, everyone interprets it according to their own views. Simply put, this might mean that generalisations and even cause-effect relationships are subject to individual experience. Think of the way that people interpret the (single) power structure within your organisation: typically, different people will describe it in different ways, as it applies to them.

Explaining the name, anti-positivists believe that all research is influenced and shaped by researchers' worldviews, leading to differing interpretations of the same reality. Again, think of the questions you might ask of people within an organisation that leads them to describe the power structure. Different questions can lead to different descriptions.

As a result, anti-positivists gravitate towards qualitative research methods and techniques to understand the different perspectives, placed in an explicative context of their own perspective.

In moving away from objective knowledge, however, anti-positivism raises questions of research validity•, that is of how trustworthy and generalisable knowledge generated as subjective interpretation might be.

• We will discuss validity in the next section.

5.3.3 Constructivism

The Constructivist research paradigm goes further and asserts that reality is a construct of our minds and so is absolutely subjective. Constructivists believe that all knowledge comes from our experiences and reflections on those experiences as formed in our mind. A distinction is also made between reality which is individually vs socially constructed, the latter being the result of social interaction within a specific cultural or historical context.

Due to its focus on experiences and subjectivity, this paradigm is also mostly associated with qualitative research approaches. The researcher focuses on participants' experiences, including their own, constructing knowledge through understanding, sense making and reconstruction.

Establishing research validity is an even more prominent issue with this paradigm.

5.3.4 Critical Theory

The Critical Theory research paradigm originated in the fields of sociology, philosophy and political theory, and asserts that social science can never be 100% objective or value-free. Therefore, like interpretivism, it assumes multiple interpretations of reality in social contexts. However, it goes a step further by asserting that reality is shaped by those who are powerful, who legitimate particular ways of perceiving the world: 'truth' is inherently political, defined by those in charge to the disadvantage of many, and challenged by those who wish to promote equality. As a result, critical researchers seek to challenge the status quo and perceive research as transformative at a social level•, confronting ideology and trying to discover and challenge the mechanisms through which exploitation and disadvantage are perpetuated in society.

• As a result, this paradigm is also called 'transformative' in the literature.

This paradigm focuses on enacting social change through scientific investigation. Critical theorists question knowledge and procedures, and acknowledge how power is used (or abused) in the phenomena or systems they're investigating. Researchers using this paradigm offer historically situated insights into society and its power structures as the basis of knowledge, approaching knowledge contribution through inquiries which are both critical and transformative, aimed at emancipation and restitution to address historical injustices. The researcher values are acknowledged and welcomed as a formative influence on the research.

Rather than reliability and validity, the quality of critical theory research is judged in terms of how well it is situated in its historical context, and the extent it acts as a stimulus for transformation, and the diminuition of ignorance and misconceptions

5.3.5 Indigenous

The paradigms just described have attracted criticisms in that they are seen as Western-European centric, imposed on indigenous cultures as a result of colonialism, hence marginalising indigenous traditions.

In counterposition, an Indigenous paradigm is emerging with the aim of decolonising research. This paradigm emphasises the connection between people, their culture, and the spiritual and natural worlds, valuing knowledge which is local to communities, and holistic in connecting all beings with nature and spirituality.

As a result, indigenous cultural practices and forms of expressions should be reflected in the way the research is conducted, including language, metaphors, oral traditions and indigenous knowledge systems.

From an ontological perspective, therefore, both physical and spiritual realities and their connection matter, alongside reciprocal relations among all living beings.

From an epistemological perspective, knowledge is relational, based on the connection between natural and spiritual worlds, and its generation is a fluid process based on oral traditions, such as storytelling, and inward exploration of personal experience in context. The codification of such knowledge is through community praxis, in which the 'Elders' are often seen as key actors in the epistemological process.

Finally, indigenous methodology is one that favours the collective involvement of indigenous people in developing, approving and implementing the research, leading to knowledge of practical use.

It is important to note that although we have tried to characterise this paradigm in relation to ontology, epistemology and methodology, some scholars reject any such classification, regarding this too as a form of colonialism imposed by a Western view of research paradigms. If you are interested in going more deeply into this debate, you could start from

add references: Hart, M. A. (2010). Indigenous Worldviews, Knowledge, and Research: The Development of an Indigenous Research Paradigm. Journal of Indigenous Voices in Social Work, 1(1).

5.3.6 What's your mindset?

Table 5.2 summarises the main paradigms we have discussed based on their ontological, epistemological and methodological standpoints. From a methodological perspective, we have indicated the main tendency of the paradigm, although the quantitative vs qualitative distinction is not as stark in practice, and a mix of methods often applies.

Table 5.2: Summarising research paradigms

	Positivism	**Post-positivism**	**Anti-positivism (Interpretivism)**	**Constructivism**	**Critical theory**	**Indigenous**
Ontology	one discoverable external reality	one discoverable external reality that can only be known imperfectly	one external reality which is interpreted subjectively	reality as the construct of one's mind	one external reality determined by socio, political and economic power factors	physical and spiritual realities and their connection; reciprocal relations between all living beings
Epistemology	objective laws and theories that can be confirmed empirically	objective laws and theories that can be falsified empirically	subjective interpretations	subjective constructions	social and historical constructions, acknowledging issues of power and social injustice	relational knowledge, indigenous knowledge systems based on oral traditions and inward exploration of experience
Researcher's role	objective, neutral	objective, neutral, aware of cognitive limitations	subjective, bringing own values, experience and bias	subjective, bringing own values, experience and bias	subjective, aware of own social position	researcher as indigenous participant in collective research
Main methods	quantitative	quantitative, with triangulation	qualitative	qualitative	qualitative	qualitative

Your own mindset may lead you to gravitate towards one or more of these paradigms, or even somewhere in between. The next activity should help you reflect on this point.

Activity: What kind of thinker am I? #110

Consider the following question and describe how you would go about answering it:
"What is the colour of swans?"
Then compare your approach to each of the paradigm. Which one is it closer to and why?

Guidance

If you can think of more than one way to approach the question, then describe and reflect on each of them in relation to the paradigms.

Discussion

I can think of a couple of ways I could tackle this question.
The first would be to start by observing the swans that live on the lake near my home, and record my observations. From that I would put forward an initial hypothesis, say that all 'swans are white,' as those are the only ones I can observe locally. I would then look online for images of swans from around the world to see if they match my observations. Having found images of black swans alongside white ones, I would then revise my hypothesis to "All swans are either white or black." This process would continue until I'm satisfied there is no further contradictory evidence I can find, hence conclude that in all probability swans are either white or black. I would have to admit that there may be swans of other colours I've yet to come across, so the statement is open to future challenges. I would also need to be convinced that I'm a neutral observer, able to determine the colour of a swan correctly and reliably. This approach closely aligns with the post-positivist paradigm, specifically: I've made observations, triangulated my direct swan observations with the review of online swan images, and formulated, rejected and then reformulated hypotheses as part of my enquiry process.
My second approach would be to ask other people. For instance, I could set up a crowd-sourcing survey inviting participants to answer the question. By analysing their answers I could then decide if there is enough consensus on the colour of swans: for instance, most participants may have identified swans to be either white or black, although some may have provided more nuanced answers, like yellowish or other. From my analysis I would draw my conclusions which may or may not be the same as in my previous approach. In this case, I would have to worry about who participated in my research. Were there enough participants from around the world to provide sufficient and diverse evidence? To which extent may their colour perception differ? What else could I do to check the validity of the outcome?

This approach aligns with the interpretivist paradigm: I have to accept that, like me, each observer in my study will make their own interpretation of what the colour of a swan is, so that I would have to account for this in my conclusions.

5.4 Research strategies

Each research discipline and area has its more-or-less well-worn paths to a successful knowledge contribution. In Stage 3, you're now at the point where you'll join researchers in your chosen area on one of those paths: as you get deeper and deeper into your research, the steps you'll take will become more and more specialised.

To identify and take such steps, you will need to devise a research *strategy*, by which we man a collection of recipes for doing research that will, if followed accurately, lead to a contribution to knowledge *even in the presence of uncertainty*. When devised, a research strategy consists of research tasks that interact in more or less complex ways, but which are sufficiently detailed that the researcher knows what to do next, even if that means making a choice between two or more next steps.

There's good news and bad news in choosing a research strategy:

- The bad news is that there are many possible choices you could make at any point.
- The good news is that, for your particular area in Masters research, there will likely be only a small subset that you need to know about.

To help you in your choice, our approach in this chapter is unapologetically practical. In Section 5.6, we will layout the options that you have together with reasons for choosing them and reasons for not choosing them. Each comes with a list of key evaluation questions the answers to which you will be expected to present as part of your dissertation. Amongst other things, the answers you give will justify how and why your work makes a contribution to knowledge. These evaluative questions in turn give you targets to aim for throughout your research, you will need to answer each of them – they will be the driver for your research and your writing up.

Before we look at research strategy in detail, we are going to consider the importance of such choice in terms your ability to defend your claim that your research has contributed new knowledge.

5.5 Defending your claim of new knowledge

Being able to assert that you have made a contribution to knowledge is the point of structuring your research through a well thought-out research strategy – hence, the importance of methodology in research.

Choosing a good strategy is only the starting point, however. Having made your claim to knowledge at the end of your project, you still need to defend it in your dissertation. That means considering, essentially, everything that could have gone wrong – any weakness – with the execution of your research strategy, and explaining how you've dealt with it.

Introducing potential research weaknesses upfront and ways to deal with them is the purpose of this section: with this information, you can then be more mindful in the choice and execution of your own research strategy.

Figure 5.1 illustrates the point we are making. At its core is your claimed knowledge contribution at end of your project. Its defence is what you need to argue in your dissertation. Such a defence has to withstand external scrutiny, say that of your examiner or the wider community of scholars, researchers or practitioners your work is intended for. You claim to knowledge is subject to a number of weaknesses (four main types are considered in this section, illustrated as potential 'cracks' in your defence), and should you recognise any of them in your research, then your defence should explain how they've been dealt with (illustrated as bandaids over the cracks). The kind of 'bandaid' will depend on what you decided to do, one of addressing, avoiding, deferring or ignoring the weakness. If you choose to address it, then some specific kinds of bandaid are available to you: the ones we consider in this section are triangulation, reflexivity and critical review.

5.5.1 Weaknesses and ways to deal with them

We can class weaknesses in claimed knowledge contribution (see figure 5.1) as follows:

- validity weaknesses, i.e., the claim you have made to new knowledge isn't sufficiently credible, trustworthy, or accurate to be considered knowledge, or can't be generalised or transferred beyond your study

- reliability weaknesses, i.e., the procedures that you have used to establish your claim of new knowledge are not dependable, cannot be replicated under the same conditions or are not sufficiently repeatable in other contexts, or the descriptions and interpretations provided are incoherent or inadequate

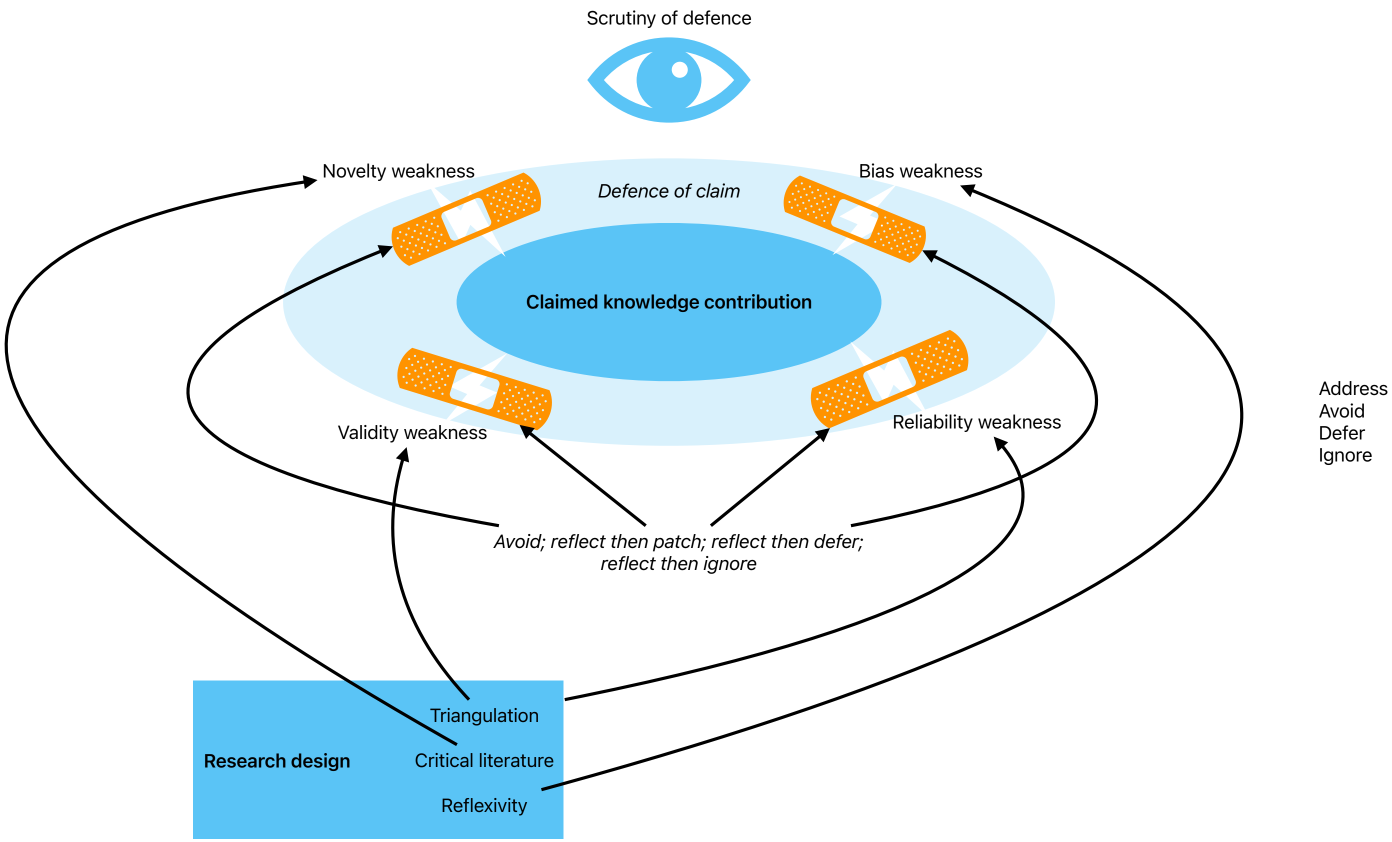

Figure 5.1: Research vulnerabilities — to edit and explain in text

- bias weaknesses, i.e., the claim you have made to new knowledge has been affected by your implicit or explicit cognitive biases, making the new knowledge invalid

- novelty weaknesses, i.e., the hole in the literature that you claimed existed doesn't actually exist. If there is no hole, then you cannot have contributed new knowledge — perhaps you missed some key papers in your literature survey or, perhaps in the time that you've taken to complete your research, someone else has made a similar contribution to knowledge as that you claim. Alternatively, while a hole may exist, the novelty of your claim may be in doubt — perhaps your research was not able to achieve all that you were hoping for.

There are, of course, connections between these types of weakness. In particular, if your research methods are not reliable, then any resulting claim to knowledge is unlikely to be valid. For instance, if the scale you use to measure the weight of an object returns different values every time (it's unreliable), then you can't draw a valid conclusion on the weight of that object. However, reliability is not sufficient for validity. For example, your scale may reliably return the same weight every time, but may overestimates it: in this case, while your scale is reliable, it is inaccurate, so that you still can't draw a valid conclusion on the weight of the object (unless you know precisely by how much your scale overestimates weights). Bias also affects validity. For instance, you may have a preconception of what the outcome of your research should be, so you discard any evidence to the contrary and only retain evidence that confirms your bias. In this case, your conclusions are untrustworthy, hence invalid. It is therefore essential to consider the weaknesses that may affect your research and take action to ensure they will not impact the validity of your claim.

As you will see in the next section, different research strategies are affected differently by these weaknesses. For instance, research based on quantitative objective measurements will focus more on ensuring reliability than research based on subjective interpretations of qualitative information, where the researcher's bias is more likely to have a negative impact.

In general, the possible actions you can take to deal with potential weaknesses fall into three options•:

• There is actually a fourth way, which is to be aware of the weakness but to ignore it. We do not recommend this as your examiner of your dissertation is likely to have detailed understanding of the research strategy you have chosen, including its potential weaknesses, and is likely to pick any methodological omissions up.

- avoid the weakness, i.e., choose a research strategy which is not troubled by the weakness. Part of the justification for the choice of research strategy can then be a discussion, if necessary, that the weakness doesn't arise.

- address the weakness, i.e., be aware of the weakness during the research and put in place further strengthening research. This might be, for instance, a second of further iteration of the research strategy which addresses discovered weaknesses in earlier research. This would be reported as part of the research design.

- acknowledge and defer•, most usually at the end of the research period when the research is complete, i.e., write a reflection on the effect the weakness had on the outcomes and commit to addressing that weakness in future research. This would be reported as part of your "Discussion" and "Conclusion and future work" chapters.

• Although it may seem to have similar outcomes, this is a much better strategy than simply ignoring the weakness as, although you don't address it, you make the examiner aware that you are aware of it. It can also give you a very neat way of filling out your future work.

If you can't avoid a weakness and you can't defer it, you have to address it. Addressing it means that your examiner will have their questions answered about the weaknesses they know occur in the type of research you're doing. Their evaluation will be through the questions they ask of your research and you must be prepared to answer them.

5.5.2 Where to defend your claim

In your defence of claimed knowledge contribution, you should consider all potential weaknesses in turn – ignoring them leaves yourself open to a negative outcome of expert scrutiny. For each, you should make arguments as to why your claim doesn't suffer from it, or if it does to some extent, that you have dealt with it in a way that ensures there is still a contribution to knowledge arising from your research.

Typically, there are two places at which weaknesses in your claimed knowledge contribution should be discussed:

- in your dissertation, in all cases
- in any *viva voce* associated with your research course•

• As not all masters research have an associated *viva voce*, weaknesses should always be addressed in the dissertation itself. Even if your course does have a *viva voce*, it can be a nerve-racking experience to be confronted by an examiner asking questions to which you have no answer because you haven't thought about it!

In general, an examiner will explore such weaknesses through a number of questions they ask of your dissertation. For each research strategy, many of these questions• can be predicted with reference to the types of weaknesses we have discussed above. Somewhere in your dissertation, then, you will need to expose your research strategy weaknesses and argue how your research has addressed them.

• If not all; although examiners will have their own way of asking them!

Here is an example paragraph taken from an actual dissertation (**miles2019dispelling**) with our commentary on specific points to the right, in the margin:

> My observational study focuses solely• on the external elements of the embouchure and what can be seen in real time with the human eye•, through the recording of video images. My analysis, and the conclusions that come from it, has been made from a purely visual perspective, captured by combinations of

• Being specific on which phenomena are studied...

• ...and on the observations made of them...

camera angles, without needing the use of any complex and expensive technologies•. In embarking on this research project, the initial intention was to measure facial muscle activity using Electromyography. This method proved to be too costly• and the heavily mathematic and science based analysis process, out of the current skill set of this researcher•. Furthermore, due to the significant evidence found in the literature regarding the internal embouchure, the concept of the tongue being a pivotal element in facilitating pitch change has been accepted as fact and deemed unnecessary for further study in this project•. Therefore the ultimate goal of my research is to inform the teaching and learning of brass wind performance, with particular reference to the role of the embouchure•. With this in mind, it is therefore important that the data obtained through this study be identifiable through the simplest means possible, so that it can be of the most benefit to the brass-playing community•.

- ...thus correcting any expectations of what might have been achieved...
- ...contextual factors prevented more sophisticated observations...
- ...and initial investigations reveals how difficult this would be
- There was no knowledge contribution to be made in this particular area...
- ...and so the knowledge contribution was ...
- ...and our research goals were set accordingly.

Activity: Which weaknesses are discussed? #111

Consider the extract above alongside our comments. Which kinds of weakness does it refer to? How were they dealt with? Which other weaknesses could have been discussed?

Discussion

We found two potential weaknesses which were considered and addressed in the research:

- novelty: by being specific on the phenomena studied (the external elements of the embouchure), the text clarifies where the claimed novelty of the research lies. This makes it easy to check against related work in the literature, something the text could have mentioned explicitly
- validity: the observation of such phenomena through video images is defended as a valid method in relation to the aim of devising a practical approach to inform teaching and learning. This is in contrast to more sophisticated, but costly, approaches that would have been possible, but deemed unnecessary for the aim of the research.

Other potential weaknesses not discussed are:

- reliability: how reliable were the observations? Would another researcher have reached similar conclusions?
- validity: the study assumes the embouchure is a key factor in the teaching and learning of a brass instrument. Where does this assumption come from?

As this is only a brief extract, it is possible, of course, that these weaknesses were considered and dealt somewhere else in the dissertation.

5.5.3 Approaches to address weaknesses

In this section, we consider three common approaches used to address weaknesses in research.

5.5.3.1 Triangulation

Triangulation **mathison1988triangulate** consists of using multiple data sources and methods, or even multiple researchers, to develop a comprehensive understanding of a phenomena under study and arrive at a particular conclusion about that phenomenon. Triangulation was introduced in the social sciences in the mid 1950s **campbell1959convergent**, and since has become an accepted approach across all disciplines, regardless of research paradigm.

The core idea behind triangulation is that if different data and methods converge towards the same conclusion, then it is more likely that such a conclusion is valid, that rival explanations can be dismissed, that the different procedures followed are reliable, and that the effect of any bias is mitigated. In this way, triangulation makes your research more credible, and your claim more defensible.

However, because triangulation applies many techniques or derives conclusions from many sources, it can result in inconsistent or contradictory findings. So, it is important to understand that triangulation does not necessarily guarantee convergence on a single proposition about a phenomenon. Instead, it provides a rich and complex picture that requires careful interpretation and explanation by the researcher. As a result, triangulation should be used cautiously and researchers should be prepared to explain and make sense of the various outcomes it may produce. Triangulation also adds complexity and requires more time and effort that must be accounted for.

Main kinds of triangulation include **denzin1978research**; **patton1999enhancing**:

Data source triangulation refers simply to using several data sources. These may be the inclusion of multiple participants to interview, or the consideration of a particular phenomenon under different conditions in space and time. For example, in an educational setting, you may wish to measure the efficacy of an educational programme on different student cohorts, possibly over different academic years, or delivered by different educators. With data triangulation you increase the validity of your claim across different contexts, so that your results are more generalisable.

Investigator triangulation involves several researchers collecting and analysing data•. For instance, you may have different researchers repeating measurements using the same lab equipment and procedures. The involvement of different researchers who independently apply the same techniques to arrive at the same conclusions, increases both reliability and validity of those outcomes, and mitigates against each researcher's bias. This is particularly important in qualitative research where data are often interpreted rather than measured precisely.

• Because there is more than one researcher involved, it is unlikely that you will be required to perform this form of triangulation in your Masters project. You may, however, be a researcher in the triangulation of another's researcher – your supervisor, for instance – which means that you should be prepared to be involved. Be sure to schedule some time with your supervisor to discuss their needs, should this be the case.

Methodological triangulation refers to the use of multiple methods in the examination of a phenomenon•. For instance, a neuropsychologist may combine direct observation of human behaviour with neurological data from brain scans to obtain a comprehensive picture of what motivates people to make certain choices. Methodological triangulation allows strengths and weaknesses of different methods to compensate for each other, increasing both reliability and validity. However, it may be difficult to combine results from different methods because of their differing ontological and epistemic stance.

• We deal with mixed method research later in this Stage.

Theory triangulation refers to the use of different theories or hypotheses to analyse data and interpret phenomena. For instance different motivation theories could be used to study resistance to change in organisations. By employing several theories, findings can be considered from different angles, compensating for possible limitations or biases of each individual theory.

Activity: Distinguishing different kinds of triangulation #112

Consider each of the following examples and indicate which kind of triangulation they represent:

- research on student experience in a university looking at student survey data and students' study results
- research on study practice and academic performance, combining an online survey and interviews with a selected number of participants
- research on sleeping patterns of the elderly, using data from care homes in the UK
- research on volcanos asking vulcanologists around the world to contribute seismological measurements over a period of time.

Discussion

These are example of, respectively:

- data triangulation, in which two different kinds of data are considered
- methodological triangulation, in which two different methods are applied
- data triangulation, in which similar data from different locations are considered
- investigator triangulation, in which several researchers are invited to collect and contribute data. Presumably, this also encompass some data triangulation in the sense that similar data from different locations around the world are collected and analysed.

5.5.3.2 Reflexivity

According to **jamieson2023reflexivity**:

> Reflexivity is the act of examining one's own assumption, belief, and judgement systems, and

> thinking carefully and critically about how these influence the research process. The practice of reflexivity confronts and questions who we are as researchers and how this guides our work.

So, reflexivity admits that the researcher isn't an objective, unbiased observer of truth, but someone whose worldviews and subjectivity influences every step of the research process. Through reflexive practice, the researcher can then engage in a more honest and transparent research process, increasing research reliability and mitigating bias.

Note that there is a difference between reflection and reflexivity. Reflection is usually done retrospectively: you could reflect on something that has happened during your study to identify important lessons for the future. In contrast, reflexivity takes place throughout the research process — before, during and after, hence has the potential to shape it. Also reflection focuses on things you have done, while reflexivity explores motivations — your assumptions, beliefs, biases, etc., behind those actions.

Reflexivity is relevant and applicable to all types of research. Qualitative research has the longest tradition of reflexivity, with qualitative researchers encouraged to examine and openly acknowledge their own beliefs and biases, and their impact on the research. In quantitative research, the acceptance of the importance of reflexivity is growing, and goes alongside an acknowledgement that there are limitations and biases in the scientific method too, so that quantitative research is not a 'gold standard' of objectivity.

Reflexivity should be embedded in all steps of the research process. In the early stages, it can apply to the choice of research problem or questions, by guiding the researcher to consider explicitly subjective factors which may explain why that particular choice was made and why the researcher is best placed to research it. In data collection, reflexivity can expose biases and unchecked assumptions which may affect how samples and data sources are selected or participants are recruited. In data analysis and their interpretation, reflexivity may lead to uncover reasons why certain evidence is given more weight or meaning, while other is discarded, for instance due to confirmation bias. In formulating conclusions, reflexivity can support "thinking about thinking"•: the process of questioning the way we think to assess how valid and reliable our conclusions are. This is particularly important because while the human brain has the potential for logic and critical thinking, these are not innate skills: rather they need developing, akin to the skills that one must develop to become, say, a proficient musician or mathematician. Psychologist have uncovered that left untrained, our brain tends to make mistakes, which stem from a variety of factors•, including errors in perceptions, flawed memories, heuristic thinking, logical fallacies and cognitive bias. Reflexivity can help us become aware of these tendencies.

• So-called 'meta-cognition'

• A fascinating series of lectures on this topic is "Your Deceptive Mind: A Scientific Guide to Critical Thinking Skills" by Steven Novella.

Activity: Reflexivity practices #113

Conduct a web search on reflexivity practices adopted by researchers. Briefly summarise what they are, and how they are useful. Comment on which of such practices you could adopt in your work.

Discussion

You may have found some or all of the following:

- Reflexive writing, such as research journals, diaries, fields notes and memos. These are common tools used by the reflexive researcher at any point in the research process to record assumptions, experiences, observations, perceptions, procedures, and decision points. They are used to bring into focus the researcher's intention and gaps in their knowledge or thinking, as well as interpersonal dynamics, including power ones.

- Positionality statement. This is a kind of reflexive writing aimed at describing researcher's characteristics (such as age, social class, race, etc.) and beliefs (such as political, philosophical, etc.) which may influence the research.

- Narrative autobiography. This is also a kind of reflexive writing focussed on the researcher's life experiences and motivations which may influence the research, particularly the researcher's interaction with participants and understanding of participants' accounts. The aim is to better prepare the researcher for their interaction with participants, so it is best conducted when planning data collection/generation.

- Reader-response exercise. This addresses how the researcher's own assumptions and experiences may affect their interpretation of participants' accounts. It consists of including a layer of codes to indicate how the researcher reacts to and interprets participants' accounts in relation to their own background and personal history. As such, this practice is useful during data analysis and interpretation.

- Collaborative reflexivity. This entails engaging in reflexivity as part of a research team, with collaborators questioning assumptions and decisions. It assumes mutual trust, and a commitment to ethics and rigorous research, regardless of seniority or status. It applies to all stages of the research process.

5.5.3.3 Returning to the literature

Addressing novelty weaknesses means returning to your literature review as your research progresses and understanding increases to cast an increasingly critical eye over it, and possibly widen its scope to further related work which may have been published more recently. Each source should be reconsidered for what you thought it originally said and what you now think it says, using any difference• to drive further reflection on your findings, methods, data generation, or even research problem. This process will help you both ensure there continues to be a gap your research can contribute to, and assess the extent of the novel contribution your research can make in relation to related work which has already been published.

• In the best case, there will, of course, be no difference!

As in the example we included at the end of Section 5.5.2, while defending your claim or explaining your research design, your reader can be made aware of this process and how it has altered your research. Deepening the critical nature of your literature review allows your reader to understand that you are a reflective researcher and can turn any novelty weakness into a research strength!

5.6 Your research strategy candidate list

While your own research strategy will be specific and unique to your project in the way it informs the research you will conduct, standard research strategies have emerged over time, influenced by research paradigms and research practice within specific disciplines. Each of them can be seen as a sort of 'recipe' which summarises common ways to conduct academic research: by adopting or combining some of these strategies, you can come up with your own specific instance for your project.

There are many standard research strategies in the literature, often with many variants: the 12 strategies we consider in this book are discussed in this section. The outcome of working through this section should be your choice of a candidate research strategy that:

- is a good fit for your research problem, i.e., that will allow you to develop a contribution to knowledge arising from your research problem
- makes the most of your current research skills and resources, i.e., the background knowledge and skills you bring to the research, the time that is available to you, and it fits with your research context.
- can be evaluated through a list of questions that could be asked of it by a knowledgeable evaluator, such as an examiner.

Table 5.3: Research strategy choice

Research Strategy candidate	**Considered**	**Excluded**	**Reason excluded**
Survey	☐	☐	
Design and Creation	☐	☐	
Experiment	☐	☐	
Case study	☐	☐	
Action research	☐	☐	
Ethnography	☐	☐	
Systematic research	☐	☐	
Grounded theory	☐	☐	
Phenomenology	☐	☐	
Simulation	☐	☐	
Mathematical and logical proof	☐	☐	
Mixed methods	☐	☐	

From the first two of these, you will gain an understanding of which steps you will be required to take to generate, analyse and interpret research data that, when complete, will make your contribution to knowledge. From the third of these, you'll be able to structure your research report – your dissertation – by describing your answers to the evaluative questions.

The 12 candidate research strategies we consider are listed in Table 5.3. For each, after a brief description explaining the focus of the strategy, we will:

compare to structure of each strategy section, at the end of editing

- describe what kind of knowledge contribution that can be made through it
- describe the ways in which data is generated and analysed within the strategy
- describe how a contribution to knowledge using the strategy will be evaluated
- ask "Is this strategy right for me?"
- provide a number of references that give more detail, if you are seriously considering the strategy

This is a lot to digest! Rather than going through all the information about each strategy in turn, we recommend you take the following steps to first reduce your list of candidate strategies from which to arrive at your chosen one.

Step 1 Consider a strategy, and read its description and type of knowledge contribution that can be made through it. Compare these with your research problem to check whether that research strategy should be a candidate for your project. When you have done this, you should check its tickbox in the first column of Table 5.3 – I've considered the strategy. If there's a clear mismatch with your research problem, you should check the tickbox in the second column – that the research strategy has been excluded – and give a reason why you have excluded it – say, the knowledge contribution it makes is not of the correct form – and you can move onto the next research strategy and repeat this step. The "Reason excluded" column will be used in the your dissertation to justify your choice of research strategy so think deeply about what you write here – you can use the text of the knowledge contribution and subsequent subsections to frame your reason for excluding it. Whatever you do, don't leave it blank!

Step 2 If you have not excluded the research strategy, then you should read further – next come the methods you would use to generate and analyse data. This gives you another reason to exclude a research strategy – that the data or participants your research needs are not accessible or the methods are not feasible within your project•. If this analysis leads you to exclude the research strategy, complete• the second tickbox column and record the reason, then move on to the next research strategy going back to Step 1.

Step 3 If you have not been able to exclude the research strategy, then you should read the "Evaluation" section•. These are questions you should be able to address once your research is completed, and which you should keep in mind from the very start. If you feel you are unlikely to be able to address them, then this gives you another reason to reject the strategy. Once again, if you have excluded the strategy, tick the box in column 2, record the reason in column 3, then move on to the next strategy and restart the process.

Step 4 If you have not been able to exclude the research strategy, it's time to look at "Is this strategy right for me" section. This lists a number of other things you should consider that might lead you to exclude it, particularly in relation to skills you may be needed, or other features of the strategy which may not align with what you can achieve within your project. If you came to reject the strategy, as before, tick the box in

• Of course, you will need to choose *one* research strategy, so be careful not to exclude something that, perhaps with some adjustment, can be made to work.

• This time, the reason will be something to do with data generation techniques not accessible.

• Perhaps taking notes on things you haven't immediately understood.

column 2, record the reason in column 3, then move on to the next strategy and restart the process. This section may include alternative strategies you could consider next, otherwise, just proceed through the list.

Step 5 If you have not been able to exclude the research strategy, then look at the "Further reading" section and record the suggested references in your bibliographical database. You will access these articles later on, to gain a deeper understanding of your candidate research strategies. You can now move on to the next strategy, and restart the process.

We have wrapped up this process in the following activity, which constitutes the most substantial practical work for you to carry on in this sub-section:

Activity: Arriving at your candidate strategy list #114

Copy Table 5.3 to your favourite word processor or spreadsheet application. Apply the process above until you have considered all the strategies, updating your table as you go along, and recording related references in your bibliographical database.

Guidance

The aim of this activity is to help you narrow down the possible choices of candidate strategy for your project, without having to dive deep into the detail of all 12 strategies presented. This is something you will do after you have completed this activity: the references recorded in your database will then provide a starting point for your review of methodology-related literature.

Once you have exhausted all the strategies, there are three possible outcomes:

- you find yourself with a single candidate research strategy, in which case you should go for it!
- you find yourself with a number of candidate research strategies, in which case you can make a choice based on your skillset, how much fun you think you could have applying it, or any other criteria you wish. You may also like to think about mixing up bits of each to give you your own mixed methods research strategy
- you find yourself without a choice, in which case you've probably been too picky... and you should try again – you can't do research without a research strategy and you're unlikely to come up with one not on this list – a completely novel one.

In all cases, you should discuss the outcome with your supervisor:

Activity: Discussing your choice with your supervisor #115

Arrange a time to talk to your supervisor about the process you have followed to identify possible choices of research strategy for your project, and what the outcome was.

Guidance

As an expert in the research process and in your field of study, your supervisor will be able to advise on whether the choices you have made are appropriate, or even recommend strategies you should consider in details.

5.6.1 Survey research

Survey research focuses on collecting, in a standardised and systematic fashion, up-to-date, real-world data from a sample of the population which is the focus of your research. Depending on the population and selected sample, large amounts of data may be collected.

5.6.1.1 Knowledge contribution

The contribution to knowledge of survey research is to uncover patterns that can be generalised from the sample to the target population.

A typical application of survey research is to predict the outcome of an upcoming election by polling data from a sample of voters.

5.6.1.2 Data generation and analysis

For your data collection, you need to identify upfront which data you will collect in a standardised matter, your target population and sample. The sample must be representative of the population in the sense that it should reflect accurately population characteristics.

Suggested by the name, a survey – a standardised set of questions administered to a number of respondents – allows the researcher to gather information about a population. Surveys can take many forms, from interviews to questionnaires to focus groups, but authors vary on what they consider appropriate•. They can

• Be sure to consider any supplied preparatory reading on the survey research strategy to ensure that you meet your supervisor's (or other's) expectations of what will be appropriate.

be administered via the internet (more traditionally by mail), over the phone, or even face-to-face. Mixed-mode surveys combine these options into more complex instruments, perhaps using a broader but simpler questionnaire to identify potential participants for a deeper face-to-face interview to follow.

In your data analysis, you seek patterns in the sample data collected to arrive at generalisations to the wider population. Statistical analysis is usually applied, possibly complemented by some thematic analysis, if open-ended questions are also included to elicit qualitative data.

5.6.1.3 Evaluation

The following questions are typically asked of survey research:

1. Reliability:
   - Are the sampling frame• and sampling techniques• used adequately explained?
   - Are the data generation and analysis methods adequately described?
   - Do they survey questions allow for consistent and dependable measures by different respondents?
   - Are significant differences between respondents and non-respondents discussed?
2. Validity:
   - Is the sampling frame appropriate? Does it provide sufficient coverage of the target population in terms of its characteristics of interest?
   - Is the sample representative? •
   - Is the response rate adequate? How were non-respondents handled?
   - Do they survey questions allow to measure or assess all that is needed?
   - Has statistical, or other, analysis been appropriately applied?
   - Are generalisations made about the target population appropriate? What reasoning chains have led to such generalisations?
3. Bias:
   - Is the questionnaire designed as to avoid leading questions, which may have an unduly influence on the respondents?

• The sampling frame is the set of individual units of the population from which the sample is drawn. Such individual units may be participants or data points in a data set.

• We will look at sampling in Stage 4.

• This relates to the question of whether the sample is sufficiently large and/or as diverse as the population.

5.6.1.4 Is this strategy right for me?

This strategy sets certain requirements of the researcher for them to be successful. These include that:

1. you must have access to an appropriate population sample, so that a sufficient volume of data can be collected and deep analysis performed. If this is not possible, for instance, because you have limited access to the population, you might like to consider case study research instead.

2. the phenomena and characteristics of the population which are of interest should be measurable through questions asked through a survey. If this is not the case that then you're not going to be able to make a contribution to knowledge about those phenomena or characteristics, and you might like to consider phenomena that can be measured, or a different population for which those phenomena can be measured.

3. while this strategy may produce lots of data in a relatively short time, the depth in the data can sometimes be lacking, given the focus on what can be measured. If deeper or more nuanced data is needed, then you may like to consider case study research instead.

4. conducting a survey means that you'll be analysing phenomena using point data, i.e., data that were collected at a point in time – that time at which the survey was answered. If your research requires longitudinal data, i.e., data that could change over time, then survey research becomes more difficult as you might need two or more surveys to collect the changing data. While it's not impossible to do this, it adds many complications: earlier participants might not be available for later surveys, their mindsets might have changed in the intervening period, etc. If this is the case, then you should consider whether the choice of phenomena is appropriate. Alternatively, you might like to consider one of the experimental research strategies described below.

5. while repeated surveys may be used to investigate causes and effects, the difficulty of doing this is one reason to reconsider phenomena or use an experimental research strategy instead. In all cases, surveys are not suitable to investigate the mechanisms behind cause and effect relationships.

6. conclusions from survey research rely on the veracity of the responses received, something you can't necessarily take for granted. Even when there is no intention to deceive, people's answers may be inaccurate due to many factors, including a tendency to wishing to provide the 'right answers', that is what they may believe is expected, or poor recall of past events or of detailed observations they

have made, or even lack of trust which may influence what they are willing to disclose. Triangulation, therefore, may be required to increase validity, but this will add complexity to the strategy. If this is not possible, then other strategies may be advisable, for instance, participant observation through ethnographic research.

5.6.1.5 Further reading

To deepen your understanding of this strategy, you can start from **dillman2014internet**; **oates2008researching**; **johannesson2014research**; **kalaian2008encyclopedia**.

5.6.2 Design science research

The design science research strategy• focuses on developing novel solutions to problems, a problem being a need in context. The solution should be an artefact, by which is meant anything designed and constructed by humans: this is a very broad definition, encompassing all that does not exist in nature, including any artificial object, construct, process, policy, model, method, etc.

• AKA Design and creation strategy.

5.6.2.1 Knowledge contribution

The contribution to knowledge is that which can be learned from the design and creation of the artefact as the solution to a problem. Knowledge contributions therefore come from an exploration of the problem, of the artefact itself, and its design, development, use, or other characteristics of the real-world problem solving process – for instance, whether it is linear or iterative, or the ways in which problem and solution understanding and validation are conducted.

This strategy leads to tangible artefacts which fit real-world contexts, and it is particularly suited to emerging and rapidly changing technology-related fields of study, where new problems emerge all the time and known solutions are sparse or become rapidly obsolete, hence necessitating continuous innovation. Lots of research in Computing is an expression of this strategy, for instance designing computational systems able to emulate human cognition, as is the case of AI•.

• Artificial Intelligence

5.6.2.2 Data generation and analysis

Data generation is through the problem-solving process of articulating the problem, and designing and constructing the solution artefact, with the interactions between actors (customers, clients, designers, others), technologies and/or knowledge as the source of data. Modelling techniques are widely applied, possibly informed by data collection techniques, like reviewing existing documents or interviews with stakeholders and experts or observation of people's behaviour. Prototyping is often used to produce proof-of-concept artefacts to test, demonstrate and improve the design.

Data analysis focuses on knowledge generated in the evaluation of both problem and artefact, including solution characteristics in relation to the extent they address the problem – the identified need in context. Specific evaluation techniques will depend on the nature of the artefact, and may include problem owner's validation, and various forms of testing, or end-users' evaluation and feedback.

By problem owner we mean the person or people who have expressed the need to be addressed and are able to establish whether the solution has met it.

5.6.2.3 Evaluation

look up more in the literature

Evaluation of the design and creation research strategy typically consists of the following questions:

1. Novelty:
   - What is the novelty in the artefact, its design, development, and/or creation?
   - To which extent does the artefact address the problem? Have its efficacy and utility been demonstrated? What evidence is provided?
2. Reliability:
   - Are all stages of the problem solving process discussed, including interactions with stakeholders?
   - Are the ways data are generated and analysed, both in problem and solution space, adequately described?
3. Validity:
   - Are appropriate approaches applied in the design and creation of the artefact?
   - How is the artefact assessed? Are the assessment criteria appropriate and documented? How were they determined?
   - Which generalisations are made from the design and creation of the artefact? Are they appropriate?

5.6.2.4 Is this strategy right for me?

For this strategy to be successful:

1. There must be demonstrable novelty. You must be able to argue that your research does not focus on 'normal' design, that is you are not simply re-implementing a solution to a well-known problem through a well-known development process and well-practiced skills•. If you cannot clearly identify that novelty, then you will not be able to claim a contribution to knowledge.

• Learning new skills may be valuable from a personal perspective, but will not, by itself, make a contribution to knowledge – learning them means that they exist already!

2. There should be a problem owner which is separate from the researcher, and who sets the requirements and context for the artefact, with the researcher working on its development for that context to meet those requirements. If you do not have access to a real-world problem owner then this strategy is not applicable.

it used to talk about client, but I think that's too specific; for instance, there may an open challenge expressed and acknowledged in the academic literature, in which case the problem owner may well be the community?

3. If the problem owner is, say, your employer or a business you are collaborating with, and for which addressing the problem is a matter of urgency, then you must establish whether it is feasible for you to deliver a novel solution in a timely fashion. Research always brings a level of uncertainly so that estimating time to success, or if success is even possible may not be easy. If you can't ensure feasibility within the timescale of your project, then you may need to rethink the problem to address.

5.6.2.5 Further reading

To deepen your understanding of this strategy, you can start from **oates2008researching**; **brocke2020introduction**.

5.6.3 Experimental research

Experimental research provides a controlled environment in which cause and effect relationships can be investigated, expressed as a hypothesis•. The strength of an experiment is that it can reduce the influence of confounding factors on a cause-effect relationship.

• A hypothesis is a tentative statement about the relationship between the phenomena to be tested in the experiment.

The potential scope of application of the experimental research strategy is wide, ranging from scientific experiments under laboratory conditions controlled by the researcher to field experiments involving people in a real-world setting in which some factors may be outside the control of the researcher.

There are pros and cons of each. While laboratory experiments are very reliable due to the high level of control, they can be very artificial, with little or no relation to a real-world context. The opposite is true for field experiments.

5.6.3.1 Knowledge contribution

The experimental research strategy contributes to knowledge through allowing cause and effect relationships between real-world phenomena to be established.

For instance, you may run an experiment to test whether the use of mobile phones just before going to sleep disrupts people's sleeping patterns.

5.6.3.2 Data generation and analysis

The experimental research strategy revolves around making an intervention within tightly controlled parameters. Observations and measurements are made of before and after the intervention and a comparison is made. Any difference is assumed associated with the intervention made.

For instance, in establishing a causal relation between the use of mobile phones and sleeping patterns, we could investigate the effect of the blue light emitted by a mobile phone on reducing the production of melatonin: this is the hormone which controls a person's sleep-wake cycle, so that its reduction is likely to disrupt a person's sleeping pattern. We would then measure the amount of melatonin produced by the body (these are our measurements) with and without exposure to the blue light of a mobile phone (this is the intervention), then analyse any difference to establish whether a causal relation exists.

So, you generate data through observations and measurements under different experimental conditions, and analyse your experimental data to explain causal relationships between the factors under study.

Depending on the complexity of the relationship between cause and effect, more or less complex experimental designs can be used. Those involving an inaccessibly large population of individuals, as might be the case for a medical drug trial, use sophisticated techniques to choose representative samples, as well as sophisticated statistical analysis to test hypotheses.

However, even simpler "local" cause-effect hypotheses may rely on the availability of a fully equipped scientific laboratory to work.

5.6.3.3 Evaluation

Typical questions in the evaluation of the experimental research include:

1. Reliability:
    - Are the experimental variables manipulated or measured adequately described?

- Is there a clear account of what is controlled?
- What are the experimental procedures? Are they sufficiently detailed so that the experiment can be repeated by an independent third party?
- In a social setting, what information is given about participants and how they were found?
- What information is given about the apparatus and the process used to make measurements?

2. Validity:

- Was a hypothesis or predicted outcome of the experiment clearly stated?
- If a population sample was selected for the experiment, how representative is it? How was it selected? Which measures were taken to avoid sample bias?
- If statistical analysis is applied, how adequate is it? Have appropriate statistical tools been used and their use justified?
- Are confounding factors or outliers identified and discussed?
- Are the statistical and other analyses convincing of the conclusions?
- Has the experiment being replicated?

5.6.3.4 Is this strategy right for me?

Although widely applicable, the experimental research strategy has some counter-indications:

1. when testable hypothesis cannot be formulated, concerning the cause-and-effect relationships of interest
2. when the cause/effect relationship is very complex, for instance, depending on many factors, which cannot be accounted for in an experiment
3. when confounding factors and variables cannot be isolated, or no level of control is possible
4. when the experiment is a one-off and cannot be repeated
5. if you don't have access to specialised equipment required
6. if you don't have (or can't develop) statistical analysis skills required

5.6.3.5 Further reading

To deepen your understanding of this strategy, you can start from **oates2008researching**; **johannesson2014research**; **field2002design**.

5.6.4 Case study research

Case study research proceeds through the in-depth study of a notable instance of a phenomenon within its real-world context, particularly when it not possible to separate the phenomenon from its context. The study of a single phenomenon requires the researcher to delve deeply into the context of that phenomenon, whether that be a project, an organisation, an engineered system, a policy, an economic or historical setting, or other. Case studies allow the researcher to study complex phenomena where several factors are at play, and to explore alternative meanings and explanations.

5.6.4.1 Knowledge contribution

Case studies focus on the 'how?' and 'why?', so that the knowledge contribution is a detailed insightful account of the phenomenon in its natural context, including when appropriate its relationships with other phenomena, and relevant processes and causal chains.

What you seek with a case study can span from exploring possible questions or hypotheses for follow-up research, to explaining why certain outcomes have occurred, to investigate changes over time. For instance, an example of case study could be a detailed investigation of the US Equifax social security breach of 2017, in which 143 million of their consumer records were stolen by hackers. This may be descriptive of the chain of events that took place or explicative of why things happened the way they did, or both.

Therefore, case studies come in many forms, including:

- exploratory: in which the researcher explores a research problem sufficiently to be able to conduct a further study. If you're considering studying for a PhD after your Masters research, then this might provide a head-start for your future research
- multiple: in which two or more instances of the phenomenon are chosen, which present both similarities and differences, to provide an even richer analysis of the phenomenon in its context
- longitudinal: in which the researcher considers the state of a phenomenon over time. This offers a natural storytelling context in which change in the phenomenon and/or its context can be analysed.

Combinations of the above are also often adopted, allowing even deeper exploration of both relationships between phenomena and how they develop over time or in response to contextual factors.

5.6.4.2 Data collection and analysis

Case studies require you to collect empirical data from a great variety of sources, and to focus on depth rather than breadth. Therefore, all data collection techniques which allow you to do so may be used, from observation of the phenomena *in situ* and the context and processes in which it participates, to surveys of those that experience the phenomena in context (through interviews, questionnaires, *etc.*), allowing for multiple stakeholder views to be taken into account, to studying forensically existing documents that directly or indirectly describe the phenomena. This will lead to much data to be collected — mainly qualitative, but also quantitative to some extent, so that their analysis can be very rich and complex.

5.6.4.3 Evaluation

An experienced researcher evaluating case study research will ask the following questions:

1. Reliability:
    - Has the type of case study conducted been clearly described and justified?
    - How were ethical considerations taken into account, particularly in relation to participants and confidential information handled?
    - Were the data generation and analysis methods adequately described?
    - Are the procedures followed appropriated documented?
2. Validity:
    - Have the criteria for choosing the particular case study been described and justified? Is the choice appropriate for the phenomenon studied?
    - Did the data generation methods generate the right type of data about the phenomenon in sufficient depth and quantity?
    - How was a detailed investigation of the phenomena conducted? Was the researcher able to work within the case study context?

- Does the research adequately describe the relationships between phenomena and the processes in which the phenomena participate?
- Is the data analysis systematic and transparent? Are the steps taken to arrive at conclusions clearly explained?
- What generalisations were made from the case study research? Are they appropriate for the phenomenon and its context?

5.6.4.4 Is this strategy right for me?

There are conditions for this strategy to be successful:

1. Case study research requires you to have access the phenomenon in its context to be able study it holistically and generate rich, detailed descriptions. As an example, if you're not a teacher, it might be difficult to gain access to a classroom to study student/teacher interactions. If access is an issue, then you should consider a different strategy, like systematic research reviews, which work from secondary sources.
2. Access to data sources, such as policy, processes or procedures within an organisation, may rely upon interaction with others. Even if you already have a good relationship with them they might not have the time to assist you sufficiently for your data generation to be successful within the timeline of your project. If time is an issue you should consider alternative sources, or even a different research strategy.
3. Being embedded within the context of the phenomenon, as might be the case, for instance, of an employee of an organisation, facilitates the investigation of the phenomenon. In this case, however, alternative research strategies are also applicable, such as ethnography or action research.
4. You must have the required knowledge to understand the phenomena under study. For instance studying the processes by which an engine controller in an aircraft is designed may require a detailed understanding of technical documentation, language and even mathematical or computational theories. Acquiring this knowledge from zero as part of your research may not be possible or may consume too much time•. In such cases you should reconsider the phenomenon to study.
5. You need to make a judicious choice of case study to be able to make any generalisations about the phenomenon beyond the particular instance. If you don't have access to a significant instance of the

• The success of your research will depend critically on climbing any learning curve quickly and successfully, even if that learning curve looks like El Capitan!

phenomenon and generalisation is an important consideration, then you should consider a different research strategy.

5.6.4.5 Further reading

To deepen your understanding of this strategy, you can start from **yin2009case**; **oates2008researching**.

5.6.5 Action research

Action research focuses on real-world situations for which improvement is sought through participatory and collaborative research. Its focus is on practice change, and continuous learning and improvement via an iterative 'plan-act-reflect' cycle which generates both knowledge and action.

5.6.5.1 Knowledge contribution

Action research should make both a contribution to knowledge *and* to practice: an action researcher strives to generate knowledge and action to address important problems that people experience in their practices, so that the knowledge contributed originates in real-world needs. The researcher is an active participant in the research, rather than solely an observer, alongside other collaborating practitioners: in fact, collaboration, alongside reflection, is a key element of this strategy.

The outcomes of action research may be new theories or methods alongside their direct implementation to improve practice within a specific professional or social setting. For example, in an educational setting, where this strategy is widely applied, a group of teachers may come together to study the composition and effectiveness of homework at each school grade, with a view to improve the balance between knowledge-based and practice-based learning.

5.6.5.2 Data generation and analysis

Similar to case studies, action research requires you, and your collaborators, to collect empirical data from a variety of sources to gain a deep understanding of the current practical situation to be improved. Common methods which allow you to do so include observations, surveys, focus groups and document reviews. In this case too, both qualitative and quantitative data are collected and analysed.

5.6.5.3 Evaluation

The evaluation of action research will include the following questions:

1. Reliability:
    - Has the work used an iterative cycle of plan-act-reflect? How many cycles were conducted?
    - Was the research collaborative? Is the level of collaboration achieved appropriate?
    - Were the data generation and analysis methods appropriately described?
2. Bias:
    - Have the researcher's personal stake and potential biases been discussed? Was a reflexivity account included?
    - Is there a reflection on self-delusion and group-think of the collaborators? How was this mitigated? Was the mitigation successful? If not, what was the outcome?
3. Valididty:
    - Was the learning from the plan-act-reflect cycle clearly identified and discussed?
    - Were the data generation methods appropriate, and was enough data generated?
    - Were detailed descriptions and accounts of findings provided?
    - Has the research generated both knowledge and action leading to change? How useful or impactful on practice are they?
    - Were generalisation made and appropriately supported by evidence, including triangulation?

5.6.5.4 Is this strategy right for me?

There are conditions for this strategy to be successful:

1. Action research focuses on action aimed at solving real-world problems in professional and other social contexts. If that's not the case for your research, then you should consider a different strategy.

2. The action researcher is expected to be embedded in the context in which the research takes place, and have a professional stake in addressing the problem beyond the research itself, for instance, as an employee of an organisation. If this is not the case for your project, then you should consider case studies instead.

3. Action research requires the involvement of other practitioners as collaborators in the research. This goes beyond being merely participants in surveys or observations: instead it requires a much higher commitment and continuous involvement in the study. If this is not possible, you should consider case study research instead.

4. Action research works through reflection, and continuous learning and improvement. As such, it does not exhibit the same level of scientific rigour as, for instance, an experiment. If scientific rigour is needed in your research, then you should consider a different strategy.

5. Action research may not be suitable to study complex causal-effect relationships. If you need to establish one such relationship, then you should consider the experimental strategy instead.

6. Generalisation can also be difficult to achieve with action research. If you need to be able to generalise your research widely, then consider case studies instead.

7. While action research is accepted and commonly applied in some social sciences, like education and healthcare, this may not be the case in your discipline. You should therefore check with your supervisor whether this strategy is acceptable or you should consider a different, strategy.

5.6.5.5 Further reading

To deepen your understanding of this strategy, you can start from **oates2008researching**; **johannesson2014research**.

5.6.6 Ethnography

The ethnography research strategy aims to study the culture of a group of people in their natural setting.

5.6.6.1 Knowledge contribution

Ethnography contributes to knowledge by providing a cultural characterisation of the group under study. Such characterisation should be one that the group members recognise and find familiar, and should be inclusive of various cultural facets, both social and economical, rather than focusing solely on one specific aspect.

While ethnography was originally developed within the discipline of anthropology, particularly for the study of indigenous populations, it can be applied widely in social settings, for instance to study the work culture within a particular profession or organisation, or the culture of online communities within social media.

5.6.6.2 Data generation and analysis

The researcher is expected to join the group and share what the group members' experience in their natural social setting in order to gain an insider's perspective and arrive at a rich, detailed characterisation. This requires the researcher to make detailed participant observations, appropriately recorded in field notes, accompanied by gathering detailed data through interviews and document reviews, linking them to the existing literature and reflecting on what they have learnt from their own experience, including their state of mind and emotional reactions. Data generation and analysis are predominantly qualitative.

5.6.6.3 Evaluation

Evaluating ethnography may involve asking the following questions:

1. Reliability:
    - Are field notes sufficiently rich and detailed? Do they capture people's actions and behaviours, and the motivating reasons?
2. Validity:
    - Is the cultural characterisation obtained sufficiently rich to account adequately the group's beliefs, customs, behaviours and interpersonal relations?
    - Was adequate time spent with the group in their natural setting? What reflection has been done on such time?
    - Are data appropriately interpreted through a cultural lens?
    - Is the ethnographic characterisation a standalone description, or has it been linked to theory, other ethnographic studies or issues in other cultures?

3. Bias:
   - Does the research include a reflexive account of the researcher?

5.6.6.4 Is this strategy right for me?

There are conditions for this strategy to be successful:

1. Ethnography requires you to be a researcher located within the context of your situated research. This can take extensive amounts of time, such as might be the case if the context of your research is the organisation for which you work. However, if you have yet to have identified the context, or have yet to reach out to it, then this requirement may mean that ethnographic research will not be successful. If you are not already close to your context of research, you may wish to consider case study research instead.

2. Even if you are already located within the context of your ethnographic research, the context must be accepting of an ethnographic approach for your research to be successful. An organisation, for instance, in which there is a culture of strict compartmentalisation may not provide sufficient opportunities for ethnographic research.

3. In ethnographic research you allow the culture under study to determine the outcomes of the research, so you should approach it without any preconception or bias. If there is any possibility that you could be biased to a particular outcome – as might happen if you feel you already know the outcome and are simply trying to confirm this – then ethnography is unlikely to lead to a successful outcome for your research. Any competent ethnographer will be particularly sensitive to expressions of bias, even if they aren't even intentional. Indeed, such bias may preclude any successful research strategy being applied.

4. Ethnography can lead to rich descriptions of complex social settings, and the characterisation produced may be very deep in representing a particular group culture. However, this may be difficult to generalise to other social groups or settings. If generalisation is an important aspect of your research, then you should consider case studies instead.

5.6.6.5 Further reading

To deepen your understanding of this strategy, you can start from **oates2008researching**; **johannesson2014research**.

5.6.7 Systematic research reviews

A systematic research review is used to generate new insights from published work, linked to a clearly defined research problem or question.

5.6.7.1 Knowledge contribution

A systematic research review is meant to advance a field of study by providing insights from across the literature not contained in individual research papers. It uses a rigorous set of criteria to identify, select, and critically appraise relevant research from previously published studies in order to generate a scholarly synthesis of the evidence in relation to an explicit research problem or question.

For example, a systematic research review could be conducted to generate new insights on the effectiveness of a specific medical treatment, in order to advance evidence-based medicine: published articles on randomised controlled trials for that treatment could be reviewed and a judgement made based on a synthesis of the results from the accumulated body of work.

5.6.7.2 Data collection and analysis

In a systematic research review you only use evidence from published studies and rely on explicit, reproducible methods for identifying the relevant research to review. Specifically, you must decide upfront your research problem/question and the set of criteria you will use to select, compare and evaluate those studies, and combine their results.

The type of analysis you will conduct will depend on the nature of the evidence you are considering and combining. In *narrative reviews*, a narrative synthesis is produced of qualitiative results, while in *meta-analysis*, statistical techniques are used to analyse and combine quantitative results. Combinations of the two are also possible.

5.6.7.3 Evaluation

Evaluation of the systematic research review will involve answers to the following:

1. Reliability:

- Are the criteria used to select, exclude, evaluate and combine the published research explicit and reproducible? Were there any deviations from this protocol and, if so, are they explained, justified and documented?

2. Validity:

    - Has the researcher accessed all relevant published research in the area?
    - Have the relative strengths and weaknesses of the research reviewed been described? To which extent have conflicts between sources been identified and, when appropriate, resolved?
    - In combining results from different studies, are significant differences between those studies appropriately acknowledged?
    - To which extent has a definitive synthesis from the literature been achieved? To which extent are the limits of current knowledge described?
    - To which extent has precision and/or generalisability been improved through the systematic research review?
    - In meta-analysis, to which extent have statistics been used to produce overarching conclusions? Were the studies sufficiently homogeneous for meta-analysis to be feasible?
    - In narrative reviews, to which extent potential bias has been acknowledged and mitigation measures applied?

5.6.7.4 Is this strategy right for me?

You should consider the following points when choosing this strategy:

1. A systematic research review is both systematic and extensive in its coverage of the topic of interest. This requires you to have a very good grasp of the subject area in order to establish appropriate criteria for the selection of all relevant published work, and this may lead to a large body of work to review. If you lack such knowledge of the filed of study or the time to conduct an extensive review of the literature, then you should consider a different strategy.

2. A systematic research review assumes that there is a substantial body of knowledge already published from which new insights can be generated. In emerging research areas, this may not be the case, so

that a systemic research review is unlikely to reach any meaningful synthesis. If there is paucity of literature on your chosen topic, then this strategy is not for you.

3. You need relatively easy access to the academic literature to be able to select the body of work to review, for instance, through a university library with a large research collection in your chosen discipline. If not, you will need to devise alternative ways to access the relevant literature, like contacting the author(s) directly. Although most authors will be happy to send their published research to you, the round trip time can introduce lengthy delays in the research process as you wait for the requested research to arrive. You may also need to be persistent to ensure that a busy author is aware of your research need. If you don't think you will be able to access easily a large proportion of the published work you need, you should rethink your research strategy.

4. Systematic research reviews are required to be transparent, reliable, and easy to replicate. You will be expected to have stated explicit inclusion and exclusion criteria so that another research would be able to arrive at the same collection of published work, and ensure that no inherent bias has influenced such choice. Choosing appropriate criteria may be difficult and may require you to iterate, starting perhaps from a broader focus, then narrowing it down as your research progresses. This, too, can be time consuming, so if your time is limited, you should consider a more time-efficient strategy for your research, perhaps one which allows you to generate your own primary evidence.

5.6.7.5 Further reading

To deepen your understanding of this strategy, you can start from **wright2007write**; **moher2009preferred**; **pollock2018systematic**.

In addition, you should consider the PRISMA statement•, a 27-item check-list whose aim is to help authors improve the reporting of systematic reviews and meta-analyses.

• http://prisma-statement.org/prismastatement/checklist.aspx

5.6.8 Grounded theory

Grounded theory aims at defining theories• on social phenomena based• on empirical data. The intention is for the theory to emerge from the collection and analysis of the data, rather than using the data to confirm or disprove a previously formulated theory, or test a previously formulated hypothesis.

• In simple terms, a theory is a system of ideas intended to explain something.

• I.e., 'grounded', hence the name!

5.6.8.1 Knowledge contribution

Grounded theory contributes knowledge in the form of theories concerning complex social phenomena, striving to provide explanations of people's choices and actions grounded in those people's own accounts and interpretations.

For example, grounded theory could be used to formulate theories on what motivates people to join or leave a particular organisation, or why employees may feel fulfilled or frustrated in their workplace.

5.6.8.2 Data collection and analysis

Grounded theory requires the systematic collection and analysis of data without any preconceived belief or theoretical framework. The data are collected, coded and analysed to identify emerging concepts, categories and relationships. The process is iterated with new data used to review and revise those concepts, categories and relationships until no more can be gained from further data collection and analysis. At this point a theory is put forward based on what was derived from the data. In this process, it is essential to be open to multiple explanations, and to explore the data from all angles in order to gain a fresh perspective.

5.6.8.3 Evaluation

The following questions should be addressed in evaluating grounded theory research:

1. Reliability:
    - Was the process followed to arrive at the theory appropriately described? Was it systematic and iterative?
2. Validity:
    - Were sufficient data collected and described? How relevant were they to the phenomenon under study?
    - Which concepts, categories and relationships were generated by the research? How are they grounded in the data? How do they contribute to the theory?
    - Has the phenomenon been examined under a broad range of conditions and from a variety of perspectives?

- Is the theory plausible in relation to the data? Does it provide sufficient explanation of the phenomenon under study? Is it general enough to account for variation in conditions and context of application?
- Can the theory be easily understood by its intended users? How useful is it in helping them understand their social reality and be the basis for action?

3. Bias:

   - Is there a reflexivity account of the researcher to guard against possible bias?

5.6.8.4 Is this strategy right for me?

In choosing this strategy, you should consider the following:

1. Grounded theory is about letting the "data to do the talking" **drew202310-grounded**, so you should not have any prior belief, theory or hypothesis you wish to put to test. If that's not the case, other strategies are more appropriate, like case studies, ethnography or experiments.

2. Grounded theory requires you to gather a significant amount of empirical data, making sure you examine a social phenomenon under various conditions and from many perspectives. If you do not have access to such data, then grounded theory cannot get started, and you should consider other strategies.

3. Grounded theory is generally time consuming, given the iterative nature of the process of gathering and analysing data. If time is an issue in your project, then you should choose a more time-efficient strategy, like case studies or experiments.

4. Grounded theory aims at generating theories concerning social phenomena. If a new theory is not the aim of your work, then you should choose a different strategy, like ethnography or case studies.

5. Grounded theory is particularly useful when there is a paucity of theories in relation to the phenomena of interest. If there are already several theories available, it is less likely grounded theory will be able to contribute something new. In such cases, you should rethink whether a new theory is actually needed or choose a different aim and strategy for your project.

5.6.8.5 Further reading

To deepen your understanding of this strategy, you can start from **smith1997understanding**; **drew202310-grounded**; **corbin1990grounded**; **strauss1998basics**; **gibson2013rediscovering**; **charmaz2014constructing**.

5.6.9 Phenomenology

Phenomenology is a research strategy that focuses on people's conscious experience of a phenomenon, that is how people perceive and give meaning to it, including any feeling and emotions it evokes.

5.6.9.1 Knowledge contribution

Phenomenology contributes knowledge by providing insights into people's lived experience, seeking to describe or interpret the essence of a phenomenon from the perspective of the people who have experienced it.

For instance, a phenomenological study of patients emergency care could focus on the experience of nurses and doctors in emergency departments.

5.6.9.2 Data generation and analysis

Data generation in phenomenology is primarily through in-depth, unstructured interviews and focus groups, which should allow participants to give their own account of their experience and surface key issues, without being influenced by the researcher. These are often complemented by participant observation, in which the researcher is immersed in the day-to-day activities of the study participants, hence sharing their experience of the phenomenon of interest. Audio and video recording, alongside field notes and journals are used to record data.

Data gathering typically results in a large quantity of qualitative data, which are both detailed and unstructured, so that qualitative methods are then needed for their analysis. The analysis process requires the researcher to set aside any preconception, assumption or bias• and focus solely on the data, considering every participant's statement or expression as equally important and relevant.

• This is referred to as 'bracketing'.

5.6.9.3 Evaluation

The following questions should be asked of phenomenological research:

1. Reliability:
   - Are the criteria for selecting the study participants properly explained and justified?
2. Validity:
   - Is the phenomenon accurately and objectively described? Is the account provided one that can be recognised by anyone who has experienced that phenomenon?
   - How have similarities and differences in the participants' experience of the phenomenon accounted for in the study? How are they dealt with in the data analysis, particularly in the coding and categorisation process?
3. Bias:
   - Is there a reflexive account of how judgments were suspended to focus on the analysis of experience?

5.6.9.4 Is this strategy right for me?

In choosing this strategy, you should consider the following:

1. The focus on phenomenology is lived experience, to uncover what is really like to experience a phenomenon from the perspective of those who have lived through it. If you do not have access to participants who can share their experience, then you should consider a different strategy.
2. Phenomenology asks you to suspend any prior belief on the phenomenon and only focus on the participants' experience. If you have a theory or hypothesis you want to test, then you should choose a different strategy.
3. The amount of qualitative data to gather and analyse is considerable, and this can be very time consuming. If time is an issue in your research, then you will need to choose a more time-efficient research strategy.
4. Phenomenology is about going deep into the experience of a phenomenon, and this constrains the number of participants in your study. If you are more interested in gaining consensus from a large number of participants, or making general predictions from your sample data, then you should choose something else, like survey research or grounded theory.

5.6.9.5 Further reading

To deepen your understanding of this strategy, you can start from **merleau1956phenomenology**; **anderson1991qualitative**; **smith2018phenomenology**; **shudak2018phenomenology**; **academic-educational-materials2019understanding**; **office2020the-phenomenological**; **groenewald2004a-phenomenological**; **hycner1985some**.

5.6.10 Simulation

The simulation research strategy builds an explicative mechanism to imitate or reproduce the behaviour of a real-world artefact or system.

5.6.10.1 Knowledge contribution

Simulation contributes knowledge by allowing the study of the simulated artefact or system under different conditions, in order to answer "What if?" questions, make predictions or gain insights on behaviour or properties, particularly when this can't be easily achieved directly on the real-world artefact or system.

Simulations are used in all disciplines and vary greatly in their purpose, nature and design. For instance: financial simulations are used to study the behaviour of the global stock market; climate simulations to study possible effects of climate change; engineering simulations, to test the properties of materials under different stress conditions; social simulations to study human behaviour in social settings, to name just few examples.

5.6.10.2 Data generation and analysis

Data are needed to inform the simulation design. Their kind and how to obtain them will depend strongly on the nature of the artefact or system under study and what your research aim is, so that all known methods for data generation apply. For instance, to simulate a new aircraft design under different wind conditions, you may need to gather data on the physical characteristics of the aircraft and the materials to be used to build it, alongside meteorological data which can be used to perform tests under different simulated conditions. On the other hand, to simulate how size and age of a population may change in future decades within a particular geographical region, you may need to gather data on current population size and age, birth and mortality rates, migration rates in and out of the region, and conditions which may affect them over time.

Data are also needed to establish measures and criteria to evaluate whether the simulation is sufficiently representative of the artefact or system being simulated. This may involve comparing simulation outputs with empirical data or theoretical predictions, or gathering expert opinions on such outputs, with the aim of establishing the extent expectations are met or significant discrepancies exist.

Whichever methods you use to gather data for your simulation design, once constructed, the simulation should allow you to generate observations of the simulated artefact or system, both past, present and future, the latter being a unique characteristic of this research strategy•. Such observations can then be analysed in order to address the research question, as well as to evaluate the simulation against the established measures or critera.

• All other strategies can only look at the past or the present.

5.6.10.3 Evaluation

Evaluation questions specific to this strategy include:

1. Reliability:
   - Is the simulation design appropriate to address the research problem/answer the research question?
   - Were simulation performance measures or criteria clearly established? How were they chosen and why?
   - How was the simulation constructed? Were the appropriate computational/mathematical/statistical techniques applied?
2. Validity:
   - Were appropriate data gathered to inform the simulation design? How were they chosen and why?
   - How was the simulation tested and improved during its development? Were different testing methods applied and the results documented?
   - How close are the simulation's outputs or behaviours to the real-world data? How was this established? Do the results make sense?

5.6.10.4 Is this strategy right for me?

Is you are considering the simulation research strategy, then you should consider the following questions:

1. The design and construction of a simulation requires advanced computational skills, often alongside mathematical and statistical skills. Do you already have such skills? If not, you are unlikely to be able to develop them in the time of your project, and should consider other research strategies instead.

2. Do I have access to the data, and possibly stakeholders, needed for the design and evaluation of the simulation? Without such data it is unlikely you would be able to build a representative simulation, hence you would not be able to generate valid and reliable results. In such case, you should consider other strategies.

5.6.10.5 Further reading

To deepen your understanding of this strategy, you can start from **dooley2017simulation**.

5.6.11 Mathematical and logical proof

A mathematical proof is a rigorous argument that demonstrates the truth of a certain proposition starting from certain assumptions. As long as the assumptions are true, then an argument is constructed in a way that guarantees that the proposition is also true. Such argument is termed 'deductive' as it starts from the assumptions and arrives at the proposition as the conclusion of the reasoning.

When the reasoning is carried out within a fully formal logical system, then we have a logical proof.

5.6.11.1 Knowledge contribution

Mathematical and logical proofs contribute knowledge in the form of true propositions, which are the means by which Mathematics functions and grows its scope and applicability.

Within a mathematical system, such truths are absolute, something which does not hold in any other scientific discipline: even in the natural sciences and by taking a (post-)positivist stance, truths are always only tentative and falsifiable, in that they hold only until new evidence emerges to contradict them.

5.6.11.2 Data generation and analysis

rethink data gen. here; add inductive and deductive reasoning

In this strategy, it does not make sense to talk about data generation and analysis.

Instead, all mathematical disciplines, relies on sets of assumptions and previously proven propositions which are taken as the starting point to generate, through proofs, new propositions, that is new truths.

5.6.11.3 Evaluation

A new proof is subject to the scrutiny of the community of mathematicians, which employs various means to check both assumptions and reasoning, so as to reach a verdict on the reliability and validity of the proof.

Such means may include using alternative deductive reasoning to check they can reach the same conclusion, using examples in support of the reasoning, or even recreating a mathematical proof within a fully formal system or using a computer-based automated checker, when applicable. You could adopt some of these approaches to improve or defend the reliability and validity of your proof.

5.6.11.4 Is this strategy right for me?

If you are considering this strategy, you should ask yourself:

1. Mathematical and logical proofs only make sense within research which is amenable to formalisation. Is that the case for your project? If not, then the notion of proof may not apply and you should consider an empirical research strategy instead.

2. You will need to be a skilled mathematician or logician to come up with a proof that can withstand the scrutiny of the mathematical community. Do you possess such skills? If that's not the case, then this strategy may not be for you•.

3. Ideally, you should seek formative feedback from an experienced mathematician as you develop your proof, to reduce the chance of mistakes or reasoning pitfalls. Do you have access to such an expert advice? If not, you should discuss with your supervisor to ensure they do have the skills to take up that role.

• One way to determine whether your background is suitable would be to read the first few pages of **lakatos2015proofs** (up to page 9 is available through google books).

5.6.11.5 Further reading

To deepen your understanding of this strategy, you can start from **Kleene1964introduction**; **lakatos2015proofs**; **antonini2011examples**; **johannesson2014research**.

5.6.12 Mixed methods research

The mixed methods research strategy• combines elements of both qualitative and quantitative research, with the aim to increase both breadth and depth of understanding of the phenomenon under study, and

• Mixed-method research should not be confused with *multi-method research*, which simply indicates the use of many methods, possibly all qualitative or quantitative.

corroboration of results, giving more confidence in the conclusions reached. As a result, triangulation is in-built within the strategy.

5.6.12.1 Knowledge contribution

The knowledge contribution is the combination of the knowledge contributed by each of the methods applied, appropriately synthesised by considering connections and contradictions between qualitative and quantitative data.

Mixed method research is particularly suited to interdisciplinary research and to the study of complex situations or social settings, particularly when one kind of method alone would not deliver the desired depth of understanding or richness of results. For example, within urban planning, you may be interested in improving pedestrians' safety, so that a mixed methods study may consider both quantitative data on pedestrian accidents and qualitative data on pedestrians' experiences and perceptions in order to identify both safe and dangerous areas to both learn lessons and plan remedial actions.

5.6.12.2 Data generation and analysis

How data are generated and analysed will depend on how the different methods are combined. Typical combinations include:

- parallel, in which separate qualitative and quantitative methods are applied to gather different sets of data. For instance, your collection of pedestrians' accident data, and pedestrian's opinions may occur in parallel, independently of one another, then the results may be analysed and compared.

- sequential, in which the methods are applied one after the other, with outcomes from the first used to inform the second. For instance, you could start with the pedestrians' experience, then collect accident data on areas which are perceived as particularly safe or dangerous.

- nested (or embedded), in which a quantitative method is applied within a wider qualitative method (or vice versa). For instance, the focus may be primarily on the qualitative pedestrians' experience, within which some statistical analysis is applied, for instance, to look for correlations between such experience and accident data.

5.6.12.3 Evaluation

Evaluation questions for this strategy will include questions on the specific methods which are combined, alongside the following questions on their combination:

1. Reliability:
    - How was the use of mixed methods justified in relation to the phenomena of interest? How has the study benefitted from their combination?
    - Is the way the methods are combined appropriately described?
2. Validity:
    - How were connections between qualitative and quantitative findings established?
    - How were conflicting or mismatched results from the different methods handled?

5.6.12.4 Is this strategy right for me?

If you are considering mixed methods research, you should take the following into account:

1. Mixed methods research requires competence in more than a single research method, which takes time to develop. If your Masters project is your first research project, it is unlikely you will have a developed understanding sufficient to apply the mixed methods research strategy, and you should consider a single method strategy. However, if your work is part of broader mixed methods research, perhaps led by your supervisor, then you may be able to contribute by focusing on the particular method you are being asked to work with.
2. Collecting and analysing both qualitative and quantitative data requires substantial time and resources. If this is going to be an issue, then a strategy with a single method focus would be a better choice.

5.6.12.5 Further reading

To deepen your understanding of this strategy, you can start from **johnson2007toward**; **denzin1978research**; **webb2000unobtrusive**.

5.7 Choosing and drafting your own research strategy

By now you should have narrowed down your list of candidate strategies to few choices, and possibly discussed those choices with your supervisor. It is now time to learn more about them in order to make a final choice for your project.

While the content of this section is brief, the two activities it contains are going to be demanding. It is important, however, that you don't skip them as they provide the foundation for your work in Stage 4.

Activity: Choosing your research strategy #116

For each candidate strategy in your list, consider the references you have recorded in your bibliographical database, and review the related literature in order to learn more about the strategy, and how you it may apply practically to your project.

At the end of the activity reach a decision on which research strategy, or combination of strategies, to adopt.

Guidance

The references we have provided are only a starting point, and you should also explore other literature on the topic. There is a vast literature on research methods, so it is easy to get lost. We recommend you look at introductory materials first to gain a broad understanding, then delve into more specialised literature for some of the details. Your supervisor will also be able to suggest appropriate reading.

As you read the literature, you should take notes to augment the summaries we have provided in the previous section, to capture your deeper engagement and growing understanding of each research strategy. By the end of this activity you should have gained a good general understanding of how it may suit your research.

In your review, you should pay particular attention to possible data generation and analysis methods under each strategy, reflecting of which may be most applicable to your project and how, alongside any risk or other factors which may affect their successful application.

It is not necessary for you to learn the fine details of each method at this point. However, by the end of this activity, you should have a clear idea of which methods you will be focusing on in Stage 4, in which you will engage with the specific procedures to apply those methods in your own project.

Your final activity in this chapter is a writing task: to draft your chosen research strategy, as a starting point for the narrative you will develop during the remainder of your project and eventually include in your dissertation. We recommend you apply the template in Table 5.4 to structure your writing.

Table 5.4: How to summarise your research strategy

Section	**Content**
Choice and justification	Indicate which strategy, or combination of strategies, you have chosen and justify this choice by considering how it aligns with the aim of your research in relation to the way it contributes
Mindset and research paradigm	Discuss how this strategy is consistent with your own mindset, with reference to the research paradigms introduced in this chapter
Reflexive statement	Summarise your own standpoint as a researcher, including specific assumptions, beliefs and potential bias you bring to the research, and the steps you will take ensure they will not weaken your research
Data and sources	Indicate the kind of data you will need to generate and analyse in your project, possible data sources you will focus on and how you will gain access
Data generation and analysis methods	Indicate the selection of methods you intend to apply in your data generation and analysis. Explain why you think they are suitable and feasible
Ethical issues	Indicate all ethical issues relevant to your chosen research strategy, including listing any regulations you may need to comply with, and explicit permissions you may need to obtain to be able to proceed with your research
Research evaluation	Reflect on the potential weaknesses which may affect your chosen strategy, and consider the related evaluation questions from the previous section, alongside other evaluation criteria you may have found in the literature. Highlights those which are most relevant to your project and indicate which actions you may take to address them

Activity: Sketching your research strategy #117

Apply the template in Table 5.4 to provide a first draft account of your research strategy.

Guidance

This first draft will be necessarily tentative, but it should provide a good starting point that you can grow and revise alongside your increasing understanding and practical application of your strategy.
It is important that you engage with all elements of the template, including the evaluation section: although your full evaluation will only be completed at the end of your project, it is essential that you start thinking about the questions you will need to address. This, in turn, will help you ensure that the steps you take in your strategy application are likely to provide satisfactory answers to those questions.

Chapter 6

Stage 4: Generating and analysing data

this section to be done at the end, once we've decided each stage LOs

You've now reached Stage 4, which means the end of your project is now in sight. In this stage you will be in the midst of your data generation and analysis, which is possibly the most exciting, yet demanding, part of your research: this is where you get your opportunity to make that contribution to knowledge.

This stage assumes that you have worked out most of your research design details and are now in a position to begin your data generation and analysis•.

• If that's not the case then you should go back to Stage 3. You should also discuss your progress with your supervisor, revisiting your project timescale and risk.

With reference to our 5-stage framework, the activities which are in focus in Stage 4 are summarised in Table 6.1, which also provides some guidance for your interaction with your supervisor during this stage.

Activity: Understanding the effort needed in this stage #118

Consider Table 6.1 carefully, paying particular attention to the entries in the 'Effort' column. Make a note of the activities which are most prominent in this stage and what their deliverables and learning outcomes are.

Discussion

Generating and analysing evidence will constitute by far your major effort in this stage (50% of study time): in particular, the framework assumes that you will have worked out the details of your research design in Stage 3, so you can focus on applying your data generation and analysis methods. You will also start to interpret you findings, an activity your will complete in Stage 5.

Table 6.1: Research activities addressed in Stage 4 (20% of project length)

Research process activities	**Deliverables**	**Learning Outcomes: by the end of this stage you will:**	**Effort**	**Suggested focus of your interaction with your supervisor**
Identifying the research problem	Research problem statement, refined as needed	be able to assess and improve your research problem statement	1%	
Reviewing the literature	Substantial draft of your literature review, refined as needed	be able to assess and improve your current draft	1%	
Setting your aim and objectives	Aim and objectives, refined as needed	be able to assess and improve your aim, objectives and related tasks	2%	
Developing the research design	Research design description, refined as needed	be able to describe data generation and analysis procedures in detail	2%	Suitability of methods and procedures
Generating and analysing evidence	Raw data appropriately organised and stored; data summaries and outcomes of data analysis	know the difference between various sampling approaches; be able to organise and store your raw data; be able to apply appropriate data analysis methods; be able to present your data and evidence in a concise and effective way	50%	Appropriateness of data analysis and presentation
Interpreting and evaluating findings	Draft summary of findings from data/evidenced generated	be able to derive findings from your data analysis and critically assess them in relation to research aim and objectives	15%	Critical and logical thinking
Reflecting and reporting	Stage 4 report; draft abstract for your project	know the purpose and content of an abstract; be able to assess your research progress and write up a substantial report, including an abstract for your project	25%	Any further improvements required, particularly in relation to critical thinking and academic writing
Planning work and managing risk	Updated risk and work plan	be able to assess risk and draw a work plan	5%	Any major adjustment required to address deficiencies or manage risk

Note that your data analysis and interpretation may also prompt you to generate more data, including, perhaps, reviewing more academic literature or even re-thinking or adjusting your aim an objectives better to reflect your improving understanding. Therefore, so you should expect some iteration back to activities you have carried out in previous stages, and revision of things you have written.

6.1 Raw data

Your *raw data* represent any data you generate and analyse as part of your research, which in turn will be determined by the choices you have made in your research design, informed by your research aim and objectives. In this chapter, we look at methods you can apply to generate and analyse your data. For each method, we provide:

- a brief description of the method;
- key procedural consideration you should take into account;
- other important issues, particularly in relation to threats to validity or feasibility within your project;
- further sources to consult for more detail.

When we say "data generation", we don't necessarily mean that you will create a new-to-the-world "data"•. We simply mean new-to-your-masters-project data, which covers a multitude of sins, including:

• Although this might indeed be the outcome of your data generation.

- the creation of a brand new data set, which did not exist before your research project. This may be the result of data collected through new observations or measurements, a new survey, questionnaire or focus group, through selecting passages from documents, etc.
- the extension of a previously collected data set with new elements, derived from those that already exist, for instance adding the mean value of a collection of numerical data, or grouping together specific distinct data into new categories that you have created;
- the collection of previous data for reinterpretation, for instance if you are rerunning a previous experiment in order to confirm its results, or doing a meta-analysis of the literature in a particular area.

Our use of the term data generation includes all of these. Of course, in making a contribution to knowledge, you're going to have to do it regardless of the data generation method and so the data you generate as part of your research must allow you to conclude something new.

Related to data generation is the concept of "data source", which is the location from which your data originates. If you are re-using existing data sets, this may well be an archive or a digital repository. For new data sets you generate, this may well be the experimental or real-world setting of your own observations and measurements, or a population of interest from which you will derive a "sample" for further analysis. The latter underpins many data generation methods, so that we will consider sampling in some detail next.

6.1.1 Sampling: what, who (and how) to choose

Sampling is the process of selecting a subset• for further analysis from a population of interest.

Sampling assumes that there is a "sampling frame" as data source: a sub-set of the collection of the population of interest from which your sample is taken. In some sense, you have already experienced sampling as part of your literature review•. Unless you had infinite amounts of time – which you didn't – and infinite patience – which you might have – you could never be 100% certain that your literature search collected *all* relevant papers: the search space is infeasibly large (and not indexed particularly well). But you were systematic and achieved a practically good• coverage because of that.

More generally, sampling is used when we wish to study a population of interest, but this is infeasibly large or inaccessible for us to be able to study every single member of it. Instead, we choose a sample which is somewhat representative of the population characteristics, hoping that by studying the sample we can establish some properties or patterns of interest which can be assumed true of the population as a whole.

Broadly speaking, sampling can either be random or non-random.

In *random sampling*• some unbiased way of choosing the subset members from the population must be established upfront to inform sample collection, which is usually completed prior to any analysis. This is used particularly in quantitative research, and when generalisation of the results to the population is of primary importance, something enabled by the lack of bias in the sample selection process.

Instead, in *non-random sampling*•, the sample choice is based on the researcher's judgement and discretion, so that some element of bias may exist. Members can be added to the sample as the research progresses, interleaving data collection and analysis, until not more collection is possible or *saturation* is reached, that is collecting more data would not bring extra relevant information. This kind of sampling is used particularly in qualitative research, where depth and richness of results are more important than the ability to generalise.

Random sampling techniques include:

• We could have said "sample" but that would have been circular.

• You might remember the relatively complex procedures for recording search terms, discovered papers, their relationships, and your growing collection of notes on them.

• By *practically good*, we mean you found the most of the most important papers, some other papers, and didn't have to read *every single paper*. I.e., you found a *representative sample*.

• Random sampling is also called *probability sampling*.

• Non-random sampling is also called *non-probability sampling*.

simple random sampling where each member of the population has exactly the same chance to be selected. It has the advantage that it is easy to implement, and given the complete randomness of the sample, generalisation is fairly reliable. However, it can be time consuming if the population if very large, and may not lead to a representative sample if the population has large sub-groups, which may be over-represented in the sample, with minority groups being under-represented.

stratified random sampling where sub-groups of the population are identified based on common characteristics, the *strata*, and sampling is random across those strata. The strata are not mutually exclusive: for instance, the population may have sub-groups defined by gender, ethnicity and level of education, which may overlap. This approach overcomes the over/under representation problem of simple random sampling; however, deciding on the strata may be difficult and will also complicate data analysis.

cluster sampling where the population is divided up in naturally occurring separate clusters, and the sample is obtained by randomly selecting some clusters and then randomly selecting members of those clusters. It is more cost-efficient than the other two approaches, but can introduce bias if the selected clusters are not representative of the whole population, so that the over/under representation problem remains.

Non-random sampling techniques include:

purposive sampling in which participants are selected by the researcher based on particular characteristics, knowledge, or expertise they have. It is often used for small, rare or unique populations, and is particularly suited to studies which intend to be deep and narrow, and for which generalisation to the population is not the main concern. As the sample choice is made by the researcher, it is prone to bias. However, it also allows the researcher to involve participants who can provide insights into such rare or unique groups.

convenience sampling where participants are selected based on their availability or accessibility. This is quick and easy, but unlikely to produce a representative sample, so, once again, bias is an issue.

snowball sampling which relies on referral from previous participants to recruit new ones. This is an effective approach when a population is difficult to access or when the topic is sensitive or tabu. This too is unlikely to generate a representative sample, and is prone to bias. However, it is a way to gain access to members of a population which may be otherwise inaccessible.

In summary, when choosing a sample, you need to consider various factors, including the aim of your study, the kind of methods you are applying, and the level of access you may have. Trade-offs are likely involved and you may not be able to obtain an ideal sample. Nevertheless, your sample will still be useful to your research, as long as you clearly explain and justify how it was obtained and what its limitations are.

Activity: Deep reading on sampling #119

Check back to your choice of research strategy. If you've chosen one which may require sampling, then you should go deeper into this topic to ensure you select the right kind of sampling for your study. We recommend you start by reading the following: **<empty citation>**

Guidance

The suggested reading is only a starting point. You should go deeper into the specific kind of sampling you are most likely to apply.

Activity: Your chosen sampling approach #120

Assuming your study requires you to perform some sampling, write down the sampling approach you are going to apply, with its justification in terms of your aim and objectives, and any trade-offs due to the practicality of accessing the sample. Record any possible weakness or limitation of your chosen approach, and how you will address them in your project.

Guidance

You can skip this activity if sampling is not required by your choice of research strategy.

6.1.2 Modern standards

Modern standards of research often require that your data be made available to other researchers so that your research can be verified or even rerun. In fact, it is increasingly the case that data sets are published and shared by entire research communities, often used as testbeds or benchmarks for new knowledge contributions. For instance, in medical applications of Machine Learning, in which new knowledge can be the fractional improvement of the performance of an AI algorithm to, say, diagnose a medical condition from images, not being able to share the data set you have used in your research can negate your knowledge contribution. Therefore, you should consider whether your data (or a sample of it) should appear as an appendix to your dissertation, or whether they should be made available in their entirety to your examiners, or even to the wider research community, and how.

Modern standards of research also require you to comply with regulations on data privacy and protection•, so that as part of your data generation process you should also consider the need to anonymise data• without losing their research value for your project or the need to release commercial in confidence or otherwise sensitive data.

• We discussed GDPR in Section **??**.

• There may be a route to your degree in which your thesis is not published. Should you have any concerns about the release of data, please do find time to discuss this with your supervisor, balancing the needs for total anonymity with those than can be achieved through data anonymisation.

6.1.3 Managing raw data

Before proceeding with your data analysis, you must ensure your raw data are properly organised and stored, so that you don't loose track of important information, and you can easily locate and refer back to appropriate data during your analysis and when writing up your research.

It is highly likely that your raw data will be in some digital form. Although techniques for doing so are outside of the scope of this book, your digital data storage should be secured against data loss either due to technical issues, such as computer failure, or due to a data breach, such as through cyber security attacks, at least to the standards required by law, any additional requirements made by your organisation, those of any participants, their organisations, and any other stakeholders•.

• Once upon a time, in a galaxy far, far away, data generation and storage used to be a *laissez-faire* thing. Today, your university or employer can be fined vast amounts of money for any data misuse, so they tend to take it more seriously. If data loss were to happen, amongst other things, it'd probably means you'll fail your degree.

It is also important that you put your raw data in a form which is useable for analysis. Spreadsheets are particularly useful for this purpose, especially if your data is quantitative, so that this is a common way to organise and store raw data. In fact, most publicly available data sets used in research and beyond are stored as spreadsheet files: if you are going to use one such data set, then your raw data are likely already organised for you!

Spreadsheets organise data in rows and columns, so that you can easily enter your raw data using rows for your observations/measurements and columns for your variables. As we will see later on•, spreadsheets come a wide range of functionalities for data manipulation and for some level of data analysis. They are also easily extensible, so that you can grow your data sets incrementally.

• See Section ??

Activity: Organising and storing your raw data #121

Consider the data and evidence you have collected or are planning to collect. List the actions you have taken/will take in relation to:

- organising your raw data
- storing and backing up your data
- protecting personal data

Make sure you complete those actions as you generate your data, and before performing any data analysis.

6.2 Data generation methods

In this section, we step through the most used data generation methods – those that were mentioned within the research strategies in Stage **??**, i.e., Interviews, Journalling, Observations, Questionnaires, Documents, Focus groups, Field work, Computational thinking, Mathematical thinking, and Statistical thinking.

cross-check with stage 3 if this is the full list

Most of these methods concern *empirical data*, that is data that is gathered through our five senses or from experience, and then used as the benchmark against which theories and advances in knowledge are made.

6.2.1 Observations

Observations constitute one of the main ways in which empirical data are generated•. In fact, according to **marvasti2014analysing**, "Observation is the foundation of science."

This method requires the researcher to make their observations• of phenomena of interest. What you will observe are core characteristics of the phenomena that you have identified as part of defining your research problem.

• Whole books have been written on observations as a research method; we can give but a shallow introduction. Further sources you can use are included at the end of this section.

• Hence the name...

Activity: Do I need to know about observations? #122

Check back to your chosen research strategy from Stage 3. Does it involve data generation using observations? If so, read through the remainder of this section and complete the activities.

Observations can be made directly, through our naked senses, or through instruments which enhance our sensory capabilities, such as a telescope, a microscope or the "a myriad of other ingenious inventions designed to make the invisible visible, the evanescent permanent, and the abstract concrete" **daston2011introduction**. Quantitative observations, say, the size or weight of an object, are usually referred to as 'measurements'.

What to observe Observations are versatile tools for almost any research domain, and your own domain will determine what sort of observations you will make. Observations range across natural phenomena – such as the different proportions of plant species that populate a wilderness garden – through to artificial phenomena – the way that buses drop off and pick up their passengers at a train station – and to social phenomena – the different ways in which a train station is used by commuters in the morning and the evening – as well as more complex combinations of each. Each will use different observations techniques and tools, and each with different constraints.

Observation types Observations can be *naturalistic*, when phenomena are observed as they happen in their natural setting – for instance, observing the behaviour of animal species in their habitat, or *structured*, when phenomena are observed in a somewhat artificial environment, such as during an experiment – for instance, giving people a specific task to perform and observing how they carry it out. In this case, often the aim is to collect quantitative data, say the speed at which the people can complete the task.

More on social observations As an observer of people, you can act as either a *participant* or a *non-participant* observer. The former is a researcher that interacts as a member of a community under observation, becoming an active participant in the group or situation under study. In effect, as a participant observer, you would be "living" alongside those you observe – you might be a commuter that uses the train station and so share the experience of the other commuters you observe. Instead, in non-participant observation, you would remain separate from the group or situation being observed – you may observe commuters using the train station, but not actively become one of them.

Depending on whether people are or not aware of being observed, observations can be *covert* or *overt*•. Covert observations have the advantage that people's behaviour is not affected by their awareness of being observed, but, of course, they raise some important ethical and legal issues, in relation to informed consent, and privacy and anonymity. If the judgement is that the phenomena observed do require privacy – perhaps you wish to observe commuters' use of restrooms in the train station or customers in a betting shop – then you must explicitly ask for permission – or change your research problem! Otherwise, in a public space, there may be no overriding expectation of privacy and observations can be done without explicit consent.

• The terms disguised and undisguised are also used in the literature.

Your university is likely to have strict regulations on the matter, or even prevent you from conducting covert observations as part of your research.

6.2.1.1 Procedural considerations

In order to apply this method, some preparation is needed for you to decide what you will observe as how. Specifically:

Phenomena You will need to decide which phenomena to observe, whether natural, artificial, or social: this choice will depend on your research problem, and aim and objectives.

Kind of observations Depending on the phenomena, you will need to decide whether you will perform naturalistic or structured observations. In addition, for social phenomena, you will need to decide which mode, whether participant, non participant, overt or covert. For the latter, you must also identify the steps you will take you ensure compliance with ethical and legal guidelines.

Time and place For all kinds of observation, you must determine the time and place at which those observations will be made. For participant observations, this choice will be determined by your participation in the group or activity being observed, which may or may not be under your control. For instance, if you are a participant observer of train station usage, then you can determine when to use the station and make your observations. However, if you are a participant observer in a change project within your organisation, then the timeline of the project will determine when your observations can take place. In all cases, you should draw a schedule which establishes the timing and frequency of your observations, and which provides an efficient way for you to conduct your observations. For instance, it may be that you make exaggerated use of the train station• to condense many months of participant observation into weeks or days – after all, your research project is time bounded – perhaps visiting ten times per day rather than just two.

• You could eat there, for instance, or use any shops that are colocated.

Use of instruments You may be able to make your observations using only your senses. However, many phenomena do not permit observation through the senses unassisted – for instance, the search for exoplanets• requires complex and delicate instruments which will be located on mountain tops. In this case, the availability of the equipment you will use will determine when and how you make your assisted observations — you will also need to gain access to the equipment, and this will constrain your schedule and may alter your research plans•.

• For instance, **jones2008exoplanets**. But don't let this exciting mission to explore strange new worlds; to seek out new life and new civilizations; to boldly go where no one has gone before distract you. Too much.

• Remember, plans never survive first contact with reality, so also plan to have a backup plan that you can use should your first plan to make your

How to record observations It is important your record what you directly observe, separate by any added interpretation• to avoid possible bias affecting recorded observations. To this end, observations are typically recorded in notebooks with a double entry, which separates pure observations from possible value judgements made by the observer – for instance, observing someone "waiting impatiently for the train door to open" is ascribing feelings to the person observed which, by their nature, are hidden from the observer, but may be inferred from the observed's body language. By separating them out, another researcher reading your notes can clearly differentiate direct observations from such inferences. In some cases, you may be able to use audio and video recording, say using your smart phone, to capture your observations for follow-up analysis. In this case, ethical issues in relation to privacy and informed consent also apply.

• That should happen later on, as part of your data analysis.

6.2.1.2 Other things to think about

Observations are by no means an easy way of generating research data, and there are many issues that can arise, including:

Hawthorne effect Overt observations can lead to the so-called Hawthorne effect•, which consists of people changing their behaviour due to their awareness of being observed. This can be mitigated by building a rapport, including spending more time with the people being observed, observing them for longer periods of time, and, in case of structured observations, by ensuring that the tasks participants are asked to do come natural to them.

• This term was coined in the 1950s in relation to a productivity study carried out at the Hawthorne Works, an electric plant in Chicago.

Observer bias All observations can be influenced by the observer's own bias, whether implicit or explicit, or the result of overfamiliarity with the phenomena of interest. To guard against it, triangulation should apply, including using different data sources and collection methods, or having multiple observers all following a standardised procedure. The use of double-entry notebooks, as described above, can also help, as they separate pure observations from interpretation and inferences made by the observer, with the latter being the subject of scrutiny for potential bias.

Volume of observations Observations can lead to vast amount of data to analyse. Different analysts, or different stages of analysis as your research progresses, may focus on different aspects of the same data. This can be a good thing should your analysis deepen due to understanding more about your observations, but may also lead to analysis drift or even "paralysis through analysis" in which no progress is made due to too much depth. To avoid this, keep a clear eye on the prize: your research goal, and set regular times at which you can reflect on progress.

6.2.1.3 Further reading

Activity: Deep dive into observations #123

To find out more about observations, take a look at these resources:
daston2011introduction;
marvasti2014analysing;
simpson2003using;
driscoll2011introduction;
angrosino2003observations;
sapsford1996data

6.2.2 Questionnaires

Questionnaires• are versatile tools for generating data from participants by asking questions•. They allow a researcher to collect participants' answers about their attitudes, preferences, opinions, behaviours, etc. You might use a questionnaire as a way of collecting statistically significant responses from a population sample, but there are other uses as well, for instance as the basis of interviews•.

- • Questionnaires are just one in a rich collection of *survey tools*, others of which are described below.
- • There's a hint in the name – *question*naire – although why two "n"s; does no millionaire, billionaire, or debonaire use them?
- • Which we cover in the next section.

Activity: Do I need to know about questionnaires? #124

Check back to your chosen research strategy from Stage 3. Does it involve data generation using questionnaires? If so, read through the remainder of this section and complete the activities.

If you do use a questionnaire, its thoughtful design is of critical importance. Otherwise, you might be asking your (willing) respondents to spend a considerable amount of their valuable time answering questions the content of which are not helpful for your research. As they might not be so willing to help a second time, getting the questions right• the first time is important.

- • Often called *questionnaire design*, although this conjures up glossy format and whizzy web-pages which is of secondary importance. Unless, your questionnaire is about the design of questionnaires, of course.

Administering questionnaires is nowhere near as difficult as it used to be as the number of online resources for doing so increases. And, probably because of this, there are plenty of resources in the literature and online to help you design your questions. Their descriptions can be a little technical, however, so the following glossary might help you engage with them better.

Essential questions This the smallest possible set of questions you absolutely need to ask to address your research aim and objectives. While using several questions will give you richer data sets, long questionnaires tend to put people off, so that fewer people may be willing to participate.

Profiling questions These questions ensure that your respondents match specific characteristics you are interested in: say, you are studying the usability of a new product, then you will need to know the extent your respondents have engaged with that product. This is particularly the case if you are running a large survey and don't know who is going to respond.

Demographic questions These are often used so that you can then compare answers across different sub-groups, say, based on gender, age or ethnicity, etc.

Response options Questions are broadly divided into *closed* and *open*-ended. Close questions restrict the possible responses to a set of given choices, while open questions allow respondents to use their own words freely to answer the question.

6.2.2.1 Procedural considerations

Using tools While you can design your questionnaires from scratch using your word processor, there are plenty of specialised digital tools, many of which are free, that can make it a lot easier•. They usually come with: templates and pre-defined question types that you can customise for your study; statistical analysis and data visualisation features that you can apply to the data you have collected; export functions that allow you to save the data to a spreadsheet for further analysis. Overall, if you need to develop questionnaires for your research, they can really help you speed up the process, so that it's well-worth the investment of time in climbing their learning curve.

• Examples include: add list here and URLs.

Drafting, testing and piloting Unless you have many years of experience in questionnaire design, your first questionnaire draft will be far from suitable. Indeed, releasing your first draft without further thought may lead to you not only generating no useful data from it, but also putting off your audience sufficiently that they may not be willing even to look at your second version. So, once you have a first draft of your questionnaire, you should test it and refine it.

Early testing can be done by asking a friend, a family member•, or a colleague to work through the questions, provide their answers and any other feedback they might have. This will give you early indications of problems with your questionnaire•, which you can spot, for instance, if the respondents are confused – which may point to a lack of clarity in the questions – or hesitant – which may point to a poor choice of response options or to inappropriate scales – or disengage before completion – which may point to too many questions being asked. Be sure to loop back to those that have helped you to check that you have addressed their comments.

• Probably, but not always a friend:)

• Although it's sometimes difficult, you'll make more progress and more quickly if you think of the questionnaire as imperfect, rather than you. You can then apply comments – even if they are negative – to the questionnaire rather than having a personal emotional reaction to them. For each comment, make sure you understand how it can be addressed in your questionnaire. This last tip also means that you can welcome (but ignore) comments that can't be addressed.

Later in the process of designing it, however, you should take expert advice including, of course, that of your supervisor, to get to the final agreed form. In addition, you could pilot your questionnaire on a small number of respondents first, then revise it as necessary before using it more widely.

6.2.2.2 Other things to think about

In designing you questionnaire you should pay particular attention to the following:

Plain language Your questions should be clear and plain, and you should avoid jargon and idioms, to ensure your participants understand what you are asking, particularly if not native speakers.

Unbiased language Your questions should also be objectives, that is you should avoid any judgemental term or tone which may reveal your own opinions or believes, or influence participants to answer in a particular way. You should also avoid questions which make assumptions about your respondents' habits or behaviours: for instance, asking participants what they eat for breakfast, assumes they all take breakfast, which may not be the case.

Double-barrelled questions Also termed "compound", these are questions that ask more than one thing, while only allowing one answer. These should be avoided as it would be difficult, if not impossible, to establish in your analysis which part of the question each participant has answered. Instead, you should split the question into separate questions each addressing a specific thing.

Closed and open questions For your closed questions you should ensure that the possible answers provided cover all possible options• and do not overlap, that is they are mutually exclusive. Instead, for your open questions you must ensure they are sufficiently constrained so that your participant's answers don't end up being too vague or off topic, hence not providing much value to your research.

• Or, at least those you're interested in.

Scales If your questions require participants to estimate or measure something, you need to worry about both validity and reliability when setting up the scales for possible answers. In this context, validity means that the chosen scale should allow respondents to measure something accurately; while reliability means that, under the same conditions, respondents will be able to come up consistently with the same (or very close) measurements.

Question grouping, ordering and flow You should group related questions• together, and establish a logical flow in sequencing groups of questions, so that topics follow naturally from one another. Question order in each group also matters: as a rule of thumb, simpler questions should precede more complex ones.

• For instance, those intended to establish a demographic of respondents.

6.2.2.3 Further reading

Activity: Deep dive into questionnaires #125

To find out more about questionnaires, take a look at these resources:
oates2008researching;
hays2003case;
burns2009action; **mcclure2002common**;
najafi2016observation;
robertson2002automated;
kielmann2012introduction

6.2.3 Interviews

Interviews are a method for generating data from participants by asking questions and recording detailed answers. They are a form of conversation between the researcher and one or more interviewees, designed by the researcher to gain insights and opinions on a specific topic. The researcher guides and controls the conversation and asks the questions.

Activity: Do I need to know about interviews? #126

Check back to your chosen research strategy from Stage 3. Does it involve data generation using interviews? If so, read through the remainder of this section and complete the activities.

The personal approach that is a characteristics of interviews means that they are a great way of accessing a (group of) individuals' feelings, thoughts, ideas, and/or experiences, data that can be difficult to generate in other ways. They can help you obtain detailed information on a specific issue or topic, asking open-ended questions which may be tackled or interpreted differently by different interviewees. They are also an effective way to investigate sensitive issues or privileged information that interviewees may not be willing to commit to writing.

Interviews can also provide direction for new research by giving expert indications of where problems lie in a particular domain. As such, interviews can often be used as a way into a discipline, filling in useful background through personal experiences, and having access to otherwise difficult to access information.

There are three main kinds of research interviews:

The structured interview serves as a repeatable framework by which each participant is asked the same questions in the same way. There is no scope for deviation from the structure, so that auxiliary questions and follow-ups are not used.

Structured interviews are the closest to being time bounded and predictable; if you only have 8 hours to conduct 24 interviews for instance, a structured interview would be the best way to achieve this.

Your skills as an interviewer will be tested by structured interviews: it is often difficult not to stray outside of the structure when an interesting answer is given, and you may have to cut a participant short if their answers overrun or diverge from the structure•.

• In our experience, this is a perennial problem, so don't underestimate the difficulties you will face as an interviewer.

The semi-structured interview serves to identify areas of interest to the researcher, with interesting responses being welcomed and followed up if appropriate. Interviewing a domain expert on your chosen topic would be well-served by a semi-structured interview as their expert knowledge could be probed with follow up questions.

The semi-structured interview does not naturally time-bound the interaction, and so – if you don't have unbounded amounts of time – you will have to balance the breadth of questions with the depth of responses.

The unstructured interview has no structure to constrain the route through the data that the interviewee wishes to take, although the interview may begin with the same question each time. As the direction may wholly be decided by the participant, you challenge may be retaining forward motion and focus during the interview.

6.2.3.1 Procedural considerations

Main factors to consider in interviews include:

Interview type In being standardised, structured interviews make it easier to compare your interviewees' answers objectively. However, interviewees are limited to the set questions, so there is no scope for digging deeper into their answers. If you need deep insights, you should use the less structured interview forms which allow you to probe your participants responses.

If you have a good level of domain knowledge, you can use the less structured interview models, as you will be able to follow your participants' answers more easily and direct their comments towards your research interests•. If you don't already have a good level of domain knowledge, then you will be putting more effort into the design of the interview, so that you can simply capture your participants' responses to your – well-designed – questions.

• Of course, you can always use structured interviews even if you do have domain knowledge – there's nothing to stop you.

Whom to interview You will need to choose your interviewees carefully. In the perfect case, you should interview until the responses you are receiving are "guessable"•. Practically, you will have limited time and resources, and limited access to interviewees, so that sampling may be required: in such case, you should follow the advice on sampling in Section 6.2.3.

• I.e., you no longer get novel answers to your questions, indicating that the topic has been covered.

Ethical and legal matters Your university will have strict guidelines on how to approach and work with human participants, which you should investigate before you contact your potential interviewees. At a minimum, those guidelines will cover informed consent, handling personal data, and health and safely, but they may also prevent you from interviewing certain groups of people, for instance minors or vulnerable adults. You should go back to the advice in Section **??** to refresh you understanding of ethical and legal issues in research.

Testing and reviewing You can apply some of the advice in Section 6.2.2 in relation to designing your interview questions. Once you've drafted your interview questions, you should do a dummy run of your interview with a willing friend, family member or colleague, and use their feedback to improve your questions•. In particular, you should consider:

• Repeat this with as many willing participants as you can until you're happy with the interview format or until you run out of willing participants, or time! Make sure that you do not dip into your target population for these preliminaries.

- whether you were able to put the participant at ease during the questionnaire. If not their nervousness might influence their ability to contribute, and you should consider what to do differently
- which questions worked well and led to useful responses, and which were confusing or led to unhelpful answers. For the latter, you should consider how to reword them – perhaps with the help of your participant•, by having alternative versions of the questions, or by removing or replacing the questions
- (if time constrained) which questions overran, and whether you can rephrase them to be less "open"
- (if structured) whether were you able to keep to your "script". You should reflect on how will you resist the temptation to probe more deeply, or whether you should to consider moving to a semi-structured or unstructured form
- whether the questions were in a logical order, ideally they grouped by topic. If not, consider re-arranging them to build responses in the most productive way
- whether you have sufficient questions to elicit the data you need, or there other questions you should ask

• "I would have asked it this way"...

Once you are satisfied with your questions, you should run them past your supervisor – they will be sure to have comments.

Recording answers You need to decide how you will capture your interviewees's answers. If you are planning to use audio or video recordings, you will need to ensure your participants are aware and give their explicit consent. If not, you will need to take notes manually. In this case, you should also test your note taking, to ensure you are able to capture everything of interest•.

• Longhand notes can be taken at 35 words per minute; spoken text is often as fast as 120 words per minute.

Where to hold the interview With the advances in video conferencing technology, interviews can be conducted effectively online, with the added bonus that they can be easily recorded, often with transcripts automatically generated. However, interviews in a physical space where you are colocated with your interviewee, remain common. For these, you will need to ensure that you have an appropriately comfortable venue for your interview, including access to comfort facilities. Public spaces – where you could share a coffee, for instance – may create a more immediate feeling of intimacy, and so deeper responses, but they may not be suitable for discussing sensitive issues or if background noise might interfere with your record keeping. Therefore, make sure to check the venue out at the appropriate time of day to ensure it is appropriate for the interview and a recording device can handle any difficulties.

Opening and closing interviews As part of giving their inform consent, interviewees should be fully aware of what you are trying to achieve in your research and what the purpose of the interview is within it. They will also be interested in how you will use their answers, and should be reassured as to any use of confidential information or personal data. It is therefore good practice to provide this information at the start of your interview, or even as part of inviting them to participate: perhaps share a sheet which includes this information and describes the research you are doing. At the end of the interview you should also thank them and explain what will happen next, including how they can get in touch if they have any further concerns and follow up questions.

6.2.3.2 Other things to think about

Making a checklist There is lots to think about when preparing and conducting interviews. Have you made all necessary arrangements to conduct the interviews? Did you obtain all necessary permissions, including informed consent? Do you know how you will record the answers? What would happen if your audio recording device went wrong? Would you have a backup for the interview? What if you forgot to turn it on?• Write a checklist of instructions for yourself to follow before and after each interview, so that you can be sure not to miss anything important.

• Oh so easy to do...

Being a good interviewer Try, to the extent possible, given the format, to allow your participant to govern the speed and direction of the interview. Allow them to talk in complete sentences without interruption, or have a good reason to interrupt. If you need to interrupt, apologise for doing so and tell them the reason why you have done so•. Be polite and encouraging, as your participant might be nervous.

• "I'm sorry to have to interrupt, but we only have 5 minutes left and ...".

6.2.3.3 Further reading

Activity: Deep dive into interviews #127

To find out more about interviews, take a look at these resources:
oates2008researching;
johannesson2014research;
secor2010social;
hays2003case;
mcclure2002common;
peoples2020write;
jorgensen2001grounded;
hycner1985some; **englander2012interview**; **ramsook2018methodological**;
robertson2002automated;
kielmann2012introduction

6.2.4 Focus groups

Focus groups engage participants in interactive discussions to develop an understanding of complex phenomena and generate new hypotheses for further research or practice. They are effective at surfacing a full range of perspectives held by the participants and, through their interaction, expand on their individual contributions. They are particularly useful to uncover data and ideas that may not come up in one-on-one interviews, and are generally a more efficient way of collecting data than multiple interviews.

Activity: Do I need to know about focus groups? #128

Check back to your chosen research strategy from Stage 3. Does it involve data generation using focus groups? If so, read through the remainder of this section and complete the activities.

Focus groups include participants who share some common characteristics or interest. They are moderated, often by the researcher, so that they combine elements of interviews and observations alongside the group discussion. The moderator plays a crucial role in facilitating group processes, maintaining focus, and controlling participant interactions. Depending on the research aim, it might be necessary to run a series of focus groups so that trends across different groups can be identified.

There are different flavours of focus group. For instance, there may be two moderators with separate roles, say one looking after the procedures, the other focusing on the discussion, or both contributing to the discussion, but taking opposite sides or one playing devil's advocate•. You could have a two-way focus group, in which there are actually two moderated groups each listening to each other's discussion, with a view to stimulate richer insights through rebuttal or further elaboration of ideas. You may also reduce the number of participants to create a more intimate 'mini' focus group.

• The term 'duelling moderators' is used in this case.

To optimise data collection from focus groups, careful attention must be paid to the composition, size and number of groups, selection and training of the moderator(s), and development of the questions used to guide the group discussion.

6.2.4.1 Procedural considerations

Group type Depending on your research aim, you should decide which kind of focus groups you will need, including whether more than one moderator is required, or if a series of focus groups would be desirable.

Group size The number of participants in a focus group is usually from between 8 to 12 participants•, although other sizes work too, the smallest useful size being 4 to 8 for 'mini' focus groups. Anticipating subject loss, you should over-recruit participants by approximately 25%.

• Is a 12-person jury simply a focus group?

Participants The purpose of a focus group is to obtain data regarding ideas, attitudes, understanding, and perceptions on a specific topic, and choosing participants that can contribute to this purpose is an important part of identifying the right participants. Participants should therefore be selected based on their experience and interest in the topic, rather than through random selection. Although the potential range of participants might be limited by context – you may need them to be selected from a small organisational group – the choice should be made so that they come from as diverse range of backgrounds, views, and experiences as possible. Participants should not, however, be chosen to be individuals suggested by fellow group members.

Moderation A skilled moderator is needed to guide the discussion. Moderators' key qualities include empathy, positive regard•, being able to use of pauses and probes effectively in the group discussion, and

• This denotes a general affirming caring, and supportive attitude.

exercising control in an unobtrusive manner. If you do not have access to a skilled moderator, then accessing moderator training for yourself might be desirable•.

• There are videos purporting to guide moderators on youtube.

Location Focus groups can be run online or participants can be physically co-located. For the latter, placing participants within an uncomfortable environment is likely to lead to negative outcomes. Given that a focus group might last for an extended period, appropriate timing should also be considered, with access to comfort facilities, etc., and an explicit timetable which includes breaks.

Choice of questions Focus groups are sometime referred to as group interviews, in the sense that the moderator seeds and controls the discussion by asking questions. It is important therefore that you consider which questions to ask, including opening questions to get the discussion going, or questions to probe further and to ensure all participants get involved. Open-ended questions are the norm in focus groups as the intention is to elicit insights, attitudes, opinions and perceptions.

Discussion etiquette You will need to establish an etiquette for the group discussion, including expected participants' behaviour, for instance in addressing each other, taking turns when speaking, whether mobile devices should be switched off, etc.

Recording the discussion Usually video or audio recordings are used to record the group discussion, so you will need explicit consent from the participants. Note taking is possible but only if there are separate moderators and recorders.

6.2.4.2 Other things to think about

Groupthink The point of a focus group is to elicit diverse views from participants, so it is important to be wary of *groupthink*, a tendency to conform to majority opinion to maintain unanimity and avoid confrontations, and which may inhibit discussion and the expression of diverging views. As a moderator you can mitigate against groupthink by asking probing questions, ensuring that a plurality of views are expressed, or playing devil's advocate in relation to prevailing ideas.

Social desirability bias This is the tendency of participants to express opinions which they think are more likeable or acceptable by the group, even if they are not honest accounts of their views or experiences.

The moderator can mitigate against this bias by framing a question in an hypothetical or indirect manner, to distance it from the participant's personal experience, the latter being something they may be reluctant to share. Establishing an atmosphere of trust, anonymity and confidentiality can also help participants being more open and honest.

Group dynamics Group culture and power relations, and participants' personality may also introduce bias and affect the end result. For instance, shy participants or introverts may feel overpowered and intimidated by assertive participants, whose views may then become prevalent. The moderator has the task to ensure all voices are heard, possibly by calling out shy participants individually, or time-limiting contributions to prevent the most talkative participants from taking over. Larger groups may be more difficult to manage and control, so that group size should be chosen wisely.

6.2.4.3 Further reading

Activity: Deep dive into focus groups #129

To find out more about focus groups, take a look at these resources:
powell1996focussmithson2000usingplummer2008focus

https://www.eiu.edu/ihec/Krueger-FocusGroupInterviews.pdf

6.2.5 Delphi

With the Delphi method•, a group of experts are consulted individually by the researcher with a view of obtaining a consensus on a particular issue, problem or topic.

• Also called Delphi technique in the literature. Its name is a reference to the ancient Greek temple that hosted the Oracle of Delphi, famous for her prophecies.

Activity: Do I need to know about the Delphi method? #130

Check back to your chosen research strategy from Stage 3. Does it involve data generation using the Delphi method? If so, read through the remainder of this section and complete the activities.

The method involves an iterative process of collecting, synthesising and circulating anonymous judgements among those experts to arrive eventually at a consensual view. At each iteration the experts can revise their opinion in light of what has emerged in the previous iteration. Anonymity is used to ensure that no individual expert exercises undue influence on the other experts, hence mitigating against groupthink, and that all participants feel free to express their opinions without any fear of judgement or criticism, hence mitigating against social desirability bias.

This method is based on the assumption that a group of experts are more likely to arrive at an informed and valid position than an individual, due to the diversity of knowledge and experience. The judgements and consensus gathered constitute the generated data that are subsequently analysed by the researcher.

The Delphi technique is suited to situations where it important to access collective expertise due to paucity of relevant published knowledge, particularly to inform decision making, policy creation, risk management or forecasting.

6.2.5.1 Operational considerations

Selecting experts Participants are selected based on their knowledge and experience in relation to the issue, topic or problem under study, so this is purposive rather than random sampling. Diversity of experts is important to ensure breadth of expertise, hence to generate valid outcomes. Between 10 and 50 experts are usually selected to participate in a Delphi study, although both smaller and bigger numbers have been used in studies reported in the literature. The more participants, the more resource-intensive the process of collecting, analysing and combining feedback is going to be.

Process Maintaining anonymity is essential throughout the process. Each expert is initially consulted separately by the researcher, who then anonymises and aggregates the group responses and circulate them to the same group of experts to seed the next round of consultation. Providing feedback at each round is the essential mechanism to foster convergence of opinions, as such feedback is used by each expert to review and refine their own opinions or judgements. In theory, this process is repeated over multiple rounds till a consensus is reached. Practically, there will only be a limited research time over which the process can be iterated. In addition, experts' availability should be taken into account, as well as possible fatigue resulting from too many iterations.

Consensus criteria It is important to establish explicit criteria to decide when consensus is reached. For instance, the researcher may establish a threshold, say when a certain percentage of the experts agree•.

• A 75% threshold is often used in the literature.

Location The method is usually executed remotely as there is no direct interaction between the experts.

6.2.5.2 Other things to think about

Resources This method is resource intensive, particular if you need to conduct several rounds, and you must ensure commitment from your participants for the whole duration of the study. If you are short of time, a focus group may be a better option.

Lack of discussion The feedback at each iteration is mediated and controlled by the researcher and there is no direct interaction or discussion among the experts. If a deeper investigation of ideas is needed, then other methods should be used, for instance interviews or focus groups.

Difficulty in reaching consensus Consensus may be difficult to reach, particularly, if you are investigating a particularly complex or contentious issue, or you are hoping for predictions concerning highly uncertain or volatile contexts. In such cases, you should reflect of the extent consensus is needed and, if not, then consider alternative methods which may allow you to explore alternative or contrasting views and positions.

6.2.5.3 Further reading

*** find more/better references

Skulmoski, G.J., Hartman, F.T. and Krahn, J., 2007. The Delphi method for graduate research. Journal of Information Technology Education: Research, 6(1), pp.1-21.

6.2.6 Journaling

Journaling is a method requiring participants in a research study to keep regular written personal records in the form of a diary• of their experiences and observations during the study. Participants are encouraged to engage in self-reflection in order to surface their inner thoughts, feelings, motivations and perceptions.

• Or journal, hence the name.

Activity: Do I need to know about journaling? #131

Check back to your chosen research strategy from Stage 3. Does it involve data generation using journaling? If so, read through the remainder of this section and complete the activities.

This method generates rich and detailed qualitative data on the participants' subjective experience. It can provide deep insights into complex phenomena, including how things change over time, and allows the collection of data on everyday experience in naturalistic settings. Because of these characteristics, it is often applied in ethnographic and grounded theory research.

6.2.6.1 Procedural considerations

Diary form Journaling can make use of either hand-written or digital diaries•. One or more diaries can be used for different aspects of the journaling process.

• Of course, accessing hand-written notes will be more labour intensive than electronic ones.

Prompts and guidance The goal of the self-reflection should be established at the beginning by the researcher and clearly explained to the participants. Journaling prompts are used to ensure that diary entries align with the objectives of the research, that is to guide participants' focus towards diary entries that will be useful to the research. Prompts can take the form of questions or comments on those diary entries. Lack of guidance or clear instructions is likely to lead to poor data, which are inconsistent or incomplete.

Participants Journalling is demanding for participants as maintaining regular diary entries over lengthy periods can be challenging. Therefore, recruiting participants willing to commit to journaling for the duration of the study is essential to the successful generation of comprehensive data. In addition, engagement with journaling should be monitored throughout the study, and perhaps research goals and prompts re-stated to help participants refocus their effort as necessary.

Managing data Journaling can generate large volumes of data from multiple participants, which must be managed carefully, and raises issues of confidentiality, privacy and more generally data protection. As a result it is essential that the researcher establishes a systematic approach to storing and backing up data, whether physical or digital.

6.2.6.2 Other things to think about

Subjectivity and bias Participants are in control of their diary entries, which, as a result are influenced by their emotions, beliefs, preconceptions and cognitive limitations. These, in turn, lead to a number of well recognised biases such as confirmation bias – focusing on evidence in support of prior beliefs, memory and recall biases – difficulties in remembering or reporting accurately past events, or social desirability bias

– only making entries deemed socially acceptable or desirable. Awareness of such biases and the use of triangulation may help mitigate resulting weaknesses.

Limited generalisability Diary entries are personal, subjective and usually specific to a particular context or setting. As a results, there may be limited scope for generalising findings based on journaling. If generalisation is an important goal of your research, then you should consider different data generation methods, like questionnaires involving random sampling.

6.2.6.3 Further reading

Activity: Deep dive into journalling #132

To find out more about journalling, take a look at these resources:
kadarisman2017classroom;
burns2009action;
james2005journaling;
peoples2020write;
feinblum2016journaling;
hayman2012journaling;
mcgrath202115;
taylor2006research;
ovens2020weaving;
giguere2012self-reflective;
bacon2014journaling

6.2.7 Fieldwork

wolcott2005art offers salutary advice:

Quote

There may be discomfort and hardship aplenty connected with the experience, ranging from the distractions of diarrhoea or lost luggage to the despair of personal failure or lost hope, but the extent of one's suffering and sacrifice are not factored into judgments about the worth of the fieldwork as fieldwork.

Fieldwork is a data generation method which requires the researcher to collect data directly in a natural setting•. The goal is to gain firsthand knowledge of the phenomena under study, and the method is widely applied across disciplines, including anthropology, sociology, archaeology, geography or environmental science.

• The 'field', hence the name.

Activity: Do I need to know about fieldwork? #133

Check back to your chosen research strategy from Stage 3. Does it involve data generation using fieldwork? If so, read through the remainder of this section and complete the activities.

Fieldwork encompasses all kinds of data collection performed directly by the researcher in that setting, be that observations and measurements, collection of samples and specimens, detailed descriptions of direct experience, or other. In sociological studies, fieldwork requires personal involvement of the researcher with the social activities under study, so that participant observations are commonly used.

Through fieldwork the researcher can generate rich, contextualised data to provide deep insights into the phenomena under study. It is particularly suited to situations in which such data cannot be obtained in any other way, and may also lead to unexpected discoveries. It is also flexible in that the researcher can pick data collection techniques to match the specific context and situation.

Fieldwork is not confined to exotic, distant locations•! Instead, it can be used in all natural settings, including, say, the researcher's own university or workplace.

• Although fieldwork may have this characteristic for some lucky researchers.

6.2.7.1 Operational considerations

Logistics, equipment and budget Depending on where the field is located, fieldwork may require some detailed planning addressing travel arrangements and accommodation, as well as access to the research site. If in a foreign country, all sort of factors must be considered, including the local transport networks, administrative processes you may need to go through, the climate, etc. You may also need specialised equipment on site, say field equipment and tools for data collection, alongside your personal protection. This can all be quite expensive, so that careful budgeting and securing the required funding in advance is essential.

Permissions and ethical issues If access to the field of interest is restricted, then you will need to gain appropriate permissions to proceed from the relevant authorities. This covers anything from obtaining permits and licences to access, say, an archeological site, to permission from your employer to perform participant observations in your workplace. The time and effort to obtain such permission must be considered upfront, and all ethical and legal implications factored in. In addition, the study must be conducted in full respect of local culture and norms.

Health and Safety In working in the field, you, and anybody else participating in the research, may be exposed to all sort of hazards, so that assessing and mitigating health and safety risk is paramount. This may involve the introduction of safety protocols, of appropriate training, and appropriate contingencies in the case of an emergency.

Managing data Fieldwork can generate large volumes of data, and may also include precious samples and specimens. All that is collected must be managed carefully, so that alongside issues of confidentiality, privacy and more generally data protection, you may also have to worry about the physical security of those samples and specimens. For this, you will need a systematic approach to storing, protecting and backing up your data, whether physical or digital.

6.2.7.2 Other things to think about

Quality of results The quality of results obtained from fieldwork depends on the data generated in the field, which, in turn, depends upon the skills of the field worker in relation to the specific techniques applied. For instance, using standardised measuring tools will increase the reliability and accuracy of measurements; a reflexive approach will help mitigate against the researcher's personal bias, including confirmation bias; triangulation may mitigate observer and social desirability bias in participant observations, etc. Whichever techniques you choose to apply in your fieldwork, you should ensure you are aware of their potential weaknesses and adopt appropriate strategies to mitigate their effect on the outcomes of your research.

Logistic challenges The logistical challenges to organise fieldwork may well be beyond what can be addressed in the limited time of a Masters project, unless you are able to contribute to a wider research effort, perhaps led by your supervisor, where all logistical issues have already been addressed.

Time and cost Fieldwork can be time consuming both for data collection and analysis, and expensive if travel is required. If time or cost are an issue in your project, then you should consider more time efficient or cheaper alternatives.

6.2.7.3 Further reading

enwiki:1211911661

is this good to include? Check!

According to **wolcott2005art**,

wolcott2005art's book is both detailed and entertaining. Reading it gives on a feeling that spending time in fieldwork with "Harry" would have been an education in itself. The book includes the importance of laundry to fieldwork, for instance, with experiences of fieldwork in a Canadian Indian reserve to illustrate.

> Activity: Deep dive into field work #134
>
> To find out more about field work, take a look at these resources:
> **wolcott2005art**;
> **randall2007fieldwork**

6.2.8 Documents

Existing documents can be used as data sources in order to develop new insights or answer research questions. Research which takes this approach is called document-based research

Or documentary research.

> Activity: Do I need to know about documents? #135
>
> Check back to your chosen research strategy from Stage 3. Does it involve data generation using documents? If so, read through the remainder of this section and complete the activities.

As a researcher, documents – in the form of academic articles – will already occupy a large proportion of your time/brain/computer. Your collection of academic papers could currently be as many as 50 or more. You will, therefore, already have good experience of interacting with documents and those interactions may well have already helped you gain valuable insights for your project.

Other documents can also be used as data sources in document-based research. The term ‘document’ is used here in a broad sense to refer to all text-based documents, but also visual materials – such paintings, maps or photographs, video and audio recordings, and any digitally stored information.

Researchers engage in document-based research by systematically examining and interpreting these documents to extract meaningful information. The documents may be of interest because of their content, or their relation to other documents, or could be studied to discover what they may reveal about their authors, or the historical or cultural context in which they were created. Therefore, a researcher’s may have a direct interest in the factual content of a document, or be interested in what that content may indirectly say about some other phenomena of interest. An example may help clarify the difference between these two modes. This is a copy of a passage from **fynes1873the-miners**:

Quote

Miner :– I believe you have something like 150 collieries to inspect?
Mr. Dunn :– Yes.
Miner :– Twenty-eight in Cumberland?
Mr. Dunn :– Yes.
Miner :– Do you think you are able to inspect all these?
Mr. Dunn :– Well, the Government thinks I am able, you know.
Another Miner :– Were you satisfied with the one shaft at this colliery, if so there is an end to the matter; if not, what steps did you take to remedy the defect? Did you apply to the Secretary of State, showing him that it was defective?
Mr. Dunn :– At this very moment there are three of the largest collieries in Northumberland – Seaton Delaval, North Seaton, and Newsham – managed by the most talented men in Northumberland, all with single shafts. Now, what would you have me to do? Do you think it is my duty to call in question the management of these pits?
Miner :– Am I to understand this is an answer to my question?
Mr. Dunn :– Well, I am not so well satisfied as if they had two, but I have not the power to alter it.

Here, a direct reading could be to identify collieries in which a single shaft existed at that time. An indirect reading could be to explore social relationships within a mining community in 18th century England.

Document-based research provides the researcher with evidence of historical events or social phenomena, including nuanced details and perspectives that may not be available through other means. In particular, documents allow the researcher to access data pertaining to different time periods, locations and cultural contexts. It is a flexible method that can be integrated in several research strategies.

6.2.8.1 Procedural considerations

Accessing documents You need to ensure you have access to the documents you need for your research. While documents are increasingly digitised and easily accessible online, it is also the case that access for many may be restricted by either policies or physical restrictions, say you wish to study restricted confidential documents in an organisation, or access rare or ancient manuscripts kept in a museum. Ensuring you have the right access at the right time in your project is essential, but can be time consuming, particularly if there are bureaucratic processes you need to go through. Related to access are issues of translation if the documents are in a language you are not familiar with, or transcription, if you sources are audio or video recordings. As well as being time consuming, these processes may introduce errors which may be difficult to spot. Lastly, it is essential you ensure that your documents are authentic: only using trusted sources is a way to do so.

Selection criteria You must develop clear and explicit selection criteria to decide which documents to include in your study, based on your research problem or question, and aim and objectives. Such criteria should help you collect an appropriate and representative selection of documents for your research, guiding you in what to include and what to leave you. The criteria should ensure that your data sources are diverse and no selection bias creeps in, which may lead to certain positions, perspectives, or types of documents to be either overrepresented or underrepresented.

Data management Alongside generic issues of data storage, protection and privacy, you also need to ensure that your source documents remain easily accessible and that their integrity is maintained: this is both to allow you to revisit those documents repeatedly during your study, and to allow other researchers to check your sources to verify and validate your findings. Whenever possible, you should digitise your source documents to enhance their accessibility and preservation.

6.2.8.2 Other things to think about

Bias in documents Documents are created by people, who necessarily inject their own personal bias into their content•, which in turn is the result of their historical, cultural and social contexts•. In addition,

• So called 'creator' bias.

• Another bias, called 'contextual' bias.

particularly in the case of ancient manuscripts, the documents that have survived may only provide a partial historical account•. Being aware of all these biases is essential to the interpretation of documents content and how they may skew or limit the research results.

• You'll have guessed there is a name for this too, which is 'survivorship' bias.

Interpretation challenges Documents are unlikely to provide a complete picture of phenomena under study, partially due to their inherent biases, but also because they may be incomplete or lack crucial details or contextual information may not be available to the researcher. Also certain phenomena may be more documented than others, so that the availability and quality of documents can vary widely across topics, history or geography. All these factors affect your ability as a researcher to interpret their content and draw robust conclusions.

Time and effort Document-based research may require large volumes of materials to be selected, collected and analysed, so that it can be very time-consuming. If time is an issue in your project, then alternative data generation methods should be considered.

6.2.8.3 Further reading

Activity: Deep dive into documents #136

To find out more about documents, take a look at these resources:
coffey2014analysing;
schreier2014qualitative

6.3 Modelling methods

So far we have discussed methods which focus on generating data from either direct observations or experience (whether the researcher's or other research participants'), or from secondary sources. Once gathered, such data are organised and then analysed by applying data analysis methods, which we will consider in the next section.

Somewhat in between data generation and analysis are modelling methods, whose aim is to build models of natural, social or artificial phenomena, that can then be used for analysis, prediction or decision making, including informing the design and engineering of new artefacts. Such models need data to inform their development and, in turn, generate new data for analysis. Modelling methods support a variety of research strategies including simulation and design science research, but also case studies in which models of socio-technical systems may be useful for investigation.

At its essence, a *model* is a representation of something, be that a system, a structure, a process or a behaviour. Possibly the most important thing to remember about modelling is expressed by the following oft-cited aphorism•:

• Box, George E. P. (1976), "Science and statistics" (PDF), Journal of the American Statistical Association, 71 (356): 791–799.

> *All models are wrong, some are useful* (Box, 1976)

which makes clear that a model should not be regarded as a faithful replication of some reality, but as a tool to investigate some aspects of that reality.

At the core of modelling is a *process of abstraction* which starts from an understanding of what is to be modelled and ends with the definition of the desired model. The nature of both determines the kind of thinking required in the abstraction process. In this section, we focus on computational, mathematical, statistical and system thinking.

6.3.1 Computational thinking

Computational thinking is needed when the end point is a computational artefact, that is something that a digital computer can execute•.

• Computational thinking has a much broader scope than what is reported here. For instance, it underpins learning and curriculum in Computing-related disciplines, as well as professional skills in related industries.

Activity: Do I need to know about computation thinking? #137

Check back to your chosen research strategy from Stage 3. Does it involve data generation using computation thinking? If so, read through the remainder of this section and complete the activities.

Computational thinking is a problem solving approach in which problems are explored with a view to identify and implement computational solutions in the form of computer programmes and systems. In addition to writing code that a computer can execute, computational thinking involves a wide range of cognitive processes such as being able to think at different levels of abstractions, to decompose problems into sub-problems, to identify useful patterns and structures in data, to conceptualise logical steps the computer should take alongside how people may interact with those programmes and systems.

Computational artefacts are becoming more and more prominent in academic research, which both makes use of existing ones and develop new, bespoke ones to advance knowledge.

6.3.1.1 Procedural considerations

Given the explosive growth in the use of computers over the past half century, you may not be surprised to hear that there are thousands of useful• tools to support computational thinking. They vary in many of their characteristics, so that you will need to make some judicious choices for your project. In particular you will need to consider:

• As well as some that are less than useful!

Programming language and paradigm This concerns the language you will use to express your code, and its underlying philosophy•.

• You may have heard of Phyton, C or Java. These are just few of the many choices of programming language available! Each language embodies some ontological assumptions as to the building blocks of code – yes, philosophy comes into play into coding too!

Computational mode This refers to the way computations take place in the implemented artefact, one of sequential, concurrent, distributed or agent-based. The latter is particularly suited to the simulation of complex systems made of many interacting, independent agents. While all programming languages allow you to develop sequential computations, specialised languages• exist for the other modes.

• You can look, for instance, at Petri Nets or NetLogo to get some ideas.

Delivery platform This refers to where your computational artefact will be made available for use, be that the web, a mobile device, or some other bespoke hardware.

Integrated Development Environment (IDE) This the combination of tools to help you develop and keep track of your code, including how it changes over time, as well as to perform tests to check its intended behaviour and to correct errors and mistakes.

Stakeholders and participants These are all the people you may have to involve to tease out requirements,•, validate your artefact or generate data by interacting with it.

• Which need will your artefact meet? Which characteristics should it have?

Development process This is the process• you will follow to determine what your code should do, and to design, implement, test and release it for use.

• Several schools of thought exist as to what constitute a good process to develop computational artefacts. You can look up Agile and Plan-driven development processes to get some ideas.

6.3.1.2 Other things to think about

Foundational knowledge If you don't have any experience of computational thinking or writing code, then you can learn, but the learning curve is going to be very steep. Unless you have direct access to experts to guide you, it is unlikely you will be able to achieve the proficiency you will need within the timeline of a Masters project.

Model validity You need to worry about two key aspects of validity when developing computational models. One is internal, and concerns the issue of whether you have made mistakes in your code: appropriate code review and testing techniques can help you take care of this. The other is external, and concerns the relation between the model itself and the reality it means to model. In order to establish this, you may need to consider several factors including:

- how well it fits the context in which it is eventually installed
- how well it addresses the problem(s) it is meant to solve, and
- how well it meets stakeholder's expectations, including any professional quality standards

Timing issues Developing computational model can be very time consuming, particularly when you need to interact with many stakeholders as part of the development, which may then require you to iterate between coding and validation several times. If you are not confident you can accommodate such a development effort within your Masters project, then you should consider other methods or reduce the scope of your model.

6.3.1.3 Further reading

Activity: Deep dive into computation thinking #138

To find out more about computation thinking, take a look at these resources:
angevine2017computational;
figueiredo2017improve;
lyon2020computational

6.3.2 Mathematical thinking

Mathematical thinking is problem solving with Mathematics. It has had many centuries more than computational thinking to develop and the tools that exist as part of it are very stable. They are also much better explored due to the efforts of many great mathematicians. However, they do require a high level of skills and sophistication in their application to achieve their full potential.

Activity: Do I need to know about mathematical thinking?	#139
Check back to your chosen research strategy from Stage 3. Does it involve data generation using mathematical thinking? If so, read through the remainder of this section and complete the activities.	

Although mathematical techniques can apply to real-world problems, they tend to create *closed form* solutions, that is solutions which can be calculated exactly from mathematical expressions. For instance, systems of differential equations are widely used in Finance to model fluctuations on stock or investment markets. As long as a real-world problem can be captured in this way, then a mathematical model is feasible. However, many real-world problems do not admit such characterisations, so that there are limitations as to what can be treated mathematically.

It should also be noted that there is a strong connection between mathematical and computational thinking in that lots of mathematical models are now implemented as computational algorithms executed by computers. These, however, require some *numerical approximations* as computers cannot calculate exact values.

Similarly to computational thinking, mathematical thinking involves various cognitive processes:

Specialising exploring a problem through examples. Each example provides the opportunity for manipulating elements that are concrete, whether they are physical manifestations or ideas.

Conjecturing when enough such examples have been examined, you can conjecture about the relationships that connect them. Through conjecturing, underlying patterns are explored, expressed, and then substantiated.

Generalising if you are lucky enough to have found a pattern, then you might try to generalise it to creating order and meaning out of a – potentially, overwhelming – amount of data.

Convincing a generalisation must be tested until it is convincing to the reader – this is the basis of the knowledge contribution from mathematical thinking.

6.3.2.1 Operational considerations

Mathematical tools This concerns the choice of the kind of mathematics to apply, including notation, and symbolic and diagrammatic representations appropriate for the problem you are trying to address.

Computational tools Should you wish to use a computer to run your mathematical models, then you will also need to make many of the choices related to computational thinking•. Note that many modern programming languages and environments include a wide range of mathematical libraries which you can use directly in your code, so that you don't have to start your code from scratch, reducing substantially the time and effort required. Such libraries are also likely to have been tested extensively, hence their code should be error-free and highly reliable.

• See Section??.

Relevant examples Although you will need to be creative in applying mathematics to your own research problem, there may be relevant examples in the literature which can provide a good starting point. Working from simple examples to more complex ones may help you establish an appropriate mathematical approach.

6.3.2.2 Other things to think about

Foundational knowledge Mathematical thinking is arrived at through creative thinking and deep study of mathematical tools and techniques. The sophistication of mathematics often means that, either:

- a particular area of research has already been taken past the abilities of a masters-research-level mathematician;
- it is not amenable to (current) mathematical tools and techniques, and further creative• mathematical thinking will be necessary to progress.

• And, most likely, deep and advanced, out of the box, out of this world, and further.

Although neither of these characteristics are insuperable, they make timely contributions to knowledge through the application of mathematical approaches difficult•. It's worth moderating your expectations of what can be achieved in mathematical research at masters level – discussion with your supervisor of what their expectations are would be very worthwhile.

• What is often missing from the mathematical literature – or what isn't always visible to the new entrant – is the often vast timescales over which mathematical progress is made. Bertrand Russell and Alfred Whitehead spent over two decades of their professional lives in the creation of the three volume *Principia Mathematica*. A fourth volume

Limitations of mathematical abstraction Mathematics abstracts from real-world complexity: in modelling traffic to improve flow through a complex junction, for instance, one would not necessarily consider the economy of individual cars, or the noise pollution created by a solution. This can reduce a real-world problem to a complexity that is approachable, but may also lead to non-solutions when applied back in the real world, for instance, leading to complaints from local home owners that noise pollution has risen through a solution. Therefore, you need to check you simplifying assumptions carefully against the real-world situation to avoid reaching invalid conclusions.

6.3.2.3 Further reading

Activity: Deep dive into mathematical thinking	#140

To find out more about mathematical thinking, take a look at these resources:
stacey1982thinking

6.3.3 Statistical thinking

Statistical thinking is problem solving with Statistics. It is used to identify patterns, trends and relationships in data from which inferences are possible through probabilistic reasoning, which acknowledges the data inherent variability and uncertainty.

Activity: Do I need to know about statistical thinking?	#141

Check back to your chosen research strategy from Stage 3. Does it involve data generation using statistical thinking? If so, read through the remainder of this section and complete the activities.

Statistical inferences are particularly valuable for prediction and forecasting – for instance, to predict the spread of a virus in a population or how the average house price in a geographical area may change over a certain period of time, or to test hypotheses•, for instance whether a medical treatment is effective. Statistical thinking is essential in quantitative analysis, which will cover in Section 6.4.2: in this section we only provide a brief introduction with a focus on modelling.

• We will introduce statistical tests in Section 6.4.2.2

6.3.3.1 Procedural considerations

Sampling Statistical modelling requires relevant data, so that you have to consider how you will obtain such data. Sampling is a way to do so•: in such case, you need to worry about both sample size and the extent it is representative of the population of interest.

• You should refer back to Section 6.2.3

Data quality Quality data are data with no missing, inconsistent or erroneous entries. Typically, you will need to pre-process your data to ensure this is the case before applying any statistical technique.

Choice of techniques You will need to decide which statistical techniques to apply in relation to the research problem you are trying to address. Like Mathematics, Statistics too includes a vast repertoire of techniques applicable to different problems. If you do not possess sufficient expertise to be able to choose by yourself, then you will need to take expert advice, as applying inappropriate techniques will lead to invalid or misleading results.

Statistical software The use of computational tools is the norm to support statistical thinking and many bespoke statistical software applications are available. In addition, many programming languages and environments now come equipped with full libraries of statistical functions ready for use•. Such applications and environments allow you to perform most statistical modelling and testing alongside data manipulation and visualisation with graphs and charts.

• R and Python are two of them.

6.3.3.2 Other things to think about

Foundational knowledge Statistical techniques can be complex and require specialised knowledge and skills to apply them effectively, particularly for advanced modelling, but also to provide meaningful interpretation of outcomes. As for mathematical thinking, unless you have sufficient foundational knowledge, it is unlikely you will be able to develop knowledge and skills beyond the basics within the remit of a Masters project.

Data bias Even when your data are of good quality, they can still be biased in that they may over- or under-represent certain characteristics of the population of interest, leading to invalid or unreliable generalisations. For instance, if all participants in a clinical trial for a new medicinal drug are male, then the effectiveness or otherwise of the drug for female patients cannot be inferred from the trial, so that any generalisation to the wider population may be unsound.

Confounding factors Unfortunately, things can still go wrong even when you have good quality, unbiased data to start with. This may be due to *confounding factors* you may not have considered in your study. For instance, say you are interested in the possible relationship between physical activity and heart health. If you only focus on (some measures for) those two variables, you are likely to miss possible effects of, say, age and gender on heart health in addition to physical activity, and may, once again, infer the wrong conclusions.

Model assumptions Statistical methods are usually based on specific assumptions made of data characteristics. For instance, many statistical tests assume that the data are normally distributed•. It is therefore essential for you to check that all required assumptions hold, otherwise your model, and any conclusions you derive from it, may be invalid.

• We will cover these topics in Section 6.4.2.2

Ethical considerations As statistical thinking relies on data, then ethical and legal issues arise in relation to how the data are obtained and used in your research, particularly around privacy and data protection. In addition, ethical issues arise in relation to social implications of applying statistical thinking in decision-making, particularly when decisions are increasingly taken by algorithms. This can lead to inequality and discrimination, as demonstrated by some shocking cases which have been reported widely, such as the COMPAS system, discriminating against black offenders, or the Amazon's recruitment algorithm, discriminating against women.

6.3.3.3 Further reading

Activity: Deep dive into statistical thinking #142

To find out more about statistical thinking, take a look at these resources:
chance2024statistical

6.3.4 System thinking

Systems thinking is yet another problem solving approach which focuses on systems and their dynamics. By *system* we mean a set of elements coming together in a complex whole and whose behaviour stems from the interaction of those elements. Any kind of system is in scope, whether natural, social or artificial, with system thinking focusing on understanding how the different elements influence each other and the system behaviour emerges from their interaction.

Activity: Do I need to know about system thinking?	#143
Check back to your chosen research strategy from Stage 3. Does it involve data generation using system thinking? If so, read through the remainder of this section and complete the activities.	

System thinking takes a holistic approach to understanding a system, encouraging different stakeholders' perspectives and a participative approach to develop a shared understanding. This also means that the enquiry process is iterative, with insights being revisited, reviewed and refined as more knowledge is acquired through ongoing analysis and interaction with stakeholders.

Like mathematical and statistical thinking, system thinking may be used in combination with computational thinking, for instance, to develop a better understanding of a system of interest before creating a computational simulation of it, or as an aid to prototyping novel computational artefacts.

System thinking also relies on system models based on diagrammatic notations, of which there is a great variety. Among the most common are•:

• This is by no means a complete list!

- *systems maps*, which allow you to sketch the structure of a system by identifying key components and sub-systems;
- *influence diagrams*, which extend system maps to show how those elements influence each other;
- *causal loop diagrams*, which are used to capture cause-and-effect relations, and particularly feedback loops in the system dynamics which affect behaviour over time;
- *stock and flow diagrams*, which augment causal loop diagrams with quantitative information that can be exploited in computational simulations;

- *UML (Unified Modeling Language) diagrams*, where UML is a standardised engineering modelling language specifically defined to capture and analyse various aspects of software systems•, either in terms of their structure or behaviour.

• Although it is also used for other kind if design and engineering, beyond software.

6.3.4.1 Procedural considerations

Scope and boundaries Before you start your investigation you need to define clearly the scope of your system of interest, its boundaries and the purpose of your analysis, to inform your data gathering and interaction with stakeholders. Your analysis should encompass different system dimensions, say social, cultural, economical or environmental.

Stakeholders You need to decide who you will involve in your research, focusing on stakeholders with an interest and understanding of the system, and ensuring that a plurality of views and perspectives are represented. If you aim for some form of intervention on an existing system, then you must also ensure you involve stakeholders who will champion or support it. In all cases, you should encourage collaboration and communication among stakeholders, including exchanging knowledge and ideas to foster shared understanding.

Data gathering To gather your data about the system you can apply any relevant method from Section **??**. It is likely you will need both qualitative and quantitative data as you are aiming for a comprehensive characterisation and analysis of your system from a plurality of perspectives.

Modelling You need to decide which notations to use to model key aspects of the system relevant to your research. You should also consider whether a computational simulation would be appropriate, in which case, you should review the operational considerations related to computational thinking. For both, you will need to develop a certain level of expertise to be able to apply them effectively in your enquiry. This will require time, and ideally some expert guidance, which you must ensure are available within the constraints of your Masters project.

6.3.4.2 Other things to think about

Complexity Analysing complex systems can be challenging, and taking a system thinking approach is time consuming and resource intensive due to the need for large amount of data to gather and protracted interactions with many stakeholders. You need to ensure access to both data and people for your system thinking enquiry to be meaningful.

Subjectivity and bias As a system thinker, you establish the system boundaries, the perspectives to take, who to involve and how to gather and interpret your data. This leaves your research open to your own bias. Reflexive practices, alongside triangulation, say by cross-validating with independent data, are therefore necessary to support the validity of your findings.

Model validity As for all modelling, your system characterisation will be based on simplifications and assumptions, which will need careful checking with respect to the system being modelled. To validate both assumptions and resulting models you could apply triangulation, including asking independent experts to review them or compare model behaviour with real-world observations.

6.3.4.3 Further reading

Activity: Deep dive into system thinking #144

To find out more about system thinking, take a look at these resources:
??

6.4 Data analysis methods

Your choice of data analysis methods is part of your research design, and relates to the kind of data and evidence you have generated, and what you are trying to achieve, that is your aim and objectives.

Analysis methods fall into two main categories, quantitative and qualitative, based on the nature of the data to analyse. In this section, we provide an introduction to some of the most common. This is far from complete and does not go very deeply into the details of each method: entire books have been written on any of them! By studying this section, you won't become an expert in any of these methods, but you will have gained enough understanding to be able to make a judicious selection for your project. After that, you should review the related specialised literature to help you apply your chosen methods appropriately. You should also talk regularly to your supervisor for further guidance.

6.4.1 Using tables to analyse data

Tables can be used to summarise both quantitative and qualitative data, as a starting point for their analysis.

Activity: Do I need to know about tables? #145

Check back to your chosen research strategy from Stage 3. Does it involve data analysis using tables? If so, read through the remainder of this section and complete the activities.

The following kinds of tables are used extensively in research and often found in dissertations.

Pivot tables Pivot tables can be used to summarise, sort, filter, re-organise or group data organised in rows and columns, and perform calculations on them, such as counting, generating totals or averages, and much more. Pivot tables are both powerful and versatile•, and one of the most widespread tools for data analysis.

You can generate a pivot table from any data set organised in rows and columns, regardless of whether the values are quantitative or qualitative: all common spreadsheet applications• include this function.

figure 6.1 gives an example: these are the first few raws of a data set related to the US housing market•. The dataset contains over 9,316 entries, each corresponding to a distinct property. Each property is characterised by a number of attributes: size in square feet, number of bedrooms and bathrooms, type of neighbourhood, the year it was built and its market price in US dollars. As you can see, this table includes both numerical and categorical variables.

Pivot tables can be used to summarise such data to answer certain questions. For instance, we may be interested in the average house price by neighbourhood and number of bedrooms, which would result in the pivot table in figure 6.2, which gives the average price of each combination. The 'grand totals' in the table are also averages, by row and by column.

Alternatively, we may be interested in finding out how many properties of each kind have been built in each neighbourhood. In this case the pivot table would look like that in figure 6.3. The grand totals in this case are counts. Note how we have added combinations of bedroom and bathroom numbers to characterise each type of property.

These are just but two examples of questions about the data you can address by using pivot tables, out of a vast range of the possibilities. If your data are organised in tables, then it is well worth spending some time becoming familiar with pivot tables.

- • In fact, they are so versatile that we'll only be able to provide few illustrative examples. Much, much more can be found online!
- • From MS Excel to Apple Numbers to Google Sheets.
- • It was taken from one of Kaggle's free datasets, the housing price dataset. Kaggle is possibly the largest and best known online community for data science and machine learning.

ID	SquareFeet	Bedrooms	Bathrooms	Neighborhood	YearBuilt	Price
1	2126	4	1	Rural	1969	US$ 215,355.28
2	2459	3	2	Rural	1980	US$ 195,014.22
3	1860	2	1	Suburb	1970	US$ 306,891.01
4	2294	2	1	Urban	1996	US$ 206,786.79
5	2130	5	2	Suburb	2001	US$ 272,436.24
6	2095	2	3	Suburb	2020	US$ 198,208.80
7	2724	2	1	Suburb	1993	US$ 343,429.32
8	2044	4	3	Rural	1957	US$ 184,992.32
9	2638	4	3	Urban	1959	US$ 377,998.59

Figure 6.1: first few rows of the example dataset

Neighborhood	Rural	Suburb	Urban	Grand Total
Bedrooms	**Price (Average)**			
2	US$ 218,323.92	US$ 216,300.13	US$ 220,050.01	**US$ 218,230.99**
3	US$ 219,053.37	US$ 220,397.86	US$ 223,737.67	**US$ 221,057.88**
4	US$ 227,774.55	US$ 224,609.50	US$ 230,086.56	**US$ 227,473.37**
5	US$ 231,112.60	US$ 231,776.73	US$ 234,894.98	**US$ 232,595.48**
Grand Total	**US$224096.13**	**US$223234.19**	**US$227166.20**	**US$224827.33**

Figure 6.2: Pivot table of average property prices by neighbourhood and number of bedrooms

	Neighborhood	Rural	Suburb	Urban	Grand Total
Bedrooms	**Bathrooms**	**ID (Sum)**			
▼ 2	1	180	220	261	**661**
	2	129	214	283	**626**
	3	155	45	75	**275**
2 Total		464	479	619	**1562**
▼ 3	1	96	130	129	**355**
	2	397	149	245	**791**
	3	127	139	889	**1155**
3 Total		620	418	1263	**2301**
▼ 4	1	142	306	228	**676**
	2	453	379	410	**1242**
	3	315	175	194	**684**
4 Total		910	860	832	**2602**
▼ 5	1	325	282	378	**985**
	2	438	127	10	**575**
	3	534	367	390	**1291**
5 Total		1297	776	778	**2851**
Grand Total		**3291**	**2533**	**3492**	**9316**

Figure 6.3: Pivot table of property counts by neighbourhood and number of bedrooms/bathrooms

Activity: Pivot tables in Excel #146

Download the housing price data set from Kaggle and re-create the pivot tables in our example. Come up with other questions you could ask of the data and generate related pivot tables.

Guidance

Feel free to use your preferred spreadsheet application for this activity, as long as it supports pivot tables – most do.
You may have to register with Kaggle to gain access to the data set.
The Excel Help facility and documentation provides all the info you need to create a pivot table. However, you could also browse some of the very many freely available online resources and tutorials on this topic.

Frequency and contingency tables Frequency tables are used to summarise the frequency (or count) of values taken by a categorical variables in a data set. For instance, after studying a degree, a student's outcome may be classed as distinction, merit, pass or fail. A frequency table can then be used to summarise the frequency of each class of outcome for a particular students' cohort, as shown in Table 6.2.

Table 6.2: Example of frequency table

	Distinction	**Merit**	**Pass**	**Fail**
Outcome	12	26	42	5

Contingency tables• are a form of frequency tables used to tabulate the value frequencies of two categorical variables. For instance, following from our previous example, we may like to tabulate the outcome value frequencies in the cohort against gender, as shown in Table 6.3.

• Also known as *cross-tabulation* tables.

Contingency tables are frequently used to summarise and analyse data collected in survey research, and are a key tool in statistical analysis.

Both frequency and contingency tables can be generated as pivot tables in a spreadsheet. In fact, the table in figure 6.3 is a contingency table.

Table 6.3: Example of contingency table

Outcome by Gender	Distinction	Merit	Pass	Fail
Female	7	12	21	2
Male	5	13	19	3
Other	0	1	2	0
Totals	12	26	42	5

6.4.1.1 Further reading

Activity: Deep dive into using tables #147

To find out more about using tables, take a look at these resources:
??

6.4.2 Statistical analysis

Statistical analysis in an umbrella terms for a set of methods which can be applied to numerical and categorical data. More precisely, in statistics data types are classified as:

- scalar, which includes all measurements and counts; with reference to the types in Section3.5.1, these are all numerical data, continuous, discrete, interval and ratio data.
- categorical, both ordinal and nominal.

There are two broad categories of statistical methods:

- descriptive statistics, whose aim is to describe data; and
- inferential statistics, whose aim is to make predictions from data.

We briefly consider each in what follows.

6.4.2.1 Descriptive statistics

Descriptive statistics are used to describe various attributes of a data set.

Activity: Do I need to know about descriptive statistics? #148

Check back to your chosen research strategy from Stage 3. Does it involve data analysis using descriptive statistics? If so, read through the remainder of this section and complete the activities.

The basics are:

- count, to establish how many entries there are in the data set
- centrality, to establish the 'centre' of the data set. Three measures are commonly used: the *mean*, which provides the average value of the data set; the *median*, which provides its mid point•; and the *mode*, which indicates the value that occurs most frequently, if any•.
- dispersion, to establish the spread of the data in the data set. Range and standard deviation are two common measures. The *range* is the difference between smallest (minimum) and largest (maximum) values. The *standard deviation* is based on a mathematical formula which considers the distance of each value in the data set from the mean. It is not essential for you to know such formula, which is automatically computed by spreadsheets and statistical software•. The larger the standard deviation, the greater the dispersion.
- skewness, to establish how symmetrically distributed the values in the data set are in relation to the centre. In the case of perfect symmetry, skewness is equal to zero, and mean and median are equal. When asymmetric, mean and median are different and the distribution may be either right (mean smaller than median, and negative skewness) or left (mean greater than median, and positive skewness) skewed. A perfectly symmetric distribution is usually referred to as a *normal distribution* or *bell curve*, from the shape of the line that can be obtained by plotting the data on a chart•.

Not all descriptive statistics apply to categorical data. In particular, the mode is used as the main measure of centrality for nominal data, while the median is used for ordinal data which are not numeric.

These are lots of definitions to digest, particularly if you haven't encountered these terms before! The following activity should help.

• Remember that quantitative data can be ordered.

• There is no mode if no value is repeated in the data set.

• Of course, you can always look it up in the literature...

• This oversimplifies the topic in order to give some intuition in case you have not come across these terms before. A lot more should be said about the normal distribution and its pivotal role in statistics!

Activity: Descriptive statistics in Excel #149

Assume you have measured the weight in grams of each apple in a basket, obtaining the following numbers: 105, 120, 122, 125, 127, 128, 129, 130, 132, 133, 135, 135, 138, 140, 128. Enter these data in an Excel sheet and use its built-in data analysis function to generate the related descriptive statistics.

Guidance

In the current version of Excel, you can access this function from the Data tab, by pressing the Data Analysis button. If you find it difficult to locate this function, you should refer to the documentation or to some of the many tutorials on this topic which are freely available online.

Discussion

You should have obtained the following values:

Attribute	**Value**
mean	128.47
median	129
mode	128
standard deviation	8.55
skewness	-1.4
range	35
minimum	105
maximum	140
count	15

There are 15 values in this data set, with range 35 (the difference between maximum and minimum values). In terms of centrality, the mean (128.47) is slightly smaller than the median (129), and Excel reports a mode at 128. In reality, if you look at the data you will see that there are two modes in this data set[a], 128 and 135, but Excel only returns the first encountered! In terms of dispersion, the standard deviation is telling us that most apple weights are within 8.55 grams of the mean (below or above), so the apple weights are similar in the apple baskets. Note that the skewness is negative, which is consistent with the mean being smaller than median, so the data distribution is right skewed.

[a] Statisticians call this *bi-modal*.

In your dissertation, you can easily present such descriptive statistics as a table, possibly adapting that automatically generated by your spreadsheet.

In addition, charts can be used to visualise the data and examine their descriptive statistics.

With scalar data, like in our example, you can use a *histogram*. The one in figure 6.4 uses the apple weights from the previous activity: on the horizontal axis, we have the distinct weights, and on the vertical axis, their frequencies, that is how many times each weight appears in the data set. Given the values you have obtained for the data set descriptive statistics, you can easily locate on the chart min and max values, and mean, median and mode. In this case, the two 'peaks' correspond to the two modes we mentioned in the activity. You can also check that most of the values are within 8.55 grams from the mean, either way: the only values left out are 105 (to the left) and 138 and 140 (to the right). Skewness is not obviously notable on this chart, so that we will use a different chart for that purpose.

Before we do that, however, it is worth noticing that given our small data set of discrete values, we have used a histogram with 'bin' size equal to one, which allows us to plot each individual apple weight. A *bin* in a histogram is essentially a way to group a number of values, with bin size establishing the spread of each bin. Frequencies are then calculated by bin. Grouping values in bins is necessary with large data sets and/or with continuous data. figure 6.5 illustrates a histogram for our example, in which the bin size is 5: that is, each bin spans a set of 5 possible values.

In order to visualise both spread and skewness, a useful chart is the boxplot, illustrated in figure 6.6 for our example. This is made of a 'box' around the median of the data, and some 'whiskers' on each side of the box•. It is obtained by dividing up the data into quartiles, each containing a quarter (or 25%) of the data, with the median in the centre. The box includes the two quartiles on each side of the median, which, together, account for half of the values in the data set. The whiskers account for the two other quartiles, with a caveat: if there are very extreme values, these are treated as possible outliers and left out of the whiskers. This is, in fact, the case in our example where value 105 is treated as an outlier in the chart: it is a dot on its own, not included in the left whisker. The whisker length provides an indication of spread: the longer the whiskers, the more spread out the data. Instead, the position of the median in relation to the extreme of the box provides an indication of skweness: in our example the median is further away from to the right edge (just!), indicating that the data distribution is slightly right-skewed (consistent with the negative skewness value in the descriptive statistics).

• Which is why this chart is also called a *box and whiskers* plot.

To be more precise, the relation between a boxplot and its underlying statistical features is illustrated in figure 6.7. The two quartiles around the median represent the interquartile range (IQR) of the data set. The whisker lengths, calculated based on the formulae in the figure, allows the identification of lower and upper bounds beyond which values are seen as extreme and represented separately as outliers. An outlier,

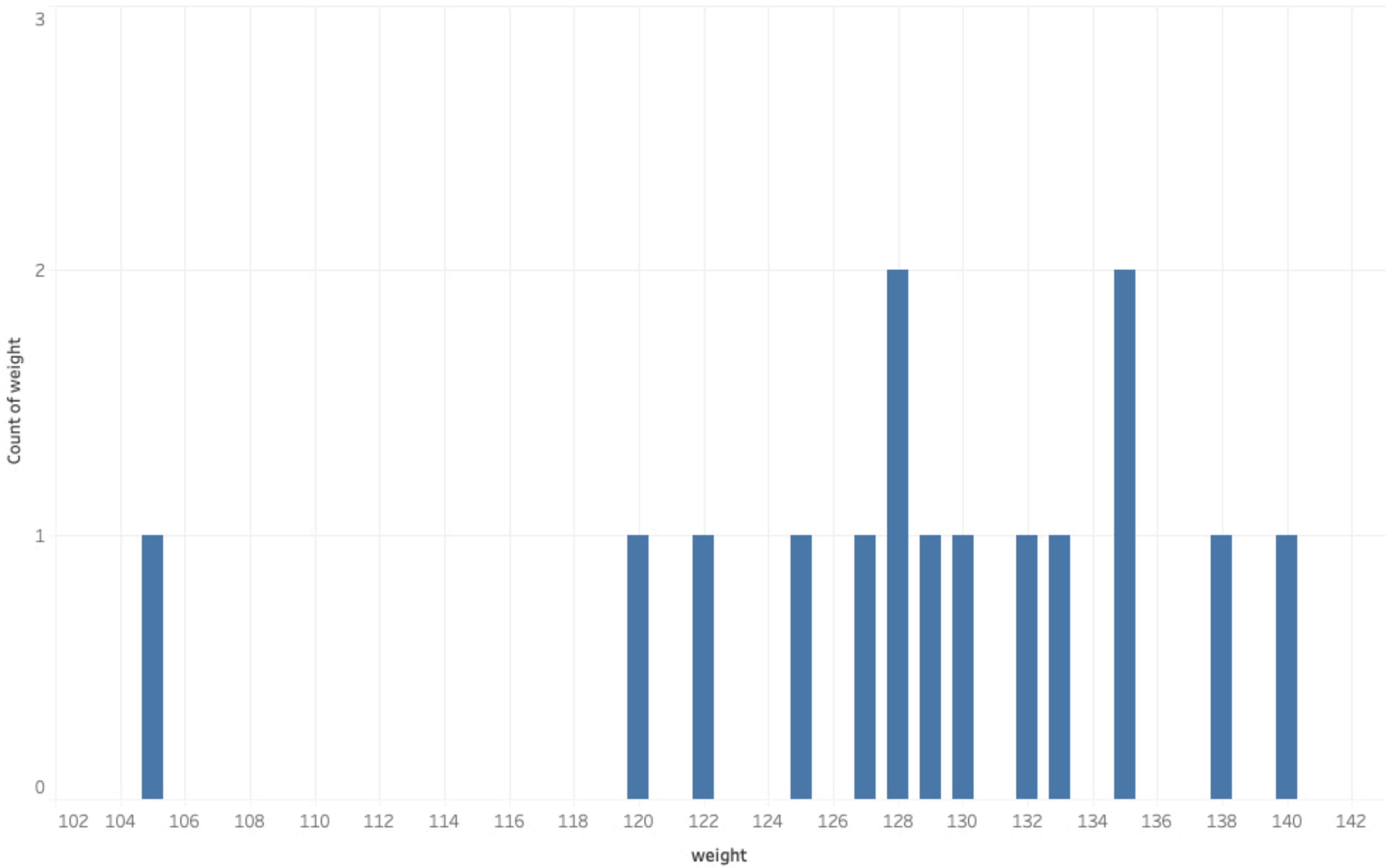

Figure 6.4: Histogram for the apple weights (bin size = 1)

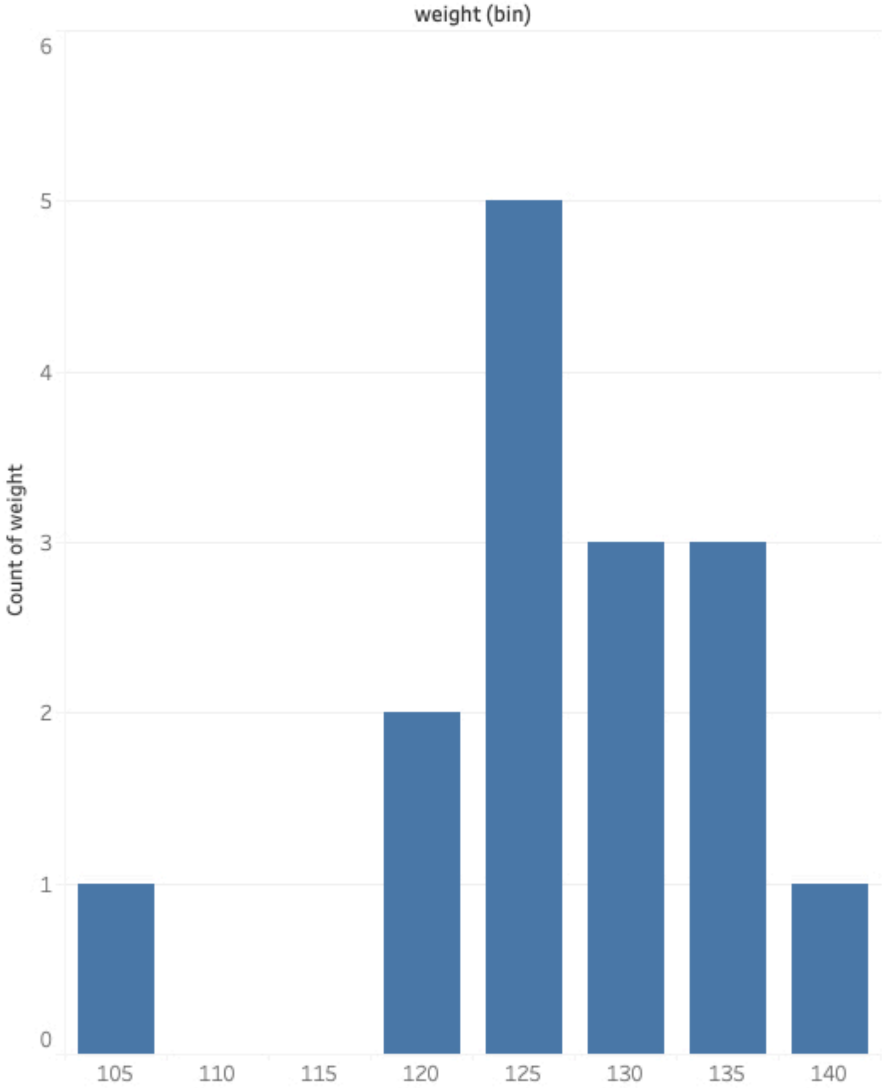

Figure 6.5: Histogram for the apple weights (bin size = 5)

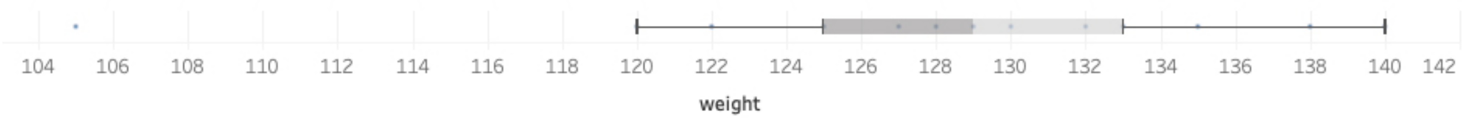

Figure 6.6: Boxplot for the apple weights

therefore, is just a value which is distant from most of the other values in the data set: it may point to an error, which should be corrected, or an anomaly, which may require further investigation, but that's not necessarily the case. However, it's good practice to investigate all outliers to understand why they have occurred.

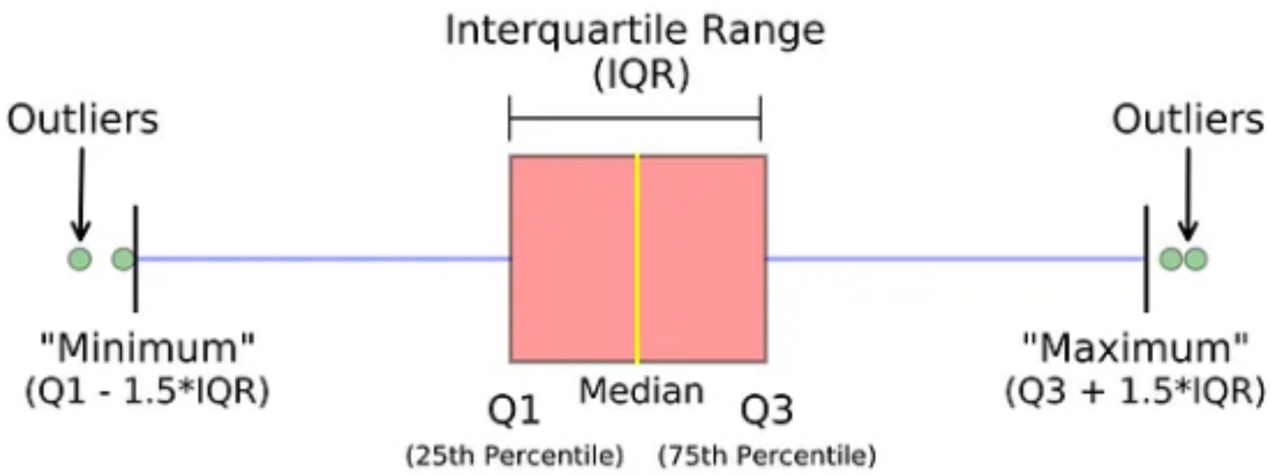

Figure 6.7: The features of a boxplot — LR to redraw as taken from the web

Table 6.4: Common charts to visualise data sets and their descriptive statistics

Chart	**Variable(s)**	**Purpose**
bar chart	one categorical	to visualise counts/frequencies/proportions/percentages
staked bar chart	two categorical	to compare counts/frequencies/proportions/percentages between two groups
histogram	one scalar	to visualise distribution, including centrality, dispersion and skewness
scatter diagram	two scalar	to visualise relationships and possible outliers
boxplot	one scale or one categorical	to visualise spread, skewness, median, IQR and possible outliers
line chart	one scalar by time	to visualise change over time

Activity: Charts in Excel #150

Go back to your Excel sheet from the previous activities and generate charts similar to those in the figures above.

Guidance

In the current version of Excel, you can generate these charts from the Insert tab, by choosing from the Statistical charts menu. If you find it difficult to locate this function, you should refer to the documentation or check some of the many tutorials on this topic which are freely available online.

Table 6.4 summarises useful charts that can be applied to visualise your data and their descriptive statistics: it includes charts we have not used in our examples, but which are very common, so that you can find plenty of study materials online should you wish to look them up and use them.

Calculating descriptive statistics and visualising data in appropriate charts, should be the first step in your statistical data analysis, as these provide useful summaries and visualisations of key properties of your data set. And, as you have found out in the activities, you do not need to be a statistician to be able to generate them!

Descriptive statistics may also help you identify errors or anomalies in the data, and can inform possible follow-up analysis, including inferential statistical analysis. Depending on your research aim and objectives, they could also be all you need in your project.

If you have collected scalar or categorical data, it is time for you to have a go at analysing them using descriptive statistics and charts.

Activity: Applying descriptive statistics to your data #151

Calculate descriptive statistics for your data set, and generate appropriate charts.

Guidance

MS Excel is relatively straightforward to use for this purpose, but feel free to use other tools you may be already familiar with, including statistical or data analytics packages. Whichever tool you use, you should ensure it supports the functionalities we have discussed in this section.

6.4.2.2 Inferential statistics

Inferential statistics relies on the concepts of population and sample: the *population* is the entire group you are interested in studying – say, all UK voters in a general election; while the *sample* is the portion or subset of that group you have access to in your research. Then the aim of inferential statistics is to establish whether patterns or effects you have observed in the sample can be generalised to, i.e., inferred for, the whole population, or whether they are the result of chance. In inferential statistics this is achieved through statistical tests.

Activity: Do I need to know about inferential statistics? #152

Check back to your chosen research strategy from Stage 3. Does it involve data analysis using inferential statistics? If so, read through the remainder of this section and complete the activities.

A statistical test tells you whether the proposition• you wish to test on your sample is likely to be true in the population under study. For this to work, your sample must be representative of the population•.

A statistical test returns a measure of *statistical significance*, which is used to provide evidence (or otherwise) that the pattern or effect you see in your sample is also likely to exist in the population, and is not just the effect of chance•. As a corollary, if your sample is very large, almost all effects observed in the sample will be likely present in the population; vice-versa, if your sample is very small, most effects observed in the sample are unlikely to be present in the population, unless they are really very large. As a rule of thumb, most tests require a sample size of at least 30 observations, but more precise sample size estimates can be made based on population size and expected significance level•.

- You can think of a proposition as an educated guess you have made based on some observations, but that has yet to be supported by evidence.
- We discussed sampling in Section **??**
- Contrary to the common language meaning of 'significance' as big or important, statistical significance only indicates that the effect is likely to exist in the population, where it may well be small or unimportant!
- Formulae for the ideal sample size are easily found in the literature and online.

Each statistical test comprises the following elements.

- **Hypotheses** There are two, *null* and *alternative* hypotheses. Inferential statistics assumes you can't prove something to be true, but you can disprove something by finding an exception. Here is a classic example: you can't prove that all swans are white, but you can disprove they are by finding a black swan! So, you must set the null hypothesis to what you want to disprove about the population, with the alternative hypothesis being what you are really interested in finding out. So, the null hypothesis is usually a statement of no pattern/effect in the population.

- **Significance** This is the level of statistical significance for the test. It's known as the *alpha* (α) value from the Greek name of the mathematical variable used to express it. Most tests are run with $\alpha = 0.05$, which gives a 5% probability that we may infer that the null hypothesis is disproved while in actually it is correct•.

• This is called a Type I error in Statistics.

- **Sample(s)** You need to have one or more (representative) samples of the population of interest on which to perform the test. Multiple samples are used in some tests, typically to compare specific statistics in different groups within the population or changes within a group over time or after an intervention of interest, say treating patients with a new pharmacological drug.

- **p-value** This is the probability calculated for your test by your statistical package, and which is used to decide the outcome of the test.

- **Decision** This is based on the p-value in relation to the α value: if the p-value is less than the α value, then the null hypothesis is *rejected*, i.e. disproved, which means your alternative hypothesis that there is an effect in the population is supported by statistical evidence.

There are very many statistical tests to choose from, depending on the kind of data you have and their distribution, the purpose of your analysis and the number of samples involved.

Statistical tests are applicable to both scalar and categorical data and can be used to compare values of specific statistics or to establish statistical relationships between variables, specifically:

- an *association* between variables means that one variable can be used to provide some information about the other

- a *correlation* is a particular type of association such that the two associated variables always change together, for instance they both increase or decrease at the same time, or when one increases the other always decreases.

Statistical tests can be used to estimate the strength of an association (i.e., the extent changes in one correspond to changes in the other) and its direction (whether the variable changes are in the same or opposite way).

We will not detail all possible statistical tests in this introductory section — once again, entire books have been written about them! Instead, we provide Tables 6.5 and 6.6 as summaries of the most common tests that you can then follow up in the literature, should you wish to apply any in your research.

Even if these tests are only a sub-set of all statistical tests available, there is a lot to digest. The next activity should help you use these table to choose an appropriate test.

Activity: Choosing an appropriate test #153

Consider the following scenarios: for each, use the information in the tables to decide which test to apply and what the null hypothesis should be. For each, write down your reasoning, choice and null hypothesis.

- *Scenario 1* to investigate the amount of sugar contained in baby food of a particular brand against a recommended threshold, from a sample of 30 products of that brand.
- *Scenario 2* to investigate the number of products per hour of two manufacturing machines in the same plant, by observing the two machines' output over 24 hours.
- *Scenario 3* to investigate the effect of temperature on the consumption of ice cream in a particular city over 12 months.
- *Scenario 4* to investigate whether taste in chocolate types, say white vs milk vs dark, is related to gender in particular country.

Guidance

To simplify things, always assume normal distributions.

Discussion

Table 6.5: Common statistical tests for comparison. *Parametric* tests apply to normally distributed data (see Section6.4.2.1), while *non parametric* tests to skewed distributions.

Purpose	**Variables**	**Example**	**Parametric**	**Non parametric**	**Notes**
to compare the sample mean against a specific value	one scalar	to investigate whether AA batteries of a particular brand have the claimed lifespan	one sample t-test	n/a	
to compare the sample proportion against a specific value	one categorical	to investigate the proportion of people who voted for a particular party in a city against that for the whole country	one sample z-test	n/a	
to compare the means of two independent samples	scalar	to compare the mean scores (dependent) of students studying the same subject with two different teaching approaches (explanatory)	independent t-test	Mann-Whitney test/Wilcoxon rank sum	two samples are *independent* when there is no reason to believe that observations in one sample are influenced or determined by those in the other
to compare the means of three or more independent samples	scalar dependent; nominal explanatory	to compare the mean scores (dependent variable) of students studying the same subject with three or more different teaching approaches (explanatory variable)	one-way ANOVA	Kruskal-Wallis test	
to compare the average difference between paired samples against a particular value	scalar dependent; time or condition as explanatory	to compare the blood pressure readings (dependent vraiable) of a group of people before and after exercising (explanatory variable)	paired t-test	Wilcoxon signed rank test	in paired samples each data point in one sample is uniquely matched to a data point in the other sample; this happens, for instance, when we measure a factor before and after an intervention, or take different readings for the same group of individuals. Because of this, paired samples are not independent.

Table 6.6: Common statistical tests for association. *Parametric* tests apply to normally distributed data, while *non parametric* tests to skewed distributions.

Purpose	**Variables**	**Example**	**Parametric**	**Non parametric**	**Notes**
to investigate correlation between two continuous variables	scalar dependent and explanatory	to investigate the relation between blood pressure (dependent) and age (explanatory)	Pearson's Correlation Coefficient	Spearman's Correlation Coefficient	
to investigate association between two categorical variables	categorical dependent and explanatory	to find out if there are gender (categorical) differences in the choice of modes of transport (categorical) in a city	chi-squared	n/a	
to investigate association between two categorical variables when the sample is small	categorical dependent and explanatory	to find out if there are gender (categorical) differences in the choice of modes of transport (categorical) in a city	fisher's Exact test	n/a	the sample size n should be less than 20
to predict the value of one variable from that of one or more other variables	scalar dependent and any kind of explanatory	to predict house prices (dependent) based on location (explanatory, categorical) and number of bedrooms (explanatory, scalar)	linear regression	n/a	linear regression relies on associations between dependent and explanatory variables
to predict the value of a binary variable from that of two or more other variables	binary categorical dependent and any kind of explanatory	to predict whether a customer is likely or not to purchase a certain product (dependent) based on previous purchased products (explanatory, categorical) and average annual spent (explanatory, scalar)	logistic regression	n/a	a binary variable has only two possible values, so that logistic regression calculates the probability of each value based on the values of the explanatory variables. Because of this logistic regression can be used as a classification method

Assuming normal distributions, for each scenario, we have considered:

- the kind of data
- number of samples and their size
- purpose of the investigation

This is what we have concluded:

- *Scenario 1* scalar variable (amount of sugar); one sample of 30 products; to compare the sample mean against the recommended threshold. The test to use is a t-test with null hypothesis that the sample mean is above the threshold.
- *Scenario 2* scalar dependent (number of products per hour) and categorical explanatory (which machine); two samples (one per machine over the time span); to compare the means of products per hours for the two machines; there is no reason to think that the working of one machine may influence that of the other. The test to use is an independent t-test with null hypothesis that the two sample means are different.
- *Scenario 3* scalar dependent (level of ice cream consumption) and scalar explanatory (temperature); one sample over the period; to investigate any relationship between the two variables. The test to apply is Pearson's correlation with null hypothesis that there is no association between the two variables. If, in addition, we wanted to make predictions on ice cream consumption based on temperature, then we could also apply linear regression.
- *Scenario 4* both dependent (chocolate taste) and explanatory (gender) are categorical; one sample from the country; to investigate association. The test to use is a Chi-squared with null hypothesis that gender has no association with chocolate taste.

6.4.2.3 Further reading

Activity: Deep dive into statistical analysis #154

To find out more about statistical analysis, take a look at these resources:
??

6.4.3 Qualitative analysis

Qualitative analysis is used to extract meaning and insights from non numerical data, be that text, images, audio or other.

The most common types of qualitative analysis are:

Thematic analysis which aims to identify recurring themes, their definition and relationships. It is applied particularly to text, e.g., transcriptions of interviews or answers to questionnaires or existing text documents, for instance to find out something about people's views, opinions, knowledge, etc.

Content analysis which aims to identify patterns used for communication, whether in text, speech, images, videos, or other, for instance, focusing on the use of certain words, themes, or concepts within that content. It can be used for many purposes, from discovering and understanding patterns, to looking at intentions behind what is expressed, or to highlighting differences of use in different contexts.

Discourse analysis which focuses on the use of language in conversations in a real-world context, including how this is influenced by historic or cultural factors, or power dynamics.

Narrative analysis which focuses on stories made and told by people to investigate their meaning and how people make sense of reality.

Activity: Do I need to know about any of the above types of qualitative analysis? #155

Check back to your chosen research strategy from Stage 3. Does it involve data analysis using any of the above types of qualitative analysis? If so, read through the remainder of this section and complete the activities.

While their goal may be different, all these frameworks apply *coding* as a core method, which we discuss next.

6.4.3.1 Coding qualitative data

A *code* is essential a label which describes an extract from qualitative data set, with *coding* the process of creating and assigning codes to categorise those extracts.

Coding is important and it helps you ensure that your analysis is systematic, and the codes will help you explore themes and patterns in the data. However, codes are not themes: they are just labels used to group similar types of data, developed to support your follow-up analysis.

There are two main approaches to coding. In *deductive coding*, the codes are decided upfront, before looking at the data, and may be based on your research problem phenomena, or may have emerged from your literature review, including codes possibly used in previous studies. In *inductive* coding, the codes emerge from the data and are not pre-defined. Deducting and inductive coding can also be combined by starting with a set of pre-defined codes then adding new codes as you review the data.

Whichever your approach, you should follow a multi-pass coding process. The first pass should consist of going through the whole data set in order to establish which codes to use. In the second pass, and any subsequent ones, you should apply the codes to the data bit by bit, say by line by line in a text, or frame by frame in a video, etc. In the second pass and subsequent passes, the initial codes are reviewed and may become more or less detailed.

There are various ways to choose codes. For instance, *in vivo* coding uses the exact language which occurs in the data: this is used, in particular, for participants' speech, especially when different languages are used. On the other hand, *descriptive*• coding uses words which encapsulate a general idea, such as 'sport' or 'running': this is particularly useful for non textual data, like images or videos.

• This is a very common approach, although there are others which you can research in the literature.

Whichever codes you end up with, you should ensure they are properly defined, so that their are unambiguous and can be applied consistently. You should use a *codebook* for this purpose, which lists all the codes and their intended meaning, and that you can revisit and refine throughout the coding process.

The last step before detailed analysis is *code categorisation*, which is the process of reviewing what you have coded and organise it into categories. For instance, from codes such as 'football', 'tennis' and 'rugby' you may define a category 'sports'. In this way, you both organise your data and establish connections between codes and coded information.

Both coding and categorisation are iterative processes which carry on until you reach saturation, that is no more is gained from further coding or categorisation. At this point, you can proceed with your chosen analysis method, whether content, thematic, narrative, discourse analysis or other, in order to identify patterns and themes, and provide your own interpretation of the data.

Coding and categorising are time consuming tasks, particularly if you have a large amount of text to code. In most research, coding data by hand is impractical and you should at least make use of a word processor, perhaps using colours and comments to code fragments of your text. Better still, you could make use of a bespoke qualitative data coding tool: many such tools are now available, some of which can also automate coding and categorisation to some extent.

Add URLs in the following question

Activity: Investigating tools for qualitative data coding #156

Conduct a web search on tools which support qualitative data coding. List up to four which appear most commonly used. For each, indicate which coding features it offers and the extent it is freely available for students' research projects.

Discussion

Qualitative analysis tools are growing and changing rapidly, particularly due to the integration and exploitation of AI capabilities.

At the time of writing this book, the most used commercial products include NVivo, ATLAS.it and MAXQDEThey all provide support for coding, with more or less extensive automation, alongside various other features such as data visualisation, statistical analysis, automatic transcripts generation from audio and video files, to name just a few. These commercial products are quite sophisticated with a steep learning curve and are usually quite expensive. They are also geared towards large research efforts, possibly by teams of researchers.

An increasing number of lighter, free products are also available. These include, for instance, Taguette, which supports manual coding and is both open source and free to use, or QDE Miner Lite, which is a free limited version of its full commercial release, and also supports manual coding. Such free products may be sufficient for Masters level research projects.

You may have found other similar tools.

6.4.3.2 Presenting qualitative data

While quantitative data can be summarised and presented using tables and charts, the same does not necessarily apply to qualitative data, which, due to their heterogeneous nature, cannot be easily set out in a standard manner.

Conveying the depth and richness of qualitative data in a succinct way is challenging, so that both selectivity and creativity are needed in presenting the data.

For textual data, like interview transcripts, verbatim quotations are often used to illustrate specific themes or points, or support certain conclusions. However, an excessive use of quotations will result in overlong accounts of the work, which may be difficult to follow or even obscure the main findings. Therefore it is important to select quotations which are particularly representative or poignant, avoiding verbose details that can be succinctly presented in the narrative around those quotations.

Diagrams, schematics or drawings can also be used effectively and imaginatively to present qualitative data and their analysis. Data visualisation is, in fact, a discipline in its own right•, and some visualisation techniques can be applied to qualitative data.

• Edward Tufte is one of the most influential figures in this field. His books provide compelling examples on how to use visualisation to present and analyse highly complex data.

Activity: Visualisation techniques for qualitative data **#157**

Conduct a web search on techniques for visualising qualitative data. List the techniques you have found and what they are used for.

Discussion

You may have encountered some or all of the following techniques:

- diagrams and schematics, to convey complex processes or structures
- graphic timelines, to summarise key events and their order
- word clouds, to summarise emerging themes or concepts from text, and their relative frequencies
- mind maps, to visualise how different ideas relate or contribute to a central concept or topic
- heat maps, to highlight trends or differences in tabulated data
- icons, alongside brief descriptions, to represent and quickly identify specific concepts

- bespoke drawings, for data which cannot be easily visualised using other standard techniques
- pie charts and bar charts, to summarise proportions and counts – which are actually quantitative, but may be the result of qualitative data analysis – of categorical data.

6.4.3.3 Further reading

Activity: Deep dive into qualitative analysis #158

To find out more about qualitative analysis, take a look at these resources:
??

6.5 Writing up your analysis

to review in light of whole draft

In writing up your data analysis in your stage report or dissertation, you will need to decide:

- how to summarise your data and evidence. This will depend on their nature, and you will need to ensure that your summaries are appropriate to convey the essence of the evidence you have generated. In the previous sections, you have considered ways in which quantitative and qualitative data can be summarised using tables and visualisations. It may also be necessary for you to include sample raw data in an appendix.
- how to report findings. Your findings are your conclusions from your data analysis and should be reported as academic arguments which rely on the evidence you have generated.
- how to structure your narrative. Depending on your chosen research strategies and methods, different structures are possible. For instance, you may choose to start with a section which summarises all your evidence followed by one in which you analyse it, which may work well, for instance, for survey research. Alternatively, you could have separate sections each including a summary and analysis of

a sub-set of your evidence: this may be appropriate for mixed methods research, with each section dealing with a different kind of data, or for design science research, with each section addressing a different design cycle. Whatever you choose, it is important that your report is effective in presenting your evidence and findings in a clear, rigorous and logical manner.

Activity: Writing up your analysis #159

Consider the data you have collected and analysed so far. Note down how you are going to address each of the points above in your report. Write an outline of your analysis section.

Guidance

A good starting point is to consider how other researchers report their data analysis and findings. To this end, go back to some of the articles you have reviewed and consider their data analysis section and any related discussion. Ensure you select articles that apply similar collection and analysis methods to those in your research design, or deal with similar types of data.

6.6 Interpreting and evaluating data

Having genearted and analysed a certain amount of data and evidence, it is time for you to start interpreting your findings in relation to your aim and objectives, and generally evaluate them in terms of their contribution to knowledge and possible limitations. This is a process you will repeat and complete in Stage 5, the concluding stage of your project, ending with your dissertation submission.

Interpreting your findings signifies addressing the following questions:

- What conclusions have you drawn from your data analysis?
- How do they relate to your aim and objectives?
- How do they relate to what you know from the literature?
- How do they relate to professional practice? (if applicable)

- Which new knowledge do they contribute?
- What do they fail to achieve?

Activity: Interpreting and evaluating your findings #160

Consider your data analysis and based on it, address each of the above questions. Write down your responses, ensuring your arguments are well-formed, with explicit reference to evidence.

Guidance

Your interpretation and evaluation of findings will be, of course, limited by the data/evidence you have generated and analysed up to this point. You will revisit and expand this work in Stage 5 in order to complete your project.

6.7 Drafting an abstract for your project

An abstract is a common way to summarise academic research. Abstracts are an integral parts of all published academic articles – you will have encountered many abstracts while reviewing the literature. They are also very common in academic dissertations, therefore it is highly likely you will be required to include one at the beginning of yours.

An abstract provides a short summary of the whole research written for a specialist audience, that is you can assume that the reader has good knowledge of the topic and field of study. It should be a stand-alone item, so that it can be understood without reference to any other part of your dissertation.

Its content should convey succinctly the research problem, how and where it arises and its significance, the research aim and research design, key results obtained by the research, their evaluation and their implications for further research or professional practice.

Writing an abstract for your research is a good exercise, even if one is not needed for your dissertation, as it gives you an opportunity to write a logical argument that connects all key elements of your research. This can help you check that all the pieces fit together in a coherent manner. It is also something you can share with your supervisor and critical friends to communicate succinctly the essence of what you have done and achieved.

Activity: Drafting your abstract #161

Write a draft abstract for your project, which should reflect your research progress to date.

Guidance

You should go back to some of the articles you have reviewed to consider the content and structure of their abstract. Choose a structure which may fit your project and write up your draft abstract accordingly. As your research is yet to be completed, you will not be able to write up the full abstract, but you should end up with a draft that you can easily complete by the end of your project.

6.8 Reflecting and reporting in Stage 4

It's time to write your Stage 4 report. As in the previous stages, before you do, it is worth reflecting on your work and learning in this stage.

Activity: Reflecting on your learning and practice #162

As you did at the end of the previous stages, in this activity you are asked to stand back and reflect deeply on what you have leant and done, the wider context of your work and your own attitude to it. Specifically, you are asked to think deeply about each of the following:

- your study this far
- the way you work
- the context of your research
- your feelings about your project

You should also think of any significant changes with respect to your reflection in the previous stages

Guidance

You should be accomplished at reflection by now. However, should you need to, you can refer back to the guidance to this activity in Stage 1, Section 3.7.

Your end-of-Stage 4 report will help you consolidate your work so far, adding yet another increment toward your full dissertation. We recommend you follow the guidance in Table 6.7 to write your report.

At the end of Stage 4, you should complete a report, extending that of Stage 3 and covering the work you have carried on in this stage. Its recommended structure and content are indicated in Table 6.7: much of the content should be carried forward from the previous stage.

Activity: Writing and assessing your report for Stage 4 #163

Using your word processor of choice, revise and expand your Stage 3 report by applying the structure and guidance in Table 6.7.
Assess your report by applying the criteria in Table 6.8. Revise and iterate until you are ready to move on.

Guidance

In completing your report, you should make good use of notes and summaries your wrote as part of the activities in this chapter. In evaluating your report, for each criteria, you should consider the related prompts, write down any further work needed for your next stage, and update your work plan and risk assessment table accordingly.

6.9 Takeaways

- Sampling is the process of selecting a sample from the population of interest, and is required in many research strategies. Many different approaches to sampling exist, depending on the nature and aim of your research.
- Questionnaires are common tools for data generations. Good questionnaire design relies on a wide range of considerations (see Section **??**).

Table 6.7: Report structure and guidance

Report template	**Guidance**
Proposed title	Your title should continue to capture succinctly your research problem and aim. *It is likely this is the same as, or very similar to, that in Stage 3*
Abstract	You should include your draft abstract providing a succinct account of your research to date
Sect 1 - Introduction 1.1 Background to the research 1.2 Justification for the research 1.3 fitness of the research	This section should continue to provide an introduction to your research topic in its wider context (as background) and your justification of why the research is worth pursuing. Its purpose is to introduce and justify your intended research in overview, before entering the detailed work of the subsequent sections. It should be well argued and supported by appropriate citations. In this section, you should also argue how the research fits within the scope of your qualification, and meets any other personal, professional or organisational criteria. *You may review this section from Stage 1 to reflect your growing understanding of the topic in context derived from your literature review.*
Sect 2 - Literature review 2.1 Review of existing relevant knowledge 2.2 Critical summary, including knowledge gap to be addressed by the research	Your review should provide a critical account of your in-depth engagement with the academic (and other) relevant literature, including identifying key trends, ideas and possible knowledge gaps. Most of your citations should point to academic articles. Your critical summary should highlight key insights from your review and provide a strong justification for your proposed research. Both coverage and depth of your review matter. You should ensure that your review is well structured, with a logical narrative flow and your arguments are well supported by evidence
Sect 3 - Research definition 3.1 Problem statement 3.2 Aim, objectives, tasks and deliverables 3.3 Knowledge contribution	You should ensure that your research problem is well articulated and appropriate for your course and your personal and professional circumstances, that your aim and objectives are consistent with research problem, that tasks and deliverables break down your objectives appropriately and are clearly related to your chosen research methods, and that the intended knowledge contribution of your research is clearly articulated
Sect 4 - Research design 4.1 Evidence and data 4.2 Research strategy and methods 4.3 Research procedures 4.4 Ethical, legal and EDI considerations	This section should demonstrate your critical engagement with all elements of research design, including a detailed account of the data and evidence needed in your research, the research methods and research strategies chosen, with justification, and applied within your project. Your account should be supported by a clear rationale and insights from the related literature, and appropriately justified in relation to your research problem, aim and objectives. It should also demonstrate your careful consideration of ethical and legal matters, and that your research complies with your

Table 6.8: Criteria for reviewing your research proposal

Criteria	Prompts
Completeness	Are all sections included and their content complete? What is missing?
Academic writing	Have you applied good academic writing practices throughout? Which main issues do you still have to address?
Logical structure and flow	Have you structured your writing appropriately to ensure a logical flow of arguments? Which restructuring may be needed?
Supporting evidence	Are your key arguments supported by appropriate references or other evidence? Which further evidence is needed?
Citation and reference style	Do all your citations and references comply with the required bibliographical style?
Avoiding plagiarism	Have you acknowledged the work of others and distinguished it from your own appropriately?
Grammar and spelling	Have you proof-read your report carefully to remove all typos and grammatical errors?

- When a large amount of raw data is collected, it is important to devise appropriate ways to store and organise them, paying particular attention to backing them up and protecting personal data.

- Tables are common ways to organise and present data, and a good starting point for data analysis. Pivot, frequency and contingency tables are commonly used in research.

- Descriptive statistics is used to describe data, with various attributes of data sets defined and calculated, such as centrality, dispersion or skewness. Charts are often used to visualise such attributes.

- Inferential statistics is used to make predictions from data, specifically to establish whether patterns or effects observed on sample data can be inferred for the whole population from which the sample was taken.

- Statistical tests are used to establish the statistical significance of observations on a sample in relation to the whole population. They are used both for comparing data to set values and to establish relationships between variables. Many statistical tests exist.

- Coding is the first step in qualitative analysis, and is the process of assigning labels to extracts from a qualitative data set to allow a systematic follow-up analysis. Different approaches to coding exist.

- Qualitative data are heterogeneous in nature, so that they cannot be easily set out in a standard manner. Many different, often bespoke, approaches to present and visualise qualitative data have been proposed in the literature.
- In writing up your data analysis you must decide how to summarise your data, how to report your findings and how to structure your narrative.
- Interpreting your findings means to indicate what you can conclude from the data, how that relate to your aim and objectives, and which new knowledge it contributes.
- An abstract is a short summary of your whole dissertation, written for a specialist audience as a stand-alone piece, that is understandable without reference to any other part of your dissertation.
- The template provided can help you structure your Stage 4 report.

Chapter 7

Stage 5: Completing your dissertation

Add summary of what has been achieved.

Stage 5 will see you completing your research project and writing up your full dissertation, ready for submission.

This stage assumes that you have made good progress with your data generation and analysis and on the interpretation of your findings. This has given you a contribution to knowledge that aligns•, and that you're ready• to put it all together into a single narrative which you will complete in this stage.

With reference to our 5-stage framework, the activities which are in focus in Stage 5 are summarised in Table 7.1, which also provides some guidance for your interaction with your supervisor during this stage.

****

- More or less, there'll be opportunities for fine tuning later! If you don't feel this is the case, there'll also be opportunities to return to specific parts of previous stages.
- You could be almost ready; most of the way towards your goal.

Activity: Understanding the effort needed in this stage #164

Consider Table 7.1 carefully, paying particular attention to the entries in the 'Effort' column. Make a note of the activities which are most prominent in this stage and what their deliverables and learning outcomes are.

Discussion

In this stage, generating and analysing data and interpreting your findings will constitute your major effort (around 60% of your study time), although considerable effort (35%) will also be needed in assessing your research overall and completing your dissertation. You shouldn't underestimate the time needed to complete and polish the dissertation so that is ready for submission, which is why the framework assume

Table 7.1: Research activities addressed in Stage 5 (30% of project length)

Research process activities	**Deliverables**	**Learning Outcomes: by the end of this stage you will:**	**Effort**	**Suggested focus of your interaction with your supervisor**
Identifying the research problem	Final research problem statement		1%	
Reviewing the literature	Full literature review		1%	
Setting your aim and objectives	Finalised aim and objectives, appropriately broken down into tasks		2%	
Developing the research design	Complete account of your research design		2%	
Generating and analysing data	Data appropriately presented and analysed, with extracts from raw data in dissertation appendix, if needed; remaining raw data appropriately stored	be able to organise and store your raw data; be able to apply appropriate data analysis methods; be able to present your data in a concise and effective way	40%	Appropriateness of data analysis and presentation
Interpreting and evaluating findings	Critical summary and evaluation of findings	be able to derive findings from your data analysis and critically assess them in relation to research aim and objectives	20%	Critical and logical thinking
Reflecting and reporting	Full dissertation, including an assessment of the whole project	be able to assess entire research; be able to complete your dissertation to the expected presentation standards	35%	Depth of critical thinking, quality of academic writing, and conformance to standards
Planning work and managing risk	Review of work from previous stage and project risk, with adjustment to work plan for Stage 5	be able to assess risk and revise a work plan	1%	Any major adjustment required to complete the project

a significant effort in this stage.

7.1 Completing your research

Building on Stage 4, in this stage you will complete your work on generating and analysing data, on their interpretation in the context of a contribution to knowledge. This will give you a substantial start of the presentation of your findings in your dissertation.

Activity: Completing your data generating, analysis, and interpretation #165

Complete your research on generating and analysing data, and the interpretation of your findings in terms of your aim and objectives. Expand on your analysis and summaries from your Stage 4 report.

Guidance

Ensure you continue to manage your raw data carefully, and that your report presents all your data/data, findings and their interpretation in a clear and rigorous manner.
This activity is likely to take up to 40% of your study time, assuming you were able to make good progress with your data collection, analysis and interpretation in Stage 4. If that's not the case, you should discuss with your supervisor what you will be able to achieve realistically in the remaining time for your project, for instance whether it would be possible to reduce the scope of your research or apply alternative, more time-efficient research strategies and methods. Ensure that any changes are appropriately accounted for in your work plan for this stage.

7.2 Assessing your research

Once you have completed your work on generating and analysing data, and interpreting your findings, it is time for you to reflect on your whole project, evaluate what you have done and draw some overall conclusions. These will form the body of the concluding chapter of your dissertation, for which you are asked to think critically about each of the following:

- **Evaluation against aim and objectives**: you should reflect on the extent your research has met its stated aim and objectives. The interpretation of your findings against aim and objectives is a good starting point to draw these summary conclusions. While your interpretation may be deep and detailed, with reference to specific data, here you are expected to highlight key conclusions based on such an interpretation. If, in the cold light of day, your research hasn't fully met your aim and objectives then you will need to establish for the reader what you have achieved: in this section you need to make a critical assessment of what your research has actually achieved.

- **Evaluation against the academic body of knowledge**: this requires you to assess the extent your findings have added to the body of knowledge in your field of study, including whether they support or question findings already known from the literature you have reviewed. You should show awareness of how your own research relates to the wider academic context.

- **Implications for practice (if any):** here you should reflect on ways in which your research may be relevant to professional practice, if applicable, including how it could lead to change and improvement. If your research is purely theoretical, then you can skip this section, and focus on the previous two items instead.

- **Validity of the research**: this require you to assess your research in terms of construct, internal and external validity. You should refer back to Stage 3 materials to refresh your understanding of validity.

- **Further research**: your research may have shed light on aspects of your research problem, or highlighted other related research problems, which you did not have the time to explore in your project. This is the place for you to discuss those of more relevance and to indicate how future research can build on the work you have done.

- **Personal reflection on your research experience**: whether or not your research project is your first experience of academic research, you should reflect on what you have learnt from a personal standpoint in relation to thinking and behaving like an academic researcher. You should address how your mindset and skills have changed, or how you would do things differently should you start anew, and any other relevant thoughts you may have.

Activity: Assessing your research overall	#166
Assess your overall research in relation to the above points, and write appropriate summaries of each for inclusion in your dissertation.	
Guidance	
For each point above, consider the related guidance to help you assess your research overall. Note that this assessment should consider all the work you have conducted in your project.	

7.3 Finalising and submitting your dissertation

It's getting exciting – you now have all the data, evidence, and arguments in a form you need to complete your dissertation. You may have nigh-on one hundred pages of carefully written prose that looks very good on your screen. It's now time to finalise your dissertation for submission.

Your dissertation should extend your Stage 4 report by covering the work you have carried on in this stage. The structure and content we recommend are indicated in Table 7.2.

7.3.1 Finding and dealing with gaps

By now, you should have something to say in each of the chapters and sections suggested in Table 7.2. Depending on your chosen research strategy the material for certain sections may extend to many pages: for an experiment, it may be that there is an extensive sections on reflexivity, triangulation, and validation. These sections may be much shorter if they appear at all, in the mathematical thinking research strategy.

Irrespective of which research strategy you have chosen, however, some sections will always have content. These include:

- list here

Some of these may simply not have been written yet• even though you know that they are needed and have things• to say – for instance, we recommend leaving the Abstract, Introduction and Conclusions until quite late in the writing process. Others you will complete next.

• Or not written to D1 – the first complete draft.

• Or will have!

Table 7.2: Dissertation structure and guidance

Dissertation template	Guidance
Title	Your title should capture succinctly your research problem and aim
Abstract	Your abstract should providing a succinct account of your research
Chapter 1: Introduction 1.1 Background to the research 1.2 Justification for the research 1.3 Fitness of the research	This chapter should provide an introduction to your research topic in its wider context (as background) and your justification of why the research is worth pursuing. Its purpose is to introduce and justify your intended research in overview, before entering the detailed work of the subsequent chapters. It should be well argued and supported by appropriate citations. In this chapter, you should also argue how the research fits within the scope of your qualification, and meets any other personal, professional or organisational criteria.
Chapter 2: Literature review 2.1 Review of existing relevant knowledge 2.2 Critical summary, including knowledge gap to be addressed by the research	Your review should provide a critical account of your in-depth engagement with the academic (and other) relevant literature, including identifying key trends, ideas and possible knowledge gaps. Most of your citations should point to academic articles. Your critical summary should highlight key insights from your review and provide a strong justification for your proposed research. Both coverage and depth of your review matter. You should ensure that your review is well structured, with a logical narrative flow and your arguments are well supported by data
Chapter 3: Research definition 3.1 Problem statement 3.2 Aim, objectives, tasks and deliverables 3.3 Knowledge contribution	You should ensure that your research problem is well articulated and appropriate for your course and your personal and professional circumstances, that your aim and objectives are consistent with research problem, that tasks and deliverables break down your objectives appropriately and are clearly related to your chosen research methods, and that the intended knowledge contribution of your research is clearly articulated
Chapter 4: Research design 4.1 Data 4.2 Research strategy and methods 4.3 Research procedures 4.4 Ethical, legal and EDI considerations	This chapter should demonstrated your critical engagement with all elements of research design, including a detailed account of the data needed in your research, the research methods and research strategies chosen, with justification, and applied within your project. Your account should be supported by a clear rationale and insights from the related literature, and appropriately justified in relation to your research problem, aim and objectives. It should also demonstrate your careful consideration of ethical and legal matters, and that your research

Activity: Putting your dissertation together #167

Using your word processor of choice, and starting from your previous report, complete your dissertation by applying the structure and guidance in Table 7.2, and making good use of your notes and summaries from all related activities you have carried out.

Guidance

Although the dissertation structure and guidance we provide is fairly standard, it is possible they don't not match exactly the requirements of your own course, which may provide a different template for you to follow. Indeed you should check and apply your course guidance, and map the structure and guidance in Table 7.2 to what is required in your course of study.

7.3.2 Revising your draft for compliance to requirements

Now that you have a complete draft of your dissertation, you should revise it to ensure it meets your course requirements.

In our experience, a Masters dissertation is usually in the range of 10,000 to 15,000 words. Often, references, abstract and appendices are excluded from the word count, but figure and table captions are included. In general, there is an expectation that the content of your dissertation is balanced across the different chapters, although it is normal for some chapters to be more substantial than others. Our recommended distribution of content across the full body of your dissertation, based on our recommended dissertation structure, is indicated in Table 7.3, as a percentage of total. This is not a hard and fast constant, but can provide a baseline for you to get an idea of the relative weight of the different chapters of your dissertation. In adapting it to the needs of your own project and course, however, you should ensure you maintain a good balance across the whole piece.

There is also an expectation that your dissertation conforms to some standard presentation conventions, which we have summarised in Table 7.4.

Activity: Reviewing your dissertation #168

Review you current dissertation draft and make all necessary adjustments to ensure it meets the guidance and requirements above, or similar requirements and guidance from your own course.

Table 7.3: Breakdown of dissertation content

Element	Breakdown	Recommended word count distribution	Equivalent for 10,000 word dissertation	Equivalent for 15,000 word dissertation
Chapter 1 Introduction	Background to the research Justification for the research Definitions (if any) Dissertation outline	10%	1000	1500
Chapter 2 Literature review	Review of existing relevant knowledge Critical summary, including knowledge gap	20%	2000	3000
Chapter 3 Research definition	Problem statement Aim, objectives, tasks and deliverables Knowledge contribution	10%	1000	1500
Chapter 4 Research design	Data Research strategy and methods Procedures Ethical considerations	15%	1500	2250
Chapter 5 Analysis and interpretation	Summary and analysis of data Summary of key findings Interpretation in relation to aim and objectives	30%	3000	4500
Chapter 6 Evaluation and conclusion	Evaluation against aim and objectives Evaluation against the academic body of knowledge Implications for practice (if any) Validity of the research Further research Personal reflection on your research experience	15%	1500	2250

Table 7.4: Presentation conventions

Fonts	Use a standard font that is easy to read, e.g. Times New Roman or Arial, with font size 11 or 12
Margins and spacing	Leave appropriate margins on both the left and the right of the page, typically around 2 cm. Use 1.5 line spacing
Your identifiers	Include your name and student identifier, possibly as a header or as part of the title page
Title page	Include a title page containing your research title. Usually the following statement is also required: “A dissertation submitted in partial fulfilment of the requirements for the degree of <name of degree>”, where you should replace <name of degree> with your own degree title
Table of content	Include a table of content after the title page
Page numbers	Number all pages, including references and appendices. In particular, use lower-case Roman numerals on the preliminary pages – iii, iv, v, etc. – and Arabic numerals starting from page 1 at the beginning of Chapter 1.
Chapter and section numbering	Number chapters sequentially using Arabic numerals starting with 1. Number sections sequentially starting with the chapter number, e.g. 1.1, 1.2, etc. for sections in Chapter 1. Number sub-sections sequentially starting with the section number, e.g. 1.1.1, 1.1.2, etc. for sub-sections in Section 1.1. You should avoid sub-sub-sections, but if needed, number them sequentially starting with the sub-section number, e.g. 1.1.1.1, 1.1.1.2, etc. for sub-sub-sections in Sub-section 1.1.1.
Figures and tables	Number all figures and tables sequentially, starting with their chapter number, e.g. 1.1, 1.2, etc. for figures in Chapter 1. Include appropriate captions positioned after figures and before tables
Lists of figures and tables	List all figures and tables after your table of content. For each include both their number and caption
Citations and references	Apply the required bibliographical style throughout
Verb tense	Your dissertation is an account of what you did in your project, so you should report your work using the past tense throughout

Guidance

While our recommendations are fairly standard, it is essential that you ensure they align with your own course requirements and guidance: if not, you should of course apply the latter. Whichever guidelines you follow, you should ensure that your dissertation fits within the overall word count, its content is appropriately balanced, and all required presentation conventions apply.

7.3.3 Final check and submission

Before submitting your dissertation, you should perform a final check, focusing on the following aspects:

- **Logical coherence**: you should ensure that all research elements of your dissertations are coherent and consistent with each other, so that there is a logical progression from research problem, to aim and objectives, to research design and its execution, to findings and conclusions.

- **Academic writing**: you should ensure that academic arguments are well formed, including being well-supported by secondary and/or primary data, that the language you use is clear and precise, and there is a good balance between description and critical reflection.

- **Proof-reading**: you should remove grammatical errors and typos, and ensure that punctuation is correct. You should also check that the narrative makes sense to the reader, for which we strongly advise you ask for help from a friend or family member: even if they are not experts on the topic of your project, they should be able to follow what you have written and get the gist of your work.

- **Conformance to presentation conventions**: you should ensure that your dissertation conforms to the the requirements of your course, follows its presentation conventions, its length is within the word limit, and its content is well balanced between chapters.

Activity: Performing your final check #169

Assess your dissertation draft against each of the points above. Revise and iterate until you are ready to submit.

Guidance

Revising your dissertation for submission is very important as you can lose a substantial proportion of marks should any of these aspects not be addressed carefully and to the expected standards.

You should now be ready to submit your dissertation. You should, of course, follow the instructions for your course of study to do so.

7.4 How your dissertation will be assessed

After submission, your dissertation will go through your university's assessment process, which is designed to ensure that your work is assessed fairly against Masters research benchmarks and your course learning outcomes. The specifics of this process will depend on your own university and course (or programme) of study, something you should investigate carefully.

Make this an activity earlier in the process.

You should also investigate the assessment criteria applied to your work. Typically, your Masters dissertation will be assessed from the following perspectives, although the specific marking scheme applied within your course may break each further:

And this

Is this earlier too?

- **Research definition and research design**: this refers to an appropriate articulation and justification of the research problem in its wider context, including your critical review of the academic literature to contextualise and justify your research problem and knowledge contribution, a well developed and justified research design, and well constructed academic arguments
- **Data generation, analysis, interpretation, and conclusion**: this refers to a competent execution of your research design, an adequate amount of data gathered and analysed, an appropriate interpretation of your findings, and a critical evaluation of your research overall
- **Presentation**: this refers to how your dissertation is put together, its cohesiveness and logical flow, including abstract, and its conformance to conventions, including an appropriate use of tables, figures and diagrams to summarise and present your work.

And extended abstract, if needed.

The assessment of your work under these criteria will contribute to your final grade, which will be established by your examiners in relation to Masters level quality benchmarks, including those summarised in Table 7.5.

These are the typical criteria for the UK. Those in your country may vary.

Add source

Activity: Assessing your own dissertation #170

Apply the three perspectives above together with the benchmarks of Table 7.5 to your dissertation. Write down your own assessment of your work as a result.

Table 7.5: Typical grade benchmarks for Masters dissertations, based on UK quality standards

Grade	Quality descriptor
Distinction	All elements of the dissertation are present, including abstract and any required appendix, and are of a high standard. In particular, the dissertation demonstrates: advanced, authoritative understanding and analysis of key issues and complex problems; strong data of a critical approach to own work and that of others; competent use of a wide range of data in support of academic arguments; appropriate and well justified selection of research strategies and methods, applied competently to own research; originality and independence of thought; compelling narrative which is coherently and logically presented; excellent presentation standards; excellent research potential
Merit	All elements of the dissertation are present, including abstract and any required appendix, and are of a good standard. In particular, the dissertation demonstrates: good understanding and analysis of key issues; good data of a critical approach to own work and that of others; good use of data in support of academic arguments; appropriate selection of research strategies and methods, applied reasonably well to own research; some originality; coherent and logically presented narrative; good presentation standards; good research potential
Pass	Some elements may be weak or missing, but all three perspectives above are sufficiently addressed. In particular, the dissertation may data some of: limited understanding and analysis of key issues; limited data of critical approach to own work and that of others; limited use of relevant data in support of academic arguments; some appropriate choices of research strategies and methods, but with limited application to own research; plausible narrative; adequate standards of presentation
Weak fail[b]	Many elements of the dissertations are very weak or missing, and not all three perspectives above are sufficiently addressed. In particular, the dissertation may data many or all of: superficial understanding and analysis of key issues; weak data of critical approach to own work and that of others; gaps in the use of data in support of academic arguments; inappropriate choice or application of research strategies and methods; weak narrative; poor standards of presentation
Complete Fail	The dissertation has critical flaws and omissions, so that is not recoverable via a resubmission. In particular, the dissertation demonstrate many or all of: lack of understanding and analysis of key issues; lack of critical approach to own work and that of others; little or no use of data in support of academic arguments; inappropriate choice or application of research strategies and methods; incoherent and confused narrative; inadequate standards of presentation

[a] In this case, a course may allow some remedial work and resubmission.
[b] In this case, a course may allow some remedial work and resubmission.

Guidance

Your course of study may provide some detailed guidance on how your dissertation will be assessed. If that's the case, you should compare that guidance to the advice in this handbook, and apply it in your own assessment of your dissertation. You should only assess the content of the dissertation as is, disregarding all other knowledge you will have of your research which is not reported.

You should take an objective stance, considering both strengths and weaknesses of your work. You could also ask a friend or a family member to assess your dissertation, then compare their assessment with yours.

7.5 Takeaways

- Completing your project and finalising your dissertation are substantial tasks, so that you must ensure you have sufficient time in your work plan.
- Your overall assessment of your project must address several dimensions, including the extent your aim and objectives were met, any new knowledge generated, its wider significance, the validity of your research and its implications for future work.
- Your dissertation should meet a range of requirements on both coverage, structure, length and presentation convention. You should ensure your work meets the requirements and follows the guidelines provided by your course of study.
- Your dissertation will be assessed following a process defined by your own course of study and university. Grade benchmarks are likely to apply, which may be based on national, or even international, benchmarks.

Chapter 8

Closing

8.1 Concluding remarks

Your dissertation submission concludes your Masters project work. If you have come that far, then you deserve much praise and this is a significant intellectual achievement. A successfully project is a strong indication that you have mastered a wider range of research and transferrable skills, which are of great value to your professional development and provide a strong foundation for any future academic or professional research you may choose to pursue, including doctoral studies.

We hope you have found conducting your own research rewarding, despite, and perhaps because of, the challenges that undoubtably you will have encountered and overcome during your project. We also hope you will have found this handbook valuable in supporting you throughout your project.

We wish you all the best for your future career and studies!

Chapter 9

Glossary

Academic literature: the collection of all published research and scholarly work.

Active reading: engaging with written materials in a way which allows you to assimilate the important points in an effective manner

Artificial Intelligence (AI): a sub-discipline of Computing, aimed at creating software systems able to simulate human intelligence processes.

Bibliographical database: a searchable collection of academic literature.

Bibliographic Management Tool (BMT): software tool used to collect and save searchable information concerning articles and other literature sources reviewed during research, including digital copies of articles and personal notes, and to generate references, reference lists and bibliographies in a variety of bibliographical styles.

Bibliography: a separate section, usually towards the end of a document, which collects full bibliographical information of sources, whether cited or not, which are relevant to the content of the document.

Bibliographical style: a set of rules which determine what citations and references should look like in academic writing.

Categorical (or nominal) data are qualitative data corresponding to categories that cannot be ordered and on which mathematical operations and function don't apply, e.g., full-time vs part-time study.

Citation: a short-cut that appears in the main body of a written academic piece to refer to a specific source in the academic (or other) literature.

Citation searching: a technique for exploring the literature based on citations in academic articles.

Critical writing: writing displaying a good balance between description, analysis, synthesis and evaluation.

Correlation: statistical relationship among two or more measures, concerning how changes in one measure are reflected in changes in the others.

Data analytics tool: sophisticated digital tools which extend spreadsheet capabilities for collating and visualising data to include some degree of automated analysis, both statistical and based on Machine Learning algorithms.

Descriptive statistics: measures used to provide meaningful summaries of data points within a dataset.

Gantt chart: a scheduling chart used to plan, organise and monitor activities and work over the duration of a project.

Google Scholar: a web search engine specialising in scholarly content.

Grey literature: collection of information produced by organisations whose primary or commercial remit is not publishing, such as as universities, government bodies or businesses (other than publishers). It includes pre-publication and non-peer-reviewed articles, theses and dissertations, research and committee reports, government reports, conference papers, accounts of ongoing research, etc.

Interval data are ordinal data, but for which we can calculate precisely the interval between any two data points. For instance, calendar dates are interval data in the sense that we can calculate precisely the interval between two given dates, e.g., the number of days in between.

Kanban board: an agile project management tool to help individuals or teams organise and track their progress on specific tasks during a project.

Machine Learning (ML): a branch of Artificial Intelligence aimed at creating software systems able to learn autonomously and improve from experience.

Numerical data are numbers, either discrete or continuous, e.g., the number of students on a module (discrete) or the average temperature in the UK in July 2023 (continuous). Numerical data can be ordered, and mathematical and statistical operations and functions apply.

Nominal data: same as categorical data

Ordinal data are data that can be arranged in an order, but are not necessarily numerical, e.g., a 5-point Likert scale from (1) Strongly disagree to (2) Disagree to (3) Neither agree nor disagree, to (4) Agree to (5) Strongly agree. While these values can be arranged in the order indicated, mathematical and statistical operations and functions don't apply.

Plagiarism: passing off someone else's work, words or ideas as your own, often as a deliberate attempt to deceive.

Research asset: information which is needed, gathered or generated by your research, including articles, data, images, tables, notes, etc, organised and managed in a disciplined and systematic manner.

Qualitative data: descriptive data, like texts, words, images, sounds, etc., including categorical (or nominal) data, e.g., full-time vs part-time study or employed vs unemployed.

Quantitative data: data that can be quantified or measured, and be given numerical values, including numerical, ordinal and interval data.

Reference: the full bibliographic information of a source in the academic (or other) literature which is cited in an academic text.

Risk: the likelihood of something going wrong combined with the impact that may have on a project.

Spreadsheet: a digital tool used to capture, display, analyse and manipulate data arranged in tables.

Version control system: a set of conventions or tools to keep track of different versions of documents and other research assets.

Chapter 10

References and further reading

Cottrell, Stella. Critical Thinking Skills : Effective Analysis, Argument and Reflection, Bloomsbury Publishing Plc, 2017. ProQuest Ebook Central, https://ebookcentral.proquest.com/lib/open/detail.action?docID=6234915.

A practical handbook to develop your critical thinking skills, packed with activities and practical advice.

Cryer, Pat. The Research Student's Guide to Success, McGraw-Hill Education, 2006. ProQuest Ebook Central, https://ebookcentral.proquest.com/lib/open/detail.action?docID=316264.

A comprehensive introduction to research skills for post-graduate research students. Some elements are more relevant than others to Masters research, so this is a good reference book to dip in and out.

Potter, Stephen (ed.) (2006) *Doing postgraduate research*, SAGE study skills, 2nd edition., Los Angeles London New Delhi, SAGE.

Another comprehensive introduction to research skills for post-graduate research students, possibly more suited to PhD students than Masters students.

Etzold, Daniel 2020). My Workflow for Reading Scientific Papers. https://betterhumans.pub/my-workflow-for-reading-scientific-papers-d4b27dbb38a6

Some practical advice from a practitioner. This is a personal account, rather than a tried-and-tested method. Nevertheless, it contains some good tips that you may find useful.

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Klopper, Rembrandt, Lubbe, Sam & Rugbeer, H., 2007. The matrix method of literature review. Alternation, 14(1), pp.262–276.

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Keshav, S. (2007) 'How to read a paper', ACM SIGCOMM Computer Communication Review, 37(3), pp. 83–84.

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M. K. S. Sastry and C. Mohammed, "The summary-comparison matrix: A tool for writing the literature review," IEEE International Professional Communication 2013 Conference, 2013, pp. 1–5, doi: 10.1109/IPCC.2013.6623891.

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Booth, W., Colomb, G.G. and Williams, J.M. (1995) *Making good arguments: an overview.* The Craft of Research, London: The University of Chicago Press.

Simon, H. A. (1969). The sciences of the artificial. The MIT Press.

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Data Protection in the EU, https://commission.europa.eu/law/law-topic/data-protection/data-protection-eu_en (Last accessed: February 2023)

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UKRI Equality, diversity and inclusions key principle. https://www.ukri.org/about-us/policies-standards-and-data/good-research-resource-hub/equality-diversity-and-inclusion/(last accessed: November 2022)