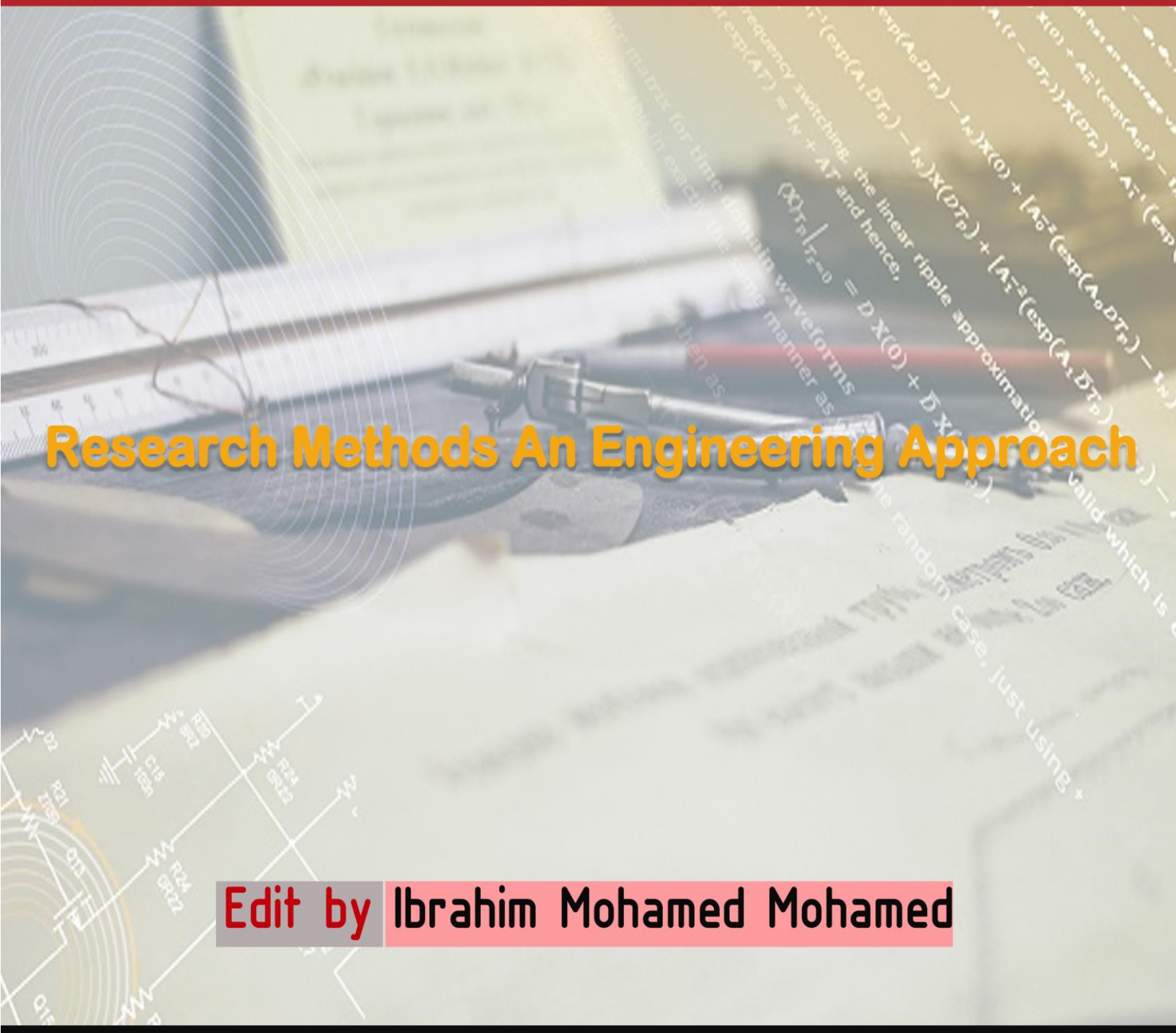

Research Methods An Engineering Approach

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Syllabus

About this course:

A PhD or master's level research project is an enormous undertaking, and you might find yourself a bit uncertain about the process or how to achieve the desired outcome. In this research course, you will learn the underlying principles that are needed to conduct research from an engineering perspective. This course is designed for engineering students conducting postgraduate research work on engineering projects. The objective of the course is to translate current research methods, which are mostly from a social science perspective, into something more relatable and understandable to engineers. Our hope for this course is to go beyond the concepts to understand the actual reasons for doing research in a certain way. While engineers are the main target audience, non-engineers will find this information useful as well. The methods taught in this course will equip you with the knowledge needed to design, plan and construct your own research process.

Chapter 1: What constitutes research?

We often want to achieve something or have an ability to do something, for whatever reason. Often this is very difficult or not possible because we lack the knowledge to do it. Research is about the process of making that missing knowledge. Knowledge about the world normally precedes knowledge how to do things. It is knowledge about the world that we are looking for.In this module you will find out how to distill the research question or problem from within your bigger objective. Normally the objective is something that is easy to motivate and describe. However the research is often bogged down by the bigger objective and the core knowledge that is required is not visible.

Chapter 2: What makes research a contribution?

What makes research output a contribution? Even if correctly executed, research which makes new knowledge is not automatically a contribution. Who will evaluate your research outputs and what are they looking for? The contribution and level of contribution is decided by the broad community of researchers in your field. This "peer review" aspect is often overlooked. These are the actual customers who want your new knowledge.In this module you will discover how your new knowledge is assessed by your peers, and what they are looking for. How you can use the peer review process to your advantage to do research that has an impact in your field.

Chapter 3: Where does my research fit in?

Your new knowledge will build on that which already exists. This is good because it allows you to use the results of others to go much further than on your own. A good foundation also lends credibility to your new knowledge. However, it also limits disruptive ideas and new fields of inquiry. In this module you will learn how to establish a solid foundation on which to build your new knowledge as well as what not to include in your foundation.

Chapter 4: Writing

Researchers are writers. You will write a thesis, a dissertation or a paper. New knowledge is always written down. Writing is often seen as a big hurdle and "writing up" is left until the final stage of research. This is almost always a bad idea. Writing is the discovery process, and it should take place continuously. In this module you will learn to use the writing process to enable the faster flow of ideas and stimulate the creation process.

Chapter 5: Argument

Reasoning and argumentation are the processes through which knowledge is evaluated. You use these techniques to evaluate the work of other. In the same way these processes will be used to evaluate and accept or reject your research. The objective of an argument is to give the reader good reasons to believe and accept your conclusion. Argument also informs the research methodology because it guides you in determining what evidence you should gather to support new knowledge. In this module you will learn to design a robust

argument to support your new knowledge that will be defendable, as well as matching the scope of your conclusion to the available evidence.

Chapter 6: Planning

How do you plan for a journey that you have never undertaken before and where the destination is unsure? Linear planning techniques using predefined milestones based on a Gantt chart do not normally give good results. The main problem with these techniques is the long time-delay before you receive feedback and are able to take corrective action. In this module you will learn techniques that allow for agile development and how to adapt to changes as you learn and discover more. Learn how to plan for new knowledge from the first day and then increase the scope and significance of your conclusion as time progresses.

What you'll learn:

- What constitutes good research
- An understanding of when research is contributing to shared knowledge
- Design of the research process
- Dealing with uncertainty in research planning
- Tools required for creative research

Prerequisites:

The course is aimed at postgraduate engineering research at the masters and doctoral level. However, the content is accessible without any previous learning

Chapter 1 :What Does Knowledge Look Like

Welcome to our course

Dear Researchers

Welcome to this “MOOC” all about research. I hope you find this course valuable and that it contributes to your advancement as a researcher, whether you are an established researcher already, a postgraduate student, or someone considering a career in research.

Welcome and thank you for signing up for this course all about research. My name is Ivan Hofsajer and I'm an electrical engineer and lecturer at the University of the Witwatersrand. I coach many students with their research and I hold regular workshops on research and research writing. I've seen many different approaches to research from the different disciplines within the engineering faculty. Each discipline has its own values and practices and ways of doing things. However every time I have looked closely at what makes a research project successful, I've always found the same foundations and core principles. It doesn't matter if you are trying to develop a new metallurgical process or plan the expansion of a city, the same fundamental research principles apply and I am going to present these principles in an engineering framework. The main core of this course is going to be about research as the process of making knowledge. Engineering is about solving problems and making things work and the thing that we are going to be making is new knowledge. I will return to this point continuously and emphasise it throughout the course. Research is about making knowledge. I'm going to assume that you are taking this course because you are interested in research and that you are interested in a certain topic or a certain discipline and you have thought about some of the major challenges and problems in that area. If you have already started with your research, you may sometimes think that things are not progressing as smoothly as you had hoped, or perhaps you are stuck and don't quite know where to go next. In that case, I hope this course will change all of that and enable you to get back up to speed again. So how is this course structured? The course will consist of six Chapters each with its own theme. Each Chapter will consist of a Section segments where I communicate the core topics and points. These will normally be short and each segment will cover only one topic. There will be some multiple-choice questions that normally have a direct bearing on what has been discussed in the Section material. Sometimes the questions will be about your own work where they will not really be a correct or an incorrect answer. These questions are designed to help you think about your own particular topic and research objective. I mentioned six Chapters each of the theme, what are those themes? In this first Chapter we are going to look at what knowledge is. This is useful for getting that objective and the important research question right. Chapter 2 is about when knowledge is accepted as a contribution. You want your knowledge to be accepted and to make a difference, but that only happens when others say. So this is what the peer-review process is all about. We will look at the importance of the community that we are producing our knowledge for. Chapter 3 is about that new knowledge can only exist in the presence of older existing knowledge. You are going to need to construct a very solid foundation of existing knowledge to build your new knowledge on. Chapter 4 is about writing. Researchers are writers and writing is probably the most important tool of our trade. You will see that it is not correct to think about doing research and then write about it, the writing is the discovery process. We will look at techniques to help this creative process along. Chapter 5 is about argument. For somebody to accept your new knowledge they need to be given reasons to believe that it is good and that they should accept it. This lies in a good argument and we will discuss the evidence that should be in place to enable you to convince someone of the correctness of your conclusion. Chapter 6 is about planning and how to go about the research process. The research process by its very nature is uncertain and will probably contain many twists and turns that you are not expecting. We will look at techniques how to plan in the face of this uncertainty. Research is one of the most rewarding and creative activities that you can be busy with and I really do hope that this course contributes positively to your research.

Getting the Most Out of the Course

As we will discover in this course, research does not always follow hard and fixed rules. That is why trying to write down a list of rules or a checklist for research is so difficult. Each research field and environment does things a bit differently. This course does not present a list of rules. Principles are discussed. To get the most from this course you will need to see how these principles apply to your own field.

HOW DOES THIS FIT IN WITH MY RESEARCH?

You will see the heading *"How does this fit in with my research"* a lot in the course. Sometimes this consists of ungraded assignments. These are where you get the concepts of the course to work for you, and where the biggest benefit lies. It is not difficult to get a passing grade in this course (and I encourage it) but what you really want is a passing grade on your PhD or MSc or a published research paper.

SELF PACED COURSE

This course is self paced. This means that you can work through the six Chapters of the course at any pace that suits you. In the past the course was timed to be released on specific dates and follow a predetermined timetable. This had the advantage that all the course participants were together at the same point in the course. This enabled the possibility of forum discussions and feedback on each others assignments. However it had the disadvantage of restricting access to certain times in the year and this did not suit everyone. The decision was taken to change to presentation of the course to self paced which eliminates the access problem, but also eliminates the possibility of group discussions in the course. If it is at all possible in your environment, (Let's say you are a Masters student at a university) I strongly suggest that you get together with a few fellow participants and discuss the aspects of the course as a group.

What are your impressions of research?

There are many questions like this one spread out in the course between the different sections. These questions ask you to think about research and also bring what is said in the course into your own work. These questions are not graded and there are no correct or incorrect answers.

The main core of the course is about research as the process of making knowledge. What do you consider research to be?

	Yes	No	Maybe
Making knowledge, do you agree with this statement?	○	○	○
Discovering how to do things.	○	○	○
Understanding how things work.	○	○	○
Building new devices.	○	○	○
Developing theories.	○	○	○
Discovering about the world around us.	○	○	○
Developing new processes.	○	○	○
Developing skills in a certain area.	○	○	○

Abilities and Abouts

We have defined research as making knowledge that does not yet exist. Now, if we are going to make this thing called knowledge, we need to know a bit more about it. You might already say that you are familiar with this thing called knowledge and that you already know many things. That is probably quite true. What I am going to do now is to challenge you with what it means to know. Because knowing can take on different forms. I am going to suggest that we do a quick exercise to illustrate this. I would like you to pause the playback in a moment and complete the sentence: I know... I am going to ask you to write this sentence down. Perhaps you can write down several of these sentences. You want to write down a sentence starting with the words, I know, and then complete it in whatever way you want. OK, now stop the playback and take a few moments to write them down. Those sentences starting with the words, I know... Very good. So right now you have completed and written down one or two sentences on what you know. Now, we are going to have a look at those sentences. Those sentences, those things that you know, can take one of several different forms. The first one is trivial. It could be that you wrote down, I know a lot, I know everything, I know nothing. This is not something that you know, this is a quantity, this is what we are going to ignore this for now. You might have said, I know Peter, or, I know Alice, or I know a place like I know London. These are examples of people or places or things that you are acquainted with. This is not the kind of knowledge that we are going to be dealing with. You might have said something like, I know how to bake bread, or, I know that the earth orbits the sun. Now, those two, I know how to bake bread and I know that the earth orbits the sun, these are the important ones for us. Let us look at the first one. I know how to bake bread. This is all about knowing how to do something. It would be correct to say that if I know how to bake bread, then I have an ability. Knowing how to means having an ability. The second one. I know that the earth orbits the sun. This is knowing about something. It would be correct to say that I have knowledge about the world around me. So, knowing means that I have knowledge about the world around me. Now, if there is only one thing that you take away from this Chapter and it is that with our research we are trying to make knowledge about the world around us and we are not trying to develop an ability. This is vitally important to understand. Confusing these two will get your research going in the wrong direction. You are not looking for an ability, you are looking for knowledge about the world. You might not be convinced by what I have just said so let us look a bit deeper at these two types of knowledge. Knowledge how to and knowledge that. Let us do a second exercise. I want you to think about an ability that you have, something that you know how to do. I am going to use the example I used earlier: I know how to bake bread. Now, take another moment and think about something that you know how to do. Pause the playback again if you want to. Even better, write down what it is that you know how to do. OK, so you have an ability to do something. As I said, I am going to use the example of baking bread. Now, I am going to ask you, what makes you able to do something? Why is it that you have that ability? If you think carefully, the ability to do something, like bake bread, comes from two things. First, I need to know about bread. I need to know about the ingredients, I need to know about their properties. I need to know about ovens, I need to know about recipes. I need to know about the processes. And we can list a whole lot more. In short, I need to know about the subject. The second thing I need are qualities that are inside me. I need to be able to follow instructions in a logical order. I need to be able to measure ingredients. I might need to have strong fingers to knead the dough. I need to be able to operate an oven and so on and so on. I will combine knowledge about bread with my own internal qualities and I will end up having the ability to bake bread. However, before I can develop the ability to bake bread, I first need to know about it.

Knowledge about the world is necessary before we can develop the ability to do something. So let us see how that fits in with our research. In the technical fields, especially in engineering, we often want to have the ability to achieve something. I am sure you can think of very many things that we would like to have the ability to do. We might say we would like to be able to develop a fuel efficient car, or become less dependent on fossil fuels, or build gearboxes that make less noise. There are a huge number of these things that we would like to be able

to do and achieve. We would like to have the ability to do these things. However, we often cannot develop these abilities because the knowledge that we need to in order to develop them is missing. In the case of the fuel efficient car, we might need to know more about the combustion process, so that we can better optimize it. A last word on the difference between knowledge about the world and ability knowledge. Knowledge about the world can be written down. I can write down the list of ingredients in my bread. I can write down the recipe. I can write down the temperature that the oven should be at. Knowledge about the world can be written down. This kind of knowledge can be copied and spread around. Someone else can improve on my recipe. As time goes forward, we can expect better and better bread. Ability knowledge, knowledge how to, resides in a person. This kind of knowledge cannot be copied and spread around. If you want the ability to do something, you either need to develop it yourself or you need to hire somebody as a consultant. Everyone who wants to develop an ability needs to start from nothing and become an expert in it. It is not possible to start building on the ability of a previous expert. So, the take home message from this segment is that in our research, we have ability knowledge and knowledge about the world that can be written down. Your research must be focused on making knowledge about the world. Your research is about completing the sentence: I know that...

What is your research focused on?

What is your research focused on?

If someone asks “what is your research all about” how do you answer that? Which statement describes it best? (This is an ungraded question and there is no incorrect answer)

- I want the ability to do something, / I want to know how to do something, / I want to be about to build something.
- I want to find out about something, / I want to see what happens when... / I want to discover why something is the way it is.
- I have not yet started any research or thought about it.

What do others think research is?

Discover what research means in your environment.

Throughout this course, we are defining research as “the process of making knowledge”. (Sometimes this is modified to “the process of making a contribution to knowledge”). Find out if others agree with this. Firstly-, if you are at an educational institution that offers degree programs based on research, track down that institutions rule book and see how your institution defines research in their rules. *Is it defined differently at different levels, e.g. Honors, Masters, Ph.D.? Is it possible to reconcile the rules with our definition?* Secondly, track down a few established researchers, (Someone with a Ph.D. or who has published research paper). Ask them for their opinion on what they think research is. If you are already busy with a research qualification, ask your adviser as well, but ask him or her last. *Does everyone agree on what research is?* Is it possible to reconcile those opinions with our definition of research?

Observations

Knowledge about the world can often fit into three different categories, in this segment we consider the observation. Right, so we have seen that there are these two types of knowledge. Knowledge about the world around us and knowledge of how to do things, ability knowledge. We have also seen that we normally need knowledge of the world around us before we can develop abilities and have ability knowledge. With our research we would like to make, or develop, new knowledge about the world around us. What might that knowledge look like? We often say we have knowledge on some subject and that we know a lot about it. Let us say internal combustion engines. Why might this might be true? Why are we able to say that we know a lot about internal combustion engines? What is it that makes this so? Presumably because we have accumulated a lot of knowledge about the engine. What did that knowledge look like? What needed to happen for us to get that knowledge about the internal combustion engine? The first place to start is probably with the things that we could read about the topic. We can go to the library and take out a textbook on the workings of an internal combustion engine and read about it. We can read about how the different parts work. Or, we might watch a YouTube Section, or we might go to an expert and ask them to tell us about engines. The important point here is that knowledge about the world around us can be written down or recorded in some way and we can access that knowledge by accessing the writing or recording. I will challenge you to think about knowledge in your own field of expertise and ask you if there is any knowledge about that topic that is not possible to write down or record. So, if we accept that knowledge about the world around us can be written down, the next question is: What are the kinds of things that we can write down that constitute knowledge. And by the kinds of things I do not mean just words. I mean, what are the words describing? I am going to say that the things that we can write down and call knowledge about the world come in three broad categories. These are the observation, the model and the recipe. These categories do not have hard rigid boundaries and definitions and they are somewhat overlapping. We are going to have a look at these in a bit more detail, but in short, the observation is just that, it is a report of what we observe. The model is an abstract way of describing what goes on in the world around us. The recipe is a way of arranging things, or doing things, so that we get a certain result. We will look at each of these three in quite some more detail because you would like to see if the knowledge that you are trying to make with your research fits into one or more of these categories. Let us start off with the observation. What is an observation? This might seem a bit trivial. An observation could be summarized as: I did some stuff and then I saw some stuff... This is a simplistic view of an observation but it is pretty accurate. The observation is the most fundamental way of obtaining information about the world around us. Just think of an explorer who climbed a mountain to see what was on the other side. The explorer might write in his diary: I saw a river... OK, so now we know something more about the world around us. There is a river on the other side of the mountain. An observation is about getting information from a source. We can write down an observation, by describing the conditions as they were and the things that were observed. Writing down an observation is normally quite easy to do. The observation by itself might not be that significant but perhaps it could be. If the thing that we are trying to observe is really strange or exciting, or is very difficult to observe then the observation on its own could be substantial. This is often the case in a new field of inquiry where we do not yet know a lot. You would also want to have some reason for looking at certain thing. For example, in chemistry you would not just want to randomly throw some chemicals together and see what happens. This is not a good way of doing things. You would rather have some sort of focus and already have some idea, some foundation about how things work so that the observation can be directed towards a certain outcome. Observation knowledge can take many different forms from something like measurements taken in the laboratory to a survey among a group of individuals, to the time it takes for a software routine to run. I would even suggest that current trends that you notice in the research literature that you read is a form of observational knowledge. Often, the observations by themselves might not be that interesting as there is just a whole lot of data that has been collected.

In such a case, this observational data might need to be processed in some form and this leads to our second category of knowledge, the model.

How does this fit in with my research?

In this unit and the next two I will ask you to think about your own field of interest and what these categories of knowledge in your field might look like. A simple way of thinking about an observation is literally “I did some stuff and saw some stuff.” Observations don't only fall into the traditional situation of a researcher setting up a microscope and peering through the lens. Sometimes it could be completely different. It could be that you use a different technique to carry out a complex calculation and you note that the time it takes to run the calculation is less. This is observational knowledge. *Try writing down what an observation might look like in your field.* (The writing it down part is important, we will get to why writing is important in Chapter 4)

Models

Models are ways of describing sometimes very complex interactions in the world about us. Models tend to hide some of the complexity and allow us to understand better. So, we have these three categories that knowledge about the world around us can fall into: the observation; the model; and the recipe. The second category that we are going to look at is the model.

What is a model?

By model, I mean a description of something that is going on in the world around us in an abstract form. Perhaps a very simple way of thinking about this is a street map. In its simplest form, this is a diagram of lines representing the actual physical layout of roads and pathways and the relationships between places. It is a way in which we can understand what is going on in reality, without actually needing to engage with reality. We can see that there is a road going from village A to village B and we can determine the distance between these two villages without having to actually walk the route and measure it. It is, however, a simplified version of reality.

For example, it might not show the condition of the road between the villages or the height of the trees next to the road. In other words, there is a lot of information that is missing. Models are all around us and I am sure that you are already familiar with a great many models. We use them all the time, even though we do not always think of them as models. We use models to understand the world around us. Think about when someone is trying to explain something to you. What do they do to try and help you understand something? They will be discussing the topic with words and giving you an explanation. Perhaps they might draw a diagram to show how things interact with one another, or even write down some math. These are all examples of models. Let us look at the example of a mass on a table and what happens when we apply a force to it. As you can see, I am immediately showing you a diagram of what I mean. Note that I am not showing you the actual mass, this is a representation of the setup I am describing. Now let us say this mass is free to move and I apply a force to it from the one side. The mass will experience an acceleration. We can describe that acceleration with a mathematical equation relating the applied force to the acceleration of that mass. This, of course, is just a statement of Newton's second law. In this case, the equation captures the behavior of the real world in an abstract form and enables us to understand what is going on. The model is showing us the relationship between different things. In this case, the relationship between the force and the acceleration, which of course depends on the mass. The model is taking reality and stripping away a great deal of complexity and leaving only what is of interest behind. For example, in the case of the mass, we ignored the friction between the mass and the table. We also ignored things like the shape and color of the mass. This gives us a simplified view of the world, but it allows us to capture what we want to describe. The model is almost always an approximation of the real world, with a lot of information left out. We can then use the model to understand the relationships in a simple and uncluttered way. We can also use the model to make predictions based on our understanding. This simple understanding can then be applied back into the real world again with all its complexity and detail. A good model allows us to understand the way the world works in a simple way. Now, the model of the mass on the table accelerating under the application of a force is a very easy model. It is described very nicely by the mathematical equation. We are, however ,not always so fortunate to have such a well behaved model. Let us take the example of the model of how a city grows and expands. This is of importance for town planners and they would like to understand how a city will grow so they can make provision for future services. This model is more difficult to define and it certainly cannot be described by a simple equation. Even listing all the factors that can have an influence, can be quite challenging. However, no matter how it is internally represented, the model is still there to describe the relationships between different things in the world and how they interact. A model of something is a very good way to capture new knowledge.

A model is something that can be written down. It can have many different forms and could take the shape of a written description, a graph, an equation, a list of events, a diagram. It could even be a statistical relationship. A model can take on very many different forms. Let us just go back and think about a model that can be represented by a diagram for a moment. I have been showing you this diagram of the three categories of knowledge as I understand them, and I am trying to explain my understanding to you. Is this figure of the three categories a model? Yes, it is. It is representing the relationships between these different categories and which, in turn, form a bigger grouping of what we said was knowledge about the world around us. In effect, I am using this model to explain how knowledge works. And just as with all models, there is a lot of complexity about knowledge and research which is not captured here. Very often, research is about building or expanding a model so that we can understand the world around us better. We want to understand things better so that perhaps we can shape and control them. In other words, we can cause something to come about. This will bring us to the third category of knowledge, the recipe.

How does this fit in with my research?

Models are a way of making sense of the world around us. They help us to be able to understand things. The model is probably the most common category of knowledge.

Models can take on many different forms such as:

- Maps
- Graphs
- Pictures
- Equations
- Descriptions
- Organograms

Can you add to this list and write down any other types of models that help you to make sense of things in your field?

Recipes

OK, so we are looking at these three categories of knowledge: the observation; the model; and the recipe. We are now going to have a look at the last category, what I call, a recipe. A recipe is just that. It is a way of arranging and doing things that brings about a desired effect. A trivial example might be the recipe to bake a loaf of bread. What does a bread baking recipe look like? It is an arrangement of ingredients and a description of what must be done so that I can have a certain effect. A loaf of bread is produced. The bread is the thing, or the effect, I wanted to bring about. Very often, we would like something to happen, or to achieve something, and we need to find out what needs to be done to bring about that effect. We might want to think about this kind of an arrangement as a design. I am going to assemble things in a way that brings about an effect. I might want to arrange bits of steel in a certain way to bring about a bridge that can handle a certain load. The arrangement and all the specifications of the bits of steel are important to bring about the result of having the bridge hold up under load. We could write down this arrangement, this recipe, and call it a reference design. These recipes can also have more abstract forms. For example, I might want to identify a certain feature in a photograph. For example, I might want to automatically read the license plate number of a motor vehicle. In this case, the recipe is sort of a software algorithm. It is a list of steps, probably mathematical in nature, that are needed to bring about the effect of license plate identification. These recipes can take on many different forms, such as a physical arrangement of parts, or a process, or an algorithm, or a procedure. You can perhaps think about a recipe as sort of a design of something. Now, does a recipe infer an ability? In the beginning of the course, we discussed ability knowledge and knowledge about the world around us. And we said we were not looking for ability knowledge, we were looking for knowledge about the world around us. So, is a recipe for accomplishing something not also an ability? If I have a recipe, a list of instructions for something, can I not then say that I also have the ability to do that? I can give you a quick example. I have a recipe, I have a list of instructions about how to play the guitar. I have the recipe, but I actually do not have the ability. I actually cannot play the guitar. So, the recipe that we are talking about in this case does not infer an ability. So, perhaps the new knowledge that you want to make with your research has the form of a recipe. A way of arranging things in the world to bring about an effect. Making this form of knowledge is a little bit risky.

It could be that the effect that you want to bring about is not possible. Let us say I have the research objective of finding a process to turn lead into gold. This is a tough objective. It could be that there is no way that I can find to do this. Or, perhaps a more realistic example might be that I am looking for a way to improve the efficiency of some process. Will I actually be able to find an efficiency improvement? Perhaps I can and this is great, but perhaps I cannot and then I have not met my objective. Does this then indicate my research has failed? Someone might say: Your research does not work, it is no good. And they will be correct. It does not work. The effect that I wanted to bring about is not there. There is no efficiency improvement. Has my research failed? It has failed in the sense that I have not achieved my objective. We want this recipe and we do not have it. However, if we formulate our objective correctly, then it could be that not all is lost. It may be possible to reformulate your objective into something like understanding why the efficiency improvement is not possible. This then becomes a modelling issue. We can now understand what the limitations are of the processes that we are trying to improve. I would suggest that this is still a good piece of research if it is done correctly. It has increased our understanding. So even though we did not find the recipe we had hoped for, we still have a piece of knowledge that can be useful. This shows very clearly the usefulness of considering research as making knowledge and not as obtaining abilities. If we follow the ability route, then when we discover that we cannot improve the efficiency of that process, we fail. However, with the knowledge approach we can always claim to have made new knowledge and present it as such. What do you think?

Should we be framing our objectives so that in the event of us not being able to achieve the recipe that we are looking for, we can fall back to understanding why it is not possible? Is it always possible to do this? Of course, someone else might come along and actually propose a different approach where it is indeed possible.

How does this fit in with my research?

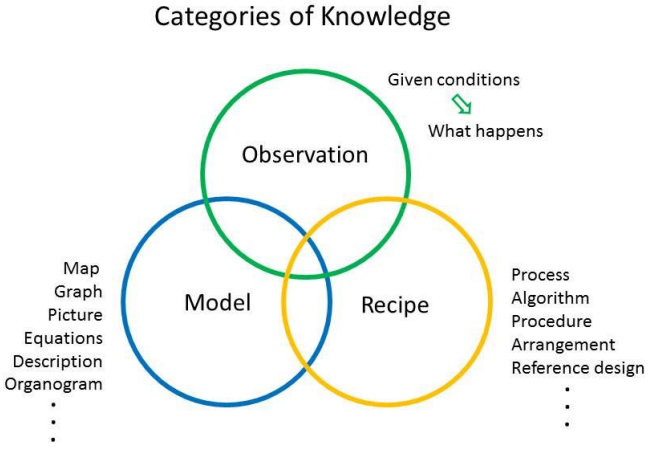
he recipe is probably the most powerful category of knowledge as this helps us to accomplish things. Coming up with a good recipe is sometimes quite difficult.

Recipes can take on many different forms such as:

- Processes
- Algorithms
- Procedures
- Arrangements
- Reference designs

Can you add to this list and write down any other types of recipes that help you accomplish things in your field?

Challenge



I have presented this diagram of the three different categories of knowledge as I see it. (Yes this is a model, it is helping us understand something) Does all knowledge about your particular field of interest fit into these categories?

Most importantly is there any knowledge about your field that you can think of that would not fall into one or more of these categories? This is important because if we consider research as making knowledge, then we need to understand what we are looking for and be able to recognize it when we see it.

Formulating the research objective

Getting the research objective right is very important. In this segment we all discuss how to go about this We have defined research as the process of making knowledge. We have also seen that the kind of knowledge that we are looking for is knowledge about the world, knowledge that can be written down. And we have also seen that this knowledge about the world could possibly take on the form of an observation, a model or a recipe. Now that is great background, but how does this translate into what we should actually be doing? How do we take all of that and apply it to an actual research problem? This is what we are going to do now. One of the most important parts of research is having the correct objective. If we know what our real objective is we can figure out a way to get there. And getting this objective, is going to form part of your first big assignment. We are going to write down a research objective. Remember, we have defined research as making new knowledge and the new knowledge is the actual objective. We are going to do this by writing a few paragraphs about the research objective. If you have already started your research and have a topic and have progressed to some extent or even a large extent, that is excellent. You can use your actual research topic for this. Perhaps you have not yet started any research and are taking this course to see if you are interested in doing research at a later stage. In that case I am going to suggest that you come up with your own research topic that is interesting to you. Perhaps think about something you feel strongly about or some problem that you see in the world around you. This problem you choose could really be anything, ranging from potholes that keep appearing in the roads in the area where you live to worrying about what is really going on with global warming. Remember that the problem in the world does not always have to have an immediately obvious practical implication. It could be that the problem is we do not understand something and we want to know more about it. With this exercise, we are not going to be concerned about the significance of the research objective, it is more about getting the research objective into the right shape. This assignment is going to be peer reviewed by the others in the class. What this means is that you will submit what you have written and others will give comment on it. We will discuss more about this in the class review process next Chapter. So, in this exercise I am going to challenge you to describe the research objective by splitting it up into three parts. We will have a part about where the problem comes from. A part about what the actual problem is. And also a part about the knowledge that we would need to address this problem. In the supplementary materials, I will give a few examples of research objectives formulated in this way. Now, let us look at those sections in a bit more detail. In that first section, we are going to describe where the problem comes from. This section should give enough background for the reader to be able to understand the next two sections. Remember as well that most of the participants in this course will not be experts in your field of study, and they will not be able to understand deep technical jargon and terminology.

So, everything that you write should be described in such a way that it could be understood by someone like me, perhaps.

My field of study is electrical engineering, and I would not be able to understand deep technical discussions of metallurgy, aerodynamics, or even something from the social sciences. The second section is about the actual problem in your field. There is something that is not right in your topic area. This could be something that we do not yet understand or that we would like to be able to do but we cannot. This can often be done by completing the sentence: I do not know, or I am worried, or I am not sure, or I would like to... In this way you can formulate that problem. Perhaps you can also describe why this is an important thing to be worried about. And how knowing the answer to this would make things better. The third section is the most important part. Here, you want to describe what the knowledge might look like that is needed to be able to address the problem that you have described. It may be that you can fit the knowledge that you need to address the problem into one of the forms that we discussed. The observation, the model or the recipe. It does not need to fall into one of these categories exclusively, and there could very well be some overlap between the categories. You can

think of this part of the assignment as that thing that you would like to be able to read in the library or online about your problem that will make it go away. This is the actual knowledge that we are looking for. Now, once you have written down that knowledge, that knowledge that you are looking for, try to describe it in a way that removes all possible terminology from your particular field of interest. You are looking for an abstract version of your new knowledge, such as, I need to know the relationship between A and B. In one of the next clips I will explain this process of abstracting the knowledge in a bit more detail. So, you might want to look at that first before attempting this abstracting part. If the knowledge that you are looking for does not fit in nicely with the categories that I have proposed, I will challenge you to explain what it is that you are doing and why you think this framework does not work for you. It could also be that the new knowledge you are looking for consists of a few different parts. This is not unusual and you can describe the different parts, but keep in mind that all those different parts need to combine into a single thing. We will look in detail at how to combine different parts into a whole later on in the course when we get to argument. In the examples that you can read through in the supplementary material, the descriptions may appear a bit simplistic and that is OK. This is not about making your work sound impressive, it is about getting your research objective into this simple form. This can sometimes be very challenging. However, if you are able to do this, then it really focuses your mind on your actual research objective. And you really need that objective to move in the right direction. I will also say that as you progress with your research, as time goes by, your objective of what the knowledge is that you are looking for, might change. Indeed, as you progress and learn more it is probably going to change. Then you can go through this exercise again and get an updated view of your knowledge objective. This is a continual process, and always be sure to bring it back down to these basics.

Example Research Objective 1

We can start off by describing some problem in the world that exists that is bugging you or worrying you and that we should be addressing. It could be that there is something we would like to do or accomplish but currently can't because we lack the knowledge to do so. It could be that there is something that already works, but we don't know why and we would like to understand it better. It could be that we want to do something to see what will happen.

My example:

The problem I am working on is that there are diesel powered trains that are spewing out diesel engine exhaust fumes at the top of the locomotives that are passing under electric power lines. I am worried that the diesel exhaust fumes will cause the electric power lines to flashover (create sparks). I am worried because I don't know what will happen and I don't know what will happen because I don't understand how the electrical conducting properties of the air above the train is modified by the exhaust fumes.

Section 1

Now describe how this problem came about, or the background that the reader would need to know to properly understand the problem. Here you want to be careful not to use too technical terms or jargon so that someone who is not a specialist in your field can still understand what the problem is that you are interested in.

My example:

In some countries, there is a mixture of electrified and non-electrified railway tracks. The electrified railway tracks have a fixed high voltage conductor that runs along the length of the track above the train. The electric locomotive connects to this high voltage conductor that runs along the top of the train via a sliding conductor attached to the top of the locomotive. Diesel powered locomotives are used on the non-electrified railway tracks, but sometimes these diesel locomotives also need to run on the electrified tracks. The fixed high voltage conductors on the electrified tracks above the train are always energized. When a diesel locomotive runs on an electrified line, the diesel exhaust fumes will blow out directly onto the energized conductor above the train. We now should have some background to be able to understand the problem that is coming next.

Section 2

Describe the problem using the background from section 1.

My problem:

I am worried that the diesel exhaust fumes will cause a huge spark between the electric power line and the diesel locomotive. I am worried because I don't know if this will happen and I don't know if this will happen because I don't understand how the electrical conducting properties of the air above the train are modified by the exhaust fumes. In particular, I suspect that the increased moisture, temperature, pressure, and particles in the exhaust fumes might be a problem. I would like to know how these parameters affect the ability of the air to withstand the high voltage difference between the train and the overhead conductor. Now I can state why this is important This is important because I do not want the high voltage overhead line causing an electrical flashover to the locomotive. This will cause damage to both the locomotive and the electrical system. If we did understand this process then we could say for certain whether or not it is ok for diesel locomotives to run safely on electrified tracks.

Section 3

Now I can describe the kind of knowledge that I need to be able to address my problem. Note that we are not yet describing how to do this, only what the end product might look like. I need a model that can describe to me what is going on. The model will tell me what the relationship is between the parameters I suspect are important and the possibility of a spark between the locomotive and the overhead line. In abstract form this could be stated as: What is the relationship between parameters A1, A2, A3, A4 and parameter B and has the form of a question. What could this knowledge look like? How can this model be represented? I suspect because each of these parameters is quantifiable that these relationships can be represented by means of equations or graphs. This is knowledge that can be written down. So even before I have started with the research I have a rough (and I emphasize the word rough) idea of the shape of the knowledge that I am going to make.

(In this problem I have already identified some parameters that could have an influence. It could also be that I do not know what these parameters might be beforehand. Then the knowledge that I need could be formulated as I suspect that the properties of the exhaust fumes are different from that of air and this might change the ability of the air to withstand the high voltage between the locomotive and the overhead line. I need a model that will tell me the how the ability of the air to withstand the voltage is changed by the exhaust fumes. In abstract form this could be: what is the relationship between A and B.)

Example Research Objective 2

Section 1 (Background and Context)

In most metal processing factories, semi-finished products (billets) are made into finished components by working/forming into different shapes and sizes. The shape and size of the component could be as small and simple as a cooking pot; it could also be big and complex as a car frame structure. The finished components are required to have uniform microstructures and good mechanical properties in order to meet service requirements, but a slight change in processing parameters significantly affect the workability/formability of these metallic components. The workability/formability can then be used to predict the final microstructure and mechanical properties of the components. To obtain uniform microstructure and good mechanical properties, it is important for engineers to understand how processing parameters such as temperature, strain and strain rate affects the workability/formability of these metals. The change in dimension during working/forming is referred to as strain while strain rate is basically how fast or slow the metal changes in dimension. As engineers, we are able to quantify and control the temperature, strain and strain rate of the forming process but the response of the metals (workability/formability) to these imposed parameters we cannot control.

Section 2 (Problem and significance)

Microstructural defects and inferior mechanical properties are obtained in some finished metallic products due to sensitivity to slight changes in temperature, strain and strain rate during forming. It is important to understand the relationship between the imposed processing parameters and the workability/formability of the metal because it helps to avoid defects in the finished products that could lead to catastrophic failure in service. It also helps to save time by avoiding the process of trial and error that is used in determining optimum processing condition. We will be able to predict the final microstructure and the mechanical properties of the finished products from the initial processing parameters.

Section 3 (The knowledge that will make the problem go away)

We need models that could describe the relationship between the processing parameters and the material's response (workability/formability). This relationship could be used to predict the material's response to imposed processing parameters. This relationship can be described using graphs, equations, and maps.

In abstract form this can be described as “How do parameters A, B, C… affect process D?”

Example Research Objective 3

Section 1 (Background and Context)

Electrical energy converters convert electrical energy from one voltage level to another. A typical example may be a cell phone battery charger. These converters (battery charger) are big and bulky because of the kinds of electronic components that are inside them. We would like to be able to make them much smaller than they currently are. Small means lower cost because less material is being used. Normally when these kinds of converters are designed they are optimized for efficiency so that it does not get too hot. They are not optimized for volume.

Section 2 (Problem and significance)

I want to be able to make these electrical energy converters as small as possible. They can be made small by optimizing the kinds of components that are used in the design. At present, the optimization is done only for efficiency. However, by bringing in additional constraints on the optimization we can get the volume as well. The problem is that we do not have good models for the volume aspects and that the current models do not contain volume information so we need to expand the model. A second problem is that even if we do have volume models for the different components, how do we use these models to optimize the converters during the design phase? Importance This is important because I want to achieve that objective of the smaller and lower cost converters. I think that lowering the cost of anything is a big deal.

Section 3 (The knowledge that will make the problem go away)

The knowledge that I need is a model. This will include the information about the volume of the components as well as the loss. At present, the input to the model are the electrical ideal characteristics of the components and the loss model tells us how much energy we will lose when we are running the component in the circuit. The volume needs to be brought into this model as well. I am also looking for a way to optimize what is going on so I need a recipe to help me design these converters so that they take up a small amount of volume. Design and optimization algorithms already exist that will optimize for efficiency I want to modify those recipes to be able to include the additional optimization constraint of volume. As I need a model that relates the ideal characteristics to the volume I can abstract this as: What is the relationship between x and y. X is the electrical specifications and y is the volume of the components. The second part is how can process x be extended to include parameter y?

Abstract forms

We have defined research as the process of making knowledge. We have also seen that the kind of knowledge that we are looking for is knowledge about the world, knowledge that can be written down. And we have also seen that this knowledge about the world could possibly take on the form of an observation, a model or a recipe. Now that is great background, but how does this translate into what we should actually be doing? How do we take all of that and apply it to an actual research problem? This is what we are going to do now. One of the most important parts of research is having the correct objective. If we know what our real objective is we can figure out a way to get there. And getting this objective, is going to form part of your first big assignment. We are going to write down a research objective. Remember, we have defined research as making new knowledge and the new knowledge is the actual objective. We are going to do this by writing a few paragraphs about the research objective. If you have already started your research and have a topic and have progressed to some extent or even a large extent, that is excellent. You can use your actual research topic for this. Perhaps you have not yet started any research and are taking this course to see if you are interested in doing research at a later stage. In that case I am going to suggest that you come up with your own research topic that is interesting to you. Perhaps think about something you feel strongly about or some problem that you see in the world around you. This problem you choose could really be anything, ranging from potholes that keep appearing in the roads in the area where you live to worrying about what is really going on with global warming. Remember that the problem in the world does not always have to have an immediately obvious practical implication. It could be that the problem is we do not understand something and we want to know more about it. With this exercise, we are not going to be concerned about the significance of the research objective, it is more about getting the research objective into the right shape. This assignment is going to be peer reviewed by the others in the class. What this means is that you will submit what you have written and others will give comment on it. We will discuss more about this in the class review process next Chapter. So, in this exercise I am going to challenge you to describe the research objective by splitting it up into three parts. We will have a part about where the problem comes from. A part about what the actual problem is. And also a part about the knowledge that we would need to address this problem. In the supplementary materials, I will give a few examples of research objectives formulated in this way. Now, let us look at those sections in a bit more detail. In that first section, we are going to describe where the problem comes from. This section should give enough background for the reader to be able to understand the next two sections. Remember as well that most of the participants in this course will not be experts in your field of study, and they will not be able to understand deep technical jargon and terminology. So, everything that you write should be described in such a way that it could be understood by someone like me, perhaps. My field of study is electrical engineering, and I would not be able to understand deep technical discussions of metallurgy, aerodynamics, or even something from the social sciences. The second section is about the actual problem in your field. There is something that is not right in your topic area. This could be something that we do not yet understand or that we would like to be able to do but we cannot. This can often be done by completing the sentence: I do not know, or I am worried, or I am not sure, or I would like to... In this way you can formulate that problem. Perhaps you can also describe why this is an important thing to be worried about. And how knowing the answer to this would make things better. The third section is the most important part. Here, you want to describe what the knowledge might look like that is needed to be able to address the problem that you have described. It may be that you can fit the knowledge that you need to address the problem into one of the forms that we discussed. The observation, the model or the recipe. It does not need to fall into one of these categories exclusively, and there could very well be some overlap between the categories. You can think of this part of the assignment as that thing that you would like to be able to read in the library or online about your problem that will make it go away. This is the actual knowledge that we are looking for. Now, once you have written down that knowledge, that knowledge that you are looking for, try to describe it in a way that

removes all possible terminology from your particular field of interest. You are looking for an abstract version of your new knowledge, such as, I need to know the relationship between A and B. In one of the next clips I will explain this process of abstracting the knowledge in a bit more detail. So, you might want to look at that first before attempting this abstracting part. If the knowledge that you are looking for does not fit in nicely with the categories that I have proposed, I will challenge you to explain what it is that you are doing and why you think this framework does not work for you. It could also be that the new knowledge you are looking for consists of a few different parts. This is not unusual and you can describe the different parts, but keep in mind that all those different parts need to combine into a single thing. We will look in detail at how to combine different parts into a whole later on in the course when we get to argument. In the examples that you can read through in the supplementary material, the descriptions may appear a bit simplistic and that is OK. This is not about making your work sound impressive, it is about getting your research objective into this simple form. This can sometimes be very challenging. However, if you are able to do this, then it really focuses your mind on your actual research objective. And you really need that objective to move in the right direction. I will also say that as you progress with your research, as time goes by, your objective of what the knowledge is that you are looking for, might change. Indeed, as you progress and learn more it is probably going to change. Then you can go through this exercise again and get an updated view of your knowledge objective. This is a continual process, and always be sure to bring it back down to these basics.

How does this fit in with my research?

There are very many ways of describing what we are actually doing in our research. Using my example of the diesel-powered trains on electrified tracks, the work can be formulated in many different ways, although not all of them are identical:

- *Question: How do diesel exhaust fumes affect the electrical insulation properties of air?*
- *Investigation: An investigation into the effects of diesel exhaust fumes on the electrical insulation properties of air.*
- *Hypothesis: The electrical insulation properties of air are affected by diesel exhaust fumes.*
- *Statement: The effects of diesel exhaust fumes on the electrical insulation properties of air.*
- *A title: The electrical insulation properties of air: The effect of diesel exhaust fumes*

Often when writing about your research there are headings of aims, objectives, questions, rationales, outcomes, contributions, targets, deliverables motivation, problem identification... Unscrambling what all of these terms might mean can be confusing. So don't try to. Rather write what the research is about in the kind of language that is easy to understand and familiar. Then you can pack it into any of the headings that a report or proposal requires. The examples given for this Chapter's written assignment makes use of the pronoun "I" and is written in a conversational tone. This is normally frowned upon in academic writing and you don't want to use that style in your final work. However, I recommend using simple language to describe what it is that you are doing so that you can really understand what is going on. Even better, remove the references to all the technical terms and then work with only a bare formulation.

Question

Do you think it is always possible to reduce research objectives down to such simple expressions such as “How does A affect B?” (This is question does not count towards a final grade)

- Research objectives can always be formulated in this way.
- No, there are some that can't.
- Mostly they can but I cant see how mine can be formulated in this way.
- I have not yet started any reaserch

Chapter 2: What Makes Your Research a Contribution?

When is Your New Knowledge accepted?

What do you think a contribution to knowledge is?

You will be making new knowledge, something that was not there before. Now you want that added to the existing knowledge. When does it get added? When does your work become part of the body of knowledge in your field? There are no correct or incorrect answers and this is ungraded, however, be sure to revisit your understanding of what a contribution is later on.

	Yes	No	Maybe
When I have uploaded my work to a publicly accessible website.	○	○	○
When the editor of the journal where I send it says so.	○	○	○
When my PhD/MSc/Project adviser says my work is good enough.	○	○	○
When the theoretical work has been validated by experiment.	○	○	○
When my work has been cited by other researchers.	○	○	○
When it has been available in the library for at least 2 years.	○	○	○
When I am convinced beyond all doubt that my work is correct.	○	○	○
When other researchers in the field say it is.	○	○	○

When Do We Accept Knowledge?

The new knowledge that you make with your research gets added to the body of existing knowledge. This normally happens when others say so. The objective with our research is to contribute to knowledge. I want to focus on this word "contribution". This word implies that we are adding something to knowledge, presumably something that was not there before. If we have a new bit of knowledge, something we have finished researching. Does this get added to the existing knowledge automatically? Is it automatically a contribution or could the situation arise where your new knowledge is not a contribution? To try to understand this, let's look at the very practical situation: When do you add something to what you know personally? You already have knowledge of many things and you are adding to that continuously as you learn. How does that process work? I want you to think back to something you have recently learned, perhaps that is something you read in the literature, perhaps while working still literature you came across a paper and you were very excited when you read it, perhaps it contained a measurement technique for a tough measurement that you need to do? When you found it you were very happy and after checking that it that it was correct you accepted it and you accepted it because you found good reasons for you to believe it is true you probably place this paper close by you. On your disk or uploaded it to your reference Manager. You made a note that this paper was important. The point here is that you said it was important. You could equally have read something that is perfectly true and that was well argued and the article gave many reasons to believe that it is true, but you discarded that paper because you were not interested in It. You say to yourself no that doesn't do anything for me, you toss it aside, you close the file on your computer. There might not have been anything wrong with that knowledge in that paper but you rejected it. That paper therefore does not contribute to your personal knowledge and it does not contribute because you say so. The important point is that the contribution to knowledge, in this case your own personal

knowledge was a subjective decision that you made. The author of the paper was not involved in that decision. Of course the would have had to write a good paper and communicate effectively, but let's assume that in both these cases the author was doing a good job of writing and arguing and presenting all the evidence that was required. The author did not make the call on whether or not that paper was a contribution to knowledge or not, you did. In the case of your own learning you are the only one making that call, in the case of research in general it is the community that will be making that call. The people that are actively involved and working in the field will read new work and judge it and they will say whether or not it is a contribution to that particular field. When it comes to your own research. You might want to think of the community, of other people in your field, as your customers they are the ones who will decide if the output of your research, your new knowledge, is indeed, a contribution. It might be that your new knowledge is good and everything was done correctly. The evidence is in place the conclusions are well-argued but the community does not consider it to be a contribution. In that case, it isn't a contribution and you have not achieved your objective of making the contribution to knowledge. This is a tough situation to be in and you want to avoid it. This is probably one of the biggest risks that exists. Are you certain that your new knowledge will be accepted as a contribution? How can you go about trying to minimize this risk? This acceptance by the community often starts with a process called peer review. Where a few selected experts in the field will review your new knowledge and make a judgment call. We will consider this peer review process in more detail in the next Section .

What is Peer Review?

The peer review process is where other expert researchers in the field review our work and comment on it. Normally with a view to accepting or rejecting the work. We have said in the previous Chapter that knowledge is something that can be written down. Why would we want to write it down? Writing it down is recording it, and a big part of that is so that we can show our work to others and spread our new knowledge in the community of other researchers. This is one of the ways that the field in which we are working develops and progresses. By sharing knowledge. Others can then use our knowledge and build upon it. We would normally like that our new knowledge, the outcome of our research, makes an impact in our field. We would like for others to value what we have done. The research process is long and difficult and we would not want our efforts to be for nothing. Now, knowledge is all around us and we can read about many things that we could consider knowledge. However, we would like to have some confidence that what we are reading is good and is something that we could accept. Writing down new knowledge and publishing it is very easy these days, and almost anyone can set up a website and publish their work on the internet, and many do. The question, however, is: is this knowledge any good? Very often, we are quite convinced that what we ourselves are doing in our research is correct and good, but will others agree with that? This is where the peer review process comes in. Before we publish our work, we first have it reviewed and checked and if it is found to be good we get a stamp of approval on it. This is what the peer review process is all about. Others will check our work. So, who are these peers who will review our work? Normally, these are other researchers who are experts in the field. They will look at our work and make a call on whether or not they think it is good. This is sort of an endorsement to others in the field, that our work is indeed good and worth looking at. Without this endorsement our work is often ignored. So how does this process work? Well, one of the places where research is recorded in, is in subject specific journals. These are publications dedicated to recording and archiving new knowledge in a specific area. These journals are often read by other researchers, also at the forefront of knowledge production in that area. We would like to get our work published in these journals because we want those other researchers to be aware of our work. We want our work to have an impact and we would like to be recognized as the ones who contributed that new knowledge. Each of these journals will have an editor and this editor appoints reviewers who he or she considers to be experts in the field of that journal. When we submit our work to the editor, they will send it out to several of these expert reviewers and ask them to evaluate it. These expert reviewers are normally anonymous to us, the authors of the knowledge. This means that the experts can speak their mind and give their real opinion without worrying about what others will say. It also means nobody can accuse us of getting our friends to endorse our work. These expert reviewers will compile a report of our research and motivate either that it should be accepted or rejected or that it looks promising but it needs more work. The reviewers will not only check that good work was done, but also if it is important enough to make an impact. The bigger the impact, the better the chances are of getting it accepted. The editor will collate these reports and then make a final pronouncement on whether or not that journal will accept the work and publish it. The author of the work normally gets to see the reports from the reviewers and see the reasons for their recommendation. The editors have a vested interest in maintaining quality, because they do not want the reputation of their journals to suffer or to get a bad name. If the journal is publishing poor work, people will stop reading that journal. This peer review process is very rigorous and the better the reputation of the journal the more difficult it is to get your work published in it, and get that important stamp of approval. However, we would like to have our work appear in these prestigious journals because it gives our work greater exposure. In this course, I am discussing this peer review process up front. I think that too often we wait until the end of the research process before we consider what others will think about our work. I will focus on it, because this acceptance by the community of researchers in our respective fields is very important. They are the ones that determine what knowledge is worth knowing and where we should be concentrating our efforts to make a difference. And as we will see they

are the ones that dictate how we should go about making that knowledge. They are, in effect, our customers and it does not make sense to build a product that our customers do not want or do not like. This might be a bit of a controversial statement and I would like to encourage a discussion of this in the forum. Is new knowledge always good or is it only good when others value it?

How do Peer Reviewers Think?

There is normally no fixed specification for what a piece of research must look like. Therefore to judge if it is good or not, general values within the research community are often applied. Right, so we have seen that knowledge is only accepted by others when they say it is OK. Our work gets reviewed by other experts in the field and they get to say if it is OK. This is the essence of the peer review process. We need to be able to convince these experts that we have done good work. Why are we doing this? Because we want that recognition, that stamp of approval, that our work is good, and that the rest of the world can have confidence that what we have done has been checked and is probably good. Therefore, this approval, this acceptance during the expert peer reviewer process is of the utmost importance. You are going to encounter this in two different places: one when you submit an article for publication in the open literature; and secondly when you submit a thesis or a dissertation or a research report for examination. In both of these cases, the process of peer review is somewhat similar although the outcome is focused differently. For the journal submission, the final outcome is the article appearing in the publication. For the examination, the outcome is an individual getting a qualification. In both cases you need to be meeting the standards and expectations of these peer reviewers because they are the actual ones who decide that your new knowledge is good or not. Therefore, we need to understand what these peer reviewers are all about and what their expectations are. Now, you might be saying that if everything hangs on the opinion of a few anonymous people, that this is not a very good process and it should be replaced. I will agree that the process has its flaws and that it does not always give the correct result. Sometimes, really good work gets rejected and sometimes poor work slips through.

However, it has been shown that generally this process gives quite good results. You may be asking why is it that we need to leave something as important as the acceptance of new knowledge or the award, or not, of a PhD to the apparently subjective opinion of a few individuals. Can't we have a very detailed and defined specification of what, for example, a PhD should be and then assess it according to that? Or, couldn't we have a well- documented specification of what a journal article should contain? And by contain I mean the knowledge and not the format. This will remove a lot of uncertainty from the process. But we do not have that specification. It doesn't exist and the folk who try to write down such a specification are normally not at all successful. Why is this? Why is there no good specification, or check-list, of what new knowledge looks like and can be compared against? I think, that at the forefront of knowledge, at the edge between what we know and what we don't know, there is a lot of uncertainty and it is difficult to say what is correct and what is not.

Of course time will tell. Once the new knowledge has been around for a while and everyone is aware of it and are trying to build upon it or verify it we will discover whether it is really good or not. However, this can take a long time and the reviewers do not have that luxury. They need to make a decision immediately. So how does the reviewer think? I am going to suggest that because they do not have that hard specification, that tick-list of requirements, they do not have that. So they fall back to the values and practices of the discipline and see whether or not there is a good fit. And I am going to suggest that that is actually all what they are doing.

They are looking for that good fit. Here is a quote taken from research that was done on how examiners examine PhD theses. It is what an experienced examiner stated during an interview about how that particular examiner examines: No first rate researcher is without a belief that they understand the standards in that field and can recognise excellence in that field. So if you ask me to examine, you are going to get my standard.

I think this captures very well what is going on in the mind of the expert reviewer. They are looking for something to recognize based on their own standards in their own field of expertise. Of course, it is not purely their own subjective standards. It is the standards and values of that specialized field.

They will have been working in that field for probably a long time and they will know and understand what that field values. They might be hard pressed to write it down explicitly, but they will say that they recognize good work when they see it. Now, the decision of the reviewers will also be seen by other researchers in the field. If the reviewers accept an article, then everyone who reads that journal will see that article when it is published. So, the reviewers are also asking the question of whether or not other researchers in the field will want to see this work. Will other researchers in the field value it? In effect, they are the custodians for the values of that particular community of researchers. Now, what do I mean by the values of a community of researchers? It sounds as if we are getting quite far away from the technical stuff and the engineering work that we are supposed to be busy with. So how is all of this relevant? It is relevant because you want these people to read your work and to do this you need to meet their standards. And by standards and values I don't just mean things like honesty and integrity. I don't think you will find any research community that would not value honesty in reporting research results. By values I mean the kind of things that researchers in your particular field look for more than others. It could be when you look at an average article in a certain journal, you find that there is a great emphasis placed on detailed mathematical rigor and every step of a derivation must be exactly correct. In another journal, you can find the authors being quite sloppy with the maths, just as long as they have the correct final result and it is backed up by rigorous experimental evidence. It is these subtleties that shape the culture of what goes on in that research community. The one values experimental work, the other values a solid theoretical foundation. So, in this section I am trying to get the message across that even in technical research, in things like engineering where we like to think in terms of absolutes and we want to distance ourselves from soft issues, we find that at the frontiers of knowledge, the hard technical specifications blur and it becomes a somewhat socially driven process. Of course, I certainly do not mean that we should ignore the technical aspects, that is absurd. That is not what I mean. The technical aspects are vital and we absolutely need to get them right. But that is not enough. We also need to be aware of the social aspect of what is going on as well. Remember, if your PhD examiner says it fails, then it fails. If the PhD examiner says it passes, then it passes. Of course, the examiner will still need to give good reasons for the decision, and those reasons could be challenged. But you would rather avoid having to challenge the reasons the examiner gives for an unsuccessful outcome.

How does this fit in with my research?

It seems as if understanding how the peer reviewer and the examiner thinks is of vital importance. (It is probably a good idea to consider how your examiner will examine your work before you submit it) If you are busy with a formal qualification at an educational institution, track down the rules again and this time look for the condition that needs to be met in the examination phase to actually qualify. (Last time we looked for your institutions definition of what research is, now we want to find out how your work is assessed) *Is it possible to reconcile our idea of peer review with the rules of your institution?*

Track down a faculty member or senior researcher and ask them if they have ever examined research work from another institution or acted as a reviewer for a journal article. Ask them about that process and how they come to a final conclusion. Try to find out if they are using fixed rules or they are making judgment calls based on their own understanding of their research field. If there are fixed rules, how are they interpreted by the examiner?

Who are Your Peers?

The peers who will evaluate your new knowledge are normally other expert researchers in the field. Do you know who they are? OK, so I have been saying how important these peers are as part of the peer review process. So, who are they and how do we discover what they want? To try and answer this I will ask you to do a quick exercise. If you are busy with your PhD or MSc or honors project, or anything with a research based assignment that needs to be assessed, who would you want to assess it? You are not allowed to choose your instructor or mentor or advisor or study leader. No. They are the ones helping you to develop. Who would you want to examine your work? You can choose from anyone in the world. If you are writing a paper and want to get it published in a journal then who would you want to review it? Who would you want to show it off to?

Of course, normally you do not know who your reviewers or examiners are, they are anonymous to you. But let us say for a moment that you could choose them. Who would you choose? I challenge you to write those names down. The people who you would choose would hopefully be ones who could understand your work and really appreciate it. If you are extensively referencing another person's work in yours, this person might be a good candidate. Or, there might be a core paper that everyone in the field cites as the foundational paper. The main author of that paper might very well be one of the leaders in the field. This is indeed someone who you would like to show your work to. Is this someone who could be an expert peer reviewer?

Yes, it probably is. I will ask you to try and list a whole bunch of folk from anywhere in the world who would be interested and excited to see your work. If you want, you can also visualize that you could travel anywhere in the world and speak to anyone about your research and show them some of your results. Where would you like to go and who would you like to see? Write these names down and also write down why you think it would be a good place to visit. Most likely it is because they are the ones who would be most interested in your work because they are also working in your field. They are the kind of people who would want to scrutinize your work because they are the ones who would like to build on it further. They are also the ones who would like to see where your results lie relative to theirs. If your list is empty, if you can't think of anyone, then you should be slightly worried. Perhaps you are still starting out and you need to find out more about the field that you are in. You might still need to discover who the important people are in your field. However, you can start with the people who's work you are already reading. The authors of a textbook or a research paper that you are reading are good places to start. Then you can follow up on them and see if they really are leaders in their field. This is not too difficult to do these days on the internet. You can find out quite easily what else these people have published and where their interests lie. And don't limit yourself to only one or two. You want to be able to write down the names of a whole lot of folk. If you are fortunate enough to be able to travel to a research conference and meet the top researchers from all over the world then that is really fantastic and a good way to discover who the experts in the field are. You can, of course, also ask your PhD advisor or study leader. They should already be familiar with the literature and who is who in the world.

You can ask them who they think might be the good researchers in the world in your field. And keep that list updated, and as you learn more about your field keep adding to that list. OK. So now you have this list of peers. Now, ask yourself the question: will the people on this list like my work? Would they be excited to read what I have written? While you are asking this question, what you are actually doing is comparing your work to the kind of work that the people on your list, your peers, produces. This is a good exercise because now you are automatically looking at what your research community values. If you say to yourself: no, I can't show my work to Professor Jones, he will ignore it because I have not done whatever part very rigorously; then that is already a very good piece of feedback. You now know that it is an important part to concentrate on.

As you read more in your field and interact with folk in your field, you will automatically start absorbing the culture of that field. For example, let us say that you are busy investigating how a certain additive changes the strength of reinforced concrete. From everything that you read and that you see other researchers in the field are doing, you discover that they are using a certain procedure to test the strength of the concrete. Immediately, you will be thinking that you will probably need to do a test like this as well on your own concrete samples. In this way, you absorb the culture of doing things and the value system of the research community that you are interacting with. It is also good to question what this community does. Initially, as an outsider, you are probably in the best position to ask if what this community is doing, is sensible. It is good to ask these questions. However, it is tough to actually change the culture of that community. In a similar way, if you are doing a PhD and want to know what is expected in the field, don't go and look in your own School's library. There are many different fields represented there. You might find that there is a huge variability between the different PhD's. No. Rather go to the university where the examiner is, the examiner that you proposed. And look at that person's recent PhD and MSc graduates. The kind of work you see in those PhD's will set the context for what your work could look like. As a final point, I will ask you to be cautious about knowledge consumers. The peers we have been discussing here are folk like you who are engaged with the process of making knowledge. Because of this they are able to really understand what you have done and they are in a real position to critique it. Knowledge consumers, on the other hand, are the folk who would want to use your new knowledge but not really able to assess its correctness immediately. For example, an insurance salesman might be very interested in some kind of a new statistical prediction tool. But the insurance salesman is a consumer of the knowledge. He wants to use it. He is not one of your peers, he could not asses the finer points of the correctness of the knowledge that lead to that tool. Only another person also engaged with making such knowledge. In other words, your peer, would be able to evaluate the correctness of the research and the knowledge that went into that tool. So, in summary, your research, your new knowledge, will be assessed and either accepted or rejected by other people. They will apply the values and expectations of the research community that they are in to assess what you have done. So, it is vitally important to understand and get to know your research community.

How does this fit in with my research?

Can you identify the top experts in your field? Can you write down the list of people in your field that you would like to show your work to. Write down where they are and why you think they would be interested in your work. Can you find work that they already approve of, e.g. journal articles, theses, dissertations? This is possibly what your work should look like.

Peer Review as an Experiment

If this acceptance by the community of researchers is so important, then it should not be left until the end to discover what they think. We have been considering the peer review process and have seen that it is very important to meet the expectations of the research community where we work. If not, then our work won't be accepted. We have considered this process as a sort of final approval. Our completed work is submitted to a journal for consideration for publication ,or a thesis or dissertation is submitted to examiners for consideration for the award of a degree. This is the final objective with the peer review process, but there are other forms of review as well, sometimes a bit less rigorous. Every time we present our work to others, and this could be in something like a Chapterly research group meeting or at a conference or even just writing a progress report. In these cases some of our work, probably not the final product, is shown to others and they might form an opinion about it. Those looking at our work might not necessarily be the leading world experts in the field, but they are probably competent researchers and are able to understand what we are doing. That's why they are looking at our work. The feedback they give might not be in the same form as the formal peer review process and probably not as rigorous, but it is still an indication of what others in the field think about our work. Sometimes, when we present our work, even in the context of a research group meeting, we are a bit nervous and worried if it will be well received. Nobody likes to present their work and to be told they are no good. This is true even in a friendly environment of, let's say, your fellow researches in your group. We are looking for that acknowledgement that what we are doing is good. And if we don't get that acknowledgement then we sometimes tend to become a bit disappointed and perhaps even despondent. In the formal review process, when we submit something to a journal and the reviewers don't like it, the reviewers can tend to be very harsh and critical. This is good because it means that the standards of the research community are high and our work has not yet met those standards.

However, when we show our work to others we are exposing a part of ourselves, of who and what we are, and it can be very intimidating if the feedback that we get is negative and it can sometimes give our confidence a bit of a knock. Sometimes, that can be so severe that we actually give up. This is, of course, not a good thing.

And if there are any of you taking this course who have already gone through this process and submitted your work that you thought was really good, and something you had been working on for a long time and it was rejected, then you know exactly what I am talking about. However, your goal as a researcher is still to make a contribution to knowledge. And feedback from other researchers in your field is an important part of getting that contribution and achieving success. In the interests of achieving this success, I am going to suggest a way of approaching the peer review process in a slightly different manner. The peer review process is important and necessary, and we can't get away from it, so let's use it to help us. I am going to suggest that you approach peer review in the same way as you would any experiment or data gathering exercise. And by peer review I mean all forms of review, from a journal submission to a presentation of provisional work in a research group setting, to an informal chat with another researcher. When you are busy with an experiment, in any form, whether in the laboratory or doing experiments, perhaps doing simulations, or running a survey, you are focused on getting data so that you can learn something. You set up the experiment in a certain way so that the results are useful to you and it probably contributes to your research in some way. Now, very often, and I will say even normally, the outcome of an experiment is not quite what you expected, at least not initially. Perhaps you are monitoring the reaction temperature of a modified chemical process and you observe that it is rising where you were expecting the modification to cause the temperature to fall. This is not unusual and it normally indicates that you need to go back and ask the question: why this might be the case?

I will suggest that when the results of your experiment are not quite what you expected, then you do not consider it to be an attack on you as a person.

It is part of the discovery process. And you use that outcome to advance. I am going to suggest that you can use the peer review process in a similar way. As a first objective, you are not trying to get approval for your work. As with any experiment, you have an expectation. In this case, that what you are doing, your research, is good, and you want to test that against your peers. You are looking for data that will confirm or not that your work is good. The data you get back from your peers, and in this case the data is what they think of your work, this data can be used to advance in the right direction. If the data that you get back is not what you expected, then that's OK. This is not an attack on you as a person, just as an unexpected temperature measurement during the experiment is not an attack on you as a person. You might say that this is what happens in any case during the peer review process. If someone says your work is not correct or you are doing something wrong then you use that to modify what you are doing. However, by depersonalizing the process, by considering the feedback to be about the new knowledge and not about you as a researcher, it can be very helpful. You can even go a step further and just like you would do in the laboratory, you can actively target the kind of feedback, in other words, the data which you are looking for. It could be, for example, that you are worried about whether or not your research problem is significant enough. In other words, you are asking the question of whether the research community thinks that what you are working on is a big deal. At your next presentation or discussion you can focus everything on the issue of if what you are doing is important, and see what everyone thinks. In a sense you could consider this to be a social experiment where the folk who are looking at your presentation are the subjects that you are studying. And you want to know something about these subjects. So, the presentation then becomes not about you showing everyone what you have done.

It becomes about you extracting information from them. In the context of a research group presentation, your sample of the research community is, of course, quite small but it is useful none the less. I would suggest that if you give a presentation and you do not extract data from the participants, it is a wasted opportunity. You can do this with a journal article as well. Your objective is to extract data from the reviewers about how the work meets the rigorous standards of the research community. Now, a word of caution with this approach. Just as with a conventional experiment, if you do it in a sloppy manner the results you get will not be very meaningful. If you send out half completed work to the reviewers of a journal they will recognize it as such and ignore it without much useful feedback. You are not going to be able to get the reviewers to do your work for you. In the same way, if you give a sloppy presentation, your audience is bound to ignore you. So, be sure to design the experiment properly and target the kind of feedback that you would want at the right audience and at the right level. Then, let the experiment run and analyse the data that you get back. I will urge you to make use of every possible opportunity to get feedback on the work that you are doing. Present it in as many forums and places as possible. And design the presentation of the work, whether it is a journal submission or a slide presentation, so that you get good data back from that process. This feedback is just as important as the feedback that you get from running your conventional experiments.

How does this fit in with my research?

As a researcher, there are probably many possible opportunities in your environment where you could present your work. Presentation does not only mean verbally, but you can also present your work in the form of a written report. Presentation could take the form of: Chatting about your work with a colleague during a coffee break, a meeting with several other researchers, a chat with your adviser, a colloquium, a seminar, a conference, reports, papers, reviews... *Make a list of the actual events in your environment, with the dates that they take place and who will be looking at your work. Given the audience, what would they be able to answer? All audiences are not equal and sometimes a diverse audience at a public presentation might not know deep technical details. What questions could you devise for these people to help you advance your research? Is it possible to shape the presentation or written work so that you target that feedback from them?*

Breaking with Convention

Sometimes if your research is really out of the ordinary or if it combines multiple disciplines it is tough to get the community to accept it. You have heard me saying this whole Chapter that you must understand your peers and what they are looking for and you must meet their expectations. You might say that I am advocating conformance. And it is true, I am. I am saying that you need to conform to the expectations and values of your research community, otherwise your work isn't going to be accepted. But on the other hand, is research not also about new ideas and breaking down previous barriers and actually not conforming? Isn't research also about challenging the existing status? I am going to say that, yes, it is. It is about challenging the existing status and doing and thinking about things differently. There was a time when everyone thought that traveling faster than the speed of sound was not possible and terrible things would happen if you attempted this. However, we now know that that was incorrect and we have moved on and that research community no longer thinks it is a crazy idea. So, challenging the existing status is something that we should be doing and it is a good thing to do. And sometimes it is necessary to reject the thinking and values of the research community in which you work, this is sometimes necessary for progress. If you are doing a small bit of incremental work that fits in nicely with that of others around you then it is normally quite easy to convince your peers that it is good new knowledge. And there is nothing wrong with doing incremental work. Most research work is incremental and it advances knowledge one small step at a time. However, if it is very different to what currently exists then you might find that you are in trouble. Think about the case where you are suggesting the concept of a jet engine, in a world of folk who only know about steam engines. Your work is not about a better steam valve or a better thermal insulation material or understanding how coal in the steam engine combusts better. No. This is such a radical departure from what already exists that if you propose the jet engine to the community who only knows about steam engines it might not be accepted and rejected as a crazy idea. But actually it is a huge breakthrough. So you might really be doing good work but it is still rejected. So what do you do now?

Should you avoid such research? No. I am not going to say that. What I am going to say is that you need to approach your research, and especially the communication of it, in a very careful way. You need to know all about the community that you hope to present your work to. Although right now your burden as a researcher is not only to ask them to accept it, but also to get them to recognize that it might have important implications in the field. This can be very difficult, especially if you are an unknown researcher in the field, which will be the case if you are just starting out on a research career. Breaking with convention and making disruptive, game changing knowledge is a good thing to do, but be prepared to have a tough time of getting it accepted. There is another type of research that also breaks with convention and which can also be difficult to get accepted and that is cross, or interdisciplinary, research.

This is where two different fields can be combined to generate something new. As an example, perhaps you are looking at a biomedical device that measures some parameter in the human body. This is possibly some sort of instrument and the research might be how the parameter in the human body can be inferred from other simple measurements. This will probably need expertise from the field of electronics and instrumentation as well as from the field of medicine. I am quite positive that the average person with a medical background will not understand the electronics and vice versa. So, in this case who do you target as your peer? Should the community where you present your work be a combination of these two fields?

If this is already an established area, then that is OK. But that might not be the case and there might not be that many researchers with this combined expertise or that community might be very small. It could even be that that community does not exist and nobody else is working in this area. So, what do we do with your work now? In this case, I think it is best to choose one or the other. Look carefully at where the actual new knowledge might lie and which is the primary field. Perhaps one of the fields is only being used as a tool.

Then the knowledge probably doesn't lie in that field. For example, if we are analyzing data from a chemical process and using advanced statistical methods to infer what is going on, then we are rightly combining the fields of chemical engineering and statistics and we will probably need to know a lot from both fields. However, we are only using the tool from statistics, and we might not be contributing new knowledge that would be of interest to others in the field of statistics. The real contribution might lie in the field of chemical engineering where we are perhaps trying to characterize the energy requirements of the process.

However, there is a problem. We are going to present our work to the community of folk in the field of chemical engineering and what might happen is that they are not familiar with this advanced statistical technique that we are using. In this case, they might not be able to properly grasp what is going on. They have no experience with that tool and they don't have confidence in it. So, it is sometimes difficult for them to believe a new result that has been obtained with that tool. In such a situation, we literally need to include in our work, some form of tutorial for the target audience, to get them up to speed. We would not send that tutorial to the experts in statistics, because they might be already be completely up to speed with that and consider it to be established knowledge. We will chat more about this type of approach in our next session on foundational work.

How does this fit in with my research?

If your research falls into the categories of either groundbreaking or interdisciplinary then you really do need to look at the research community very closely and identify it very well. Be cautious to present the work in a way that is accessible to the existing community. This might mean approaching it from an angle that they already understand and are comfortable with. *Get the names of the folk who would be interested in your work and really motivate to yourself why they are the right ones to review your work. Do they have sufficient background to be able to appreciate your work? Do you need to bring them up to speed in the area they are not familiar with?*

Chapter 3: Constructing a Knowledge Foundation

New and Existing Knowledge

We can only interpret new knowledge within the context of what we already know. This is important for our research, as our new knowledge will also be interpreted within the context of what already exists. We have been talking about research as the process of making new knowledge and in this Chapter we are going to be talking about one of the prerequisites for new knowledge and that is existing knowledge. New knowledge is built upon a foundation of existing knowledge. And new knowledge cannot actually exist without this foundation. We are going to look at how that foundation of knowledge needs to be constructed so that our new knowledge will be supported by it. Some folk call this foundation a literature survey. I am not going to use that term again. If you ask different people what they think a literature review is, or a literature survey is,

you get a whole range of very different responses and that normally indicates that you need to look deeper at what is really going on. That's what we are going to do here, we will look at the foundation of knowledge that you need to construct the new stuff. If you want to call that a literature survey or a literature review, that's OK, but I am not going to use that term here. Right, so the core principle of this Chapter is going to be that new knowledge can only exist in the presence of old knowledge. To illustrate this, let's look at a trivial example.

I am going to give you a piece of knowledge. Here it is: "P Jones's flight is delayed due to a storm." Is that knowledge? Yes, it is. It is telling us something about the world around us. OK, so what is it saying? Presumably, some person is travelling, by aeroplane, and there is a storm somewhere and they won't be arriving at the planned time. That is quite obvious, but it assumed that we already know many things. We know that a "flight" means travel by aeroplane; we know that a storm could disrupt air travel, we know that P Jones is probably a passenger and so on. Our background knowledge allows us to interpret that piece of knowledge. I am sure that everyone looking at that piece of knowledge, "P Jones's flight is delayed due to a storm" will agree that I have given a valid possible interpretation of it. However, I am also quite sure that nobody will really think that this is a big deal. But let's say that you that you have additional knowledge, things that you already know before you discover about P Jones's flight. Let's say that P Jones is Professor P Jones from a collaborating research group. Professor Jones is coming to give a special lecture in your department.

The lecture is scheduled for this afternoon. Given this background knowledge, our understanding and interpretation of the new knowledge changes quite dramatically. In the first instance, we are only mildly interested in it, in the second case we might be prompted to action because it looks like the plans for this afternoon's lecture are falling apart. A second scenario can be described. Let's say we have some different background knowledge. Let's say the storm that is causing the delay is a tornado. The airport the flight is coming in to is here in Johannesburg. Tornadoes in this area are very rare and no air travel has ever been affected by them in the past. So, with this different background we can interpret the new knowledge completely differently. In this case, it might be that the new knowledge is interesting because it is possibly pointing to something like climate change. So, with this simple example, the new knowledge that we were given that "P Jones's flight is delayed due to a storm". That new knowledge can have vastly different interpretations depending on what your background is. Your perception of that new knowledge can change depending on what else you know. You can change from being indifferent about it to being very excited.

It will also influence on whether or not you consider that new knowledge to be a contribution. Everything that we say or do is interpreted by others in the context of what already exists. In particular, our research, as we make new knowledge, is interpreted in the context of what is already known in our field. Our new knowledge is supported and becomes significant only because of the existing knowledge around it.

So, we need to pay very close attention to this foundation of existing knowledge. And we will start by looking at how to build this foundation in the next section.

Parts of the Foundation

A foundation of existing knowledge is important to be able to understand the new knowledge that is being built. This Section sketches the main points that need to be in place to make this foundation. To properly understand the knowledge foundation that needs to be in place, we are going to look at it from the point of view of that short essay that you wrote about your own research project as part of the assignment of Chapter 1.

That assignment has already been submitted and is in the process of being reviewed. However, we are going to revisit it now and use it as an example to see what foundational knowledge is needed to build it into a solid piece of research. If you did indeed submit that assignment then you can look at your own, but if not, then you can follow along with one of the examples that I gave. This three section essay is the core of our research and shows very clearly what our objective is in making new knowledge. Let's have a look at that structure again.

Section 1 was the background to be able to understand everything else that follows. Section 2 contained the problem in that field and why it is an important problem to work on. Section 3 showed what the new knowledge might look like that will make this problem go away, as well as an abstract form of that knowledge.

Now, let's see what existing knowledge is needed to build the foundation for our new knowledge. You might already have guessed that the background to the problem in section one is obviously the existing knowledge that the reader would need to know so that they can understand the rest of everything else. That is why we included it. This is the context of your research and this is a description of what the field already looks like.

In section 2 there is a part that says why the problem that you are considering, is important. Why it is a big deal? Why, after making the new knowledge, the world will be a better place? This is the significance of the problem. The significance can normally be argued from the point of view that there is indeed an existing problem and that we know this by looking at what already exists in the field around us. We need existing knowledge to make the case that there is a problem and that it is important. In section 3 we described the new knowledge that is needed to fix the problem. The word, new, implies that what we are looking for does not yet exist. This is, of course, in keeping with our definition of research, which is making new knowledge. We need to be sure that the knowledge we are busy making is indeed new and that it does not already exist somewhere else. If it does already exist somewhere else then there is no point in remaking it. We can infer that the knowledge that we are going to make does not yet exist by describing what other knowledge already exists and by pointing out that our part is missing. This shows that what we have is original. To do this, we again need the existing knowledge. Now, in this three part essay that we wrote, there was another part that we didn't write because we weren't ready for it yet. That is the part that describes how we are going to make the new knowledge. We have already looked at the new knowledge that we are going to make in an abstract form, which is the start of answering the question of how to do it, but we didn't actually fill in any of the details. Making the new knowledge will entail doing lots of things and putting all the evidence in place so that our new knowledge is believable. The things that we will be doing and the way we go about them and the tools and existing models and the theories that we will use will need to be discussed. These tools and models and how we use them normally already exist, such as measurement procedures and mathematical proofs and statistics and data gathering and so on.

These tools can be considered existing knowledge and they can be discussed so that it becomes obvious to the reader of our work that we really do need a particular tool or model and that we are going to use it correctly.

All of this again comes from the existing knowledge. So, in summary, we need to have existing knowledge in place before we can present our new knowledge to the rest of the world. If it is not in place then our new knowledge cannot be properly understood by everyone else. This foundation of existing knowledge, the context, the significance, the originality and the tools that we need are all part of existing knowledge. Where does this existing knowledge come from? Normally, we find this knowledge by reading and surveying the literature in our field of specialization. With this foundation in place, the new knowledge that we will make will be much more difficult to challenge than without that foundation in place. When busy with that essay, you already started to build this foundation without even realizing it. Now, that foundation needs to be very strong and you make it strong with lots of references to the literature. We are going to look at some of the techniques for doing that next.

How does this fit in with my research?

In this segment the foundation of knowledge needed to construct new knowledge was given as:

- The context of background needed to understand the problem.
- The actual problem that is being worked on and its significance.
- The knowledge that is needed and that it does not yet exist.
- The tools and methods and approaches needed to make the new knowledge.

Do you think that in your research project each of these are needed? Is there something else that your project might require that is different from these?

It is very important to be reading and reviewing the literature. Sometimes, in guidelines and templates for research reporting, there is a section called “literature review”. If your work is required to have a section called “literature review”, what parts of the foundational knowledge that we have been discussing in this Chapter should be included in it? Should everything be included or should some of it be spread around elsewhere? If your own research community insists on a section or chapter called a literature review then be sure to meet that expectation, but also be sure to find out what they think should be in it.

Reading

When reading the literature it is important to evaluate and select important and relevant material from within a paper or textbook. Even more important is shaping that knowledge to fit into your foundation. We have seen that new knowledge can only exit in the presence of older knowledge. The older knowledge, that which already exists, is needed to understand and support your new knowledge that you are going to make. Without this foundation of existing knowledge we cannot make that new knowledge. So, we need to get that foundation in place. And that means we need to be aware of what is already happening in our field.

What does that mean?

It means learning. It is as simple as that. We need to learn about our field so that we have the existing knowledge to build that foundation. We need to be learning about the knowledge in the field that was established long ago and also about the more recent knowledge. And we need to be busy with this learning continuously, all the time without letting up. This is because the recent knowledge in our field is always changing. It defines that changing frontier between what is known and what is not known. So, you need to be reading and learning all the time. We have seen that the knowledge about our field is stuff that can be written down and recorded. And this is written down in textbooks and research papers. Often, but not always, the textbooks contain the older established knowledge and the research papers the newer work. When starting out on a research project, your advisor might say to you something like: "Go and read up on the topic." What your advisor is really saying is: "Go and become an expert in this field."; "Go and learn about what exists in the field". You might go and read the textbook on your topic. This will give you the older, established knowledge and give you the background to be able to read the newer work. Then you can progress to that newer work recorded in the research papers. Now, very often, reading a textbook is not too difficult. The author of the textbook will normally start from the basics and take you, the reader, through everything that you need to be able to understand that topic. Very often, the textbook has been written with the goal of being a teaching instrument. It is like taking a course at a university or doing one here on edx. The work is structured so that you can hopefully get to grips with it easily. This is not at all the case with a research paper. The goal of a research paper is normally to present a small piece of new knowledge, and that new knowledge will not have stood the test of time in the same way as the knowledge in a textbook would have. A research paper is normally not written as a tutorial or as a teaching instrument. This means that it can be very difficult to fathom what is going on in it. The research paper is written for other researchers out on the edge of knowledge and it assumes that the reader already knows a lot in that field. So, especially when you are starting out, there will probably be a great deal of work in that research paper that you do not understand at all. Don't worry. As you learn more about your field it will become clearer, but be prepared to take some time to do that. You may find yourself continually going back to other sources to try and interpret what is going on in a particular research paper. This is part of that learning process. Now, your objective with all this reading and learning, is to be able to get the knowledge that we need to build the foundation. But how do we start building that foundation? I am going to suggest a possible technique that I think works very well. You will, of course, already have read many things before in your life and internalized the knowledge that you have read.

This is the learning process and it works different for different people. But I am going to ask you to take a moment and think about how you read with a view to learning. It could be that as you are reading and you come across something that you consider to be very important for your work, a core principle or a description of something that just sounds really good. And you are excited to have found it. What do you do? It could be that you highlight that section or you underline it. Or, you put an asterisk in the margin. This is quite normal. You evaluated something and are emphasizing that part so you can come back to it later.

You are saying to yourself: "this is important and I need to remember this." Why? Probably because it is going to contribute to your work in some way. If we consider the intellectual processes involved, you are busy with assessment and memorization. You are saying it is important and you are marking it so you don't forget it. But remember, what we want to do is build this foundation of knowledge, we want to synthesize. We want to make something that was not there before, your particular foundation that you going to build upon. So, how do we bring in this synthesis part? I am going to suggest that after you have marked or highlighted the section, and it doesn't matter how big or small that section is, put the paper away or close the book. Then write. Write about why you are highlighting that section. Don't copy it. Copying it is not synthesis. As you write about why you think that part is important and what it contains, you are automatically changing it and making it fit into your foundation in the way that makes sense. You are shaping and crafting that piece of knowledge to fit where you need it to fit. If you can't shape it so that it fits, in other words, you can't really write down why it is important, then it could be that it's not the right knowledge for the job, or you might first need other knowledge in that area to properly understand that. You may be tempted to skip the writing step. You may say to yourself that you already know where it fits and you don't actually need to write it down.

I am going to suggest that you fight that urge and you actually do write it down. It's only in writing it down that you make that knowledge part of your foundation. It is the synthesis stage and you don't want to ignore that. We are going to discuss a lot more about writing next Chapter, where we will see why this writing step is so important. In conclusion, to build the knowledge foundation that you need, you need to be reading and learning continually. But that is not enough, you also need to be writing about what you have read.

How does this fit in with my research?

Keep a reading journal. This is a Section of what you are reading and your thoughts and impressions of the work you have read as well as how that work is relevant to your own. The form of this journal could be whatever you are comfortable with, from writing in a physical notebook to electronic notes on a tablet. Be sure to always write the complete reference to the original work so that you can find it again as well as using many keywords so that you can track down the writing that you have done. Writing this journal and keeping it updated can be one of the most important things to do. If you skip the writing stage you are destined to reread the literature again. How are you currently tracking your reading and do you think this reading journal is a good idea?

Navigating the Literature

It can be difficult to find the right work to read so that you can build your knowledge foundation. A possible technique of using the paradigm of a meeting of experts is discussed in this Section . So, last time we discussed about reading and learning and a possible technique of how to use what you have read to build the foundation of knowledge that you need. So, now the question arises of: "what should I read?" This is a difficult one. A tempting answer is to say: "read everything that exists in the world and use what is useful." However, this is not sensible. The volume of knowledge out there, the amount of written work, is huge. This is not possible to do. However, finding the right work to read can be difficult. The literature where knowledge is archived is very fragmented and there are bits and pieces all over the place. Very rarely will you find everything that you want close together in one place. Sometimes this happens in a textbook but the knowledge recorded in textbooks is often more background and fundamental.

It is good to read the textbooks, but the newer knowledge that defines the frontier between what is known and what is not known is not normally in those textbooks. The newer knowledge is spread out everywhere.

So, how do you deal with this? I am going to again suggest a technique, this time for trying to chart your way through the literature so that you can find the knowledge that you need for your foundation. First of all, you probably already have some focus of what you are looking for, even if that focus may be a bit vague. There is something in your work that you want to know more about. Something that you need to help make your new knowledge. Or, perhaps you want to know if the new knowledge that you are hoping to make is indeed new and doesn't already exist. But how do you use that focus to find the answer? We discussed last Chapter about the community of researchers out there. The other researchers who will one day evaluate your new knowledge and decide if it is a contribution or not. We saw that it was important to be able to identify that community because we need to know their values and how they think, so that we can meet their expectations. While that community of researchers may be very big, it is good to be able to identify at least some of them so we can really visualize them as people and what they might say and do. I am going to suggest to use this concept to help chart your way through the literature. In engineering, and in most other fields, when we need to know about things that we don't already know, we sometimes hire a consultant, perhaps several. These are normally experts in what we need to know and we ask them to advise us. I am going to suggest that we use this same approach with reading the literature. In your mind, visualize yourself sitting at a large table in a conference room. You are having a meeting and you are allowed to invite experts to the meeting to consult with you. Of course, those experts that you invite to your meeting are the authors of the research papers. And what they have written is what they are saying. You have this expert consultant in your meeting and you ask your question. And you see how the expert responds. Of course, what this really means is that you are reading the paper with your question in mind and seeing if you are satisfied with the answer that you get. It could be, that that expert has nothing to say, then you dismiss that person and invite another.

Get in a few more consultants and ask them your question and see what they say. They might respond with the kind of answer that you are looking for or maybe a part of an answer. Now, you can interrogate them further. You can ask something like: "are you sure?" Now, you are looking for more evidence to be convinced.

Or, perhaps another expert might confirm what the original one has said. So, you gain some confidence in what they are saying. So, in this way you can think about the literature out there as a discussion among the different members of the research community. And slowly a picture of what is going on will start to emerge.

There could very well be a disagreement among the consultants around the table. The one might say one thing and the other something else. This is, of course, when the conclusions of two different authors on a topic disagree with each other. In this case, you ask for more information and bring in perhaps another consultant.

But don't bring in too many, because then the meeting becomes noisy. One of the consultants might say that they heard something from someone else. In other words, the author is referencing someone else. Then you invite that person as well and you ask them directly. In other words, you are reading the paper that was referenced. As the discussion is taking place, you can minute that meeting with the consultants. In other words, you write down what is going on in that meeting and you record the conversation. Now, if someone is silent and not contributing to this conversation, kick them out. Or, if someone is just babbling on and not really saying anything, kick them out as well. After a while you will have your community of experts that you can rely on and that will help you build that foundation. Now, let's take a step back for a moment because you might very well accuse me now of playing games. And research is serious stuff.

However, this idea of visualizing the literature out there as a discussion among experts is very useful and I will encourage it. It not only gives you a way of moving through the literature, but it also forces the people in the field into the forefront. It makes sure that you consider the community of people in your field. Remember, it is that community of people that will actually specify what is good and what is not. Those are the people whose expectations you need to meet. As you work through the literature in this way, by considering not only the knowledge that is written down, but also the people who made that knowledge, you automatically, even subconsciously, begin to understand the way that researchers deal with knowledge in that area. And you take on board those values and practices of the field and you will start to work in a similar way. This is very important because when you write your final work that goes out, those other researchers will recognize your maturity in the field and be more ready to accept what you have written. So, I will urge you to give this approach a try, you don't have anything to lose. You will still end up with the knowledge that you need to build your foundation.

How does this fit in with my research?

You will always need to be searching for the relevant literature and keeping up to date with it. If you are busy with a small project your adviser might just give you a single important paper to read. But with a larger one you will be searching for your own literature to read. For this you will need a strategy as there is just too much work out there to read everything. Will the reading journal idea from the previous segment and the idea of the consultancy from this segment combine to give you a way forward? Is there another strategy that is better for your work? A strategy is important.

Conceptualizing Research

Coming up with a good research objective is difficult, it must be original, significant and achievable. We haven't yet discussed coming up with a good research objective. When we were busy with the research assignment back in Chapter one, I said that if you were already working on a research project then you should use that project, and if you didn't have one, to just think of any problem in the world that was exciting for you.

That was good enough for that exercise which was about getting the research objective into the correct form,

but it does not really mean that the problem that you took on is actually a good research objective. So, what makes for a good research objective? We already know the characteristics that a research objective must have, such as it must have new knowledge at the centre, and that it must be accepted by the community of other researchers and recognized as significant. But how do we actually get to that research objective? In other words, how do you conceptualize the research? Earlier on, we discussed an additional requirement for a good research project. Besides being original and significant it should also be do-able. By this I mean that it should be achievable. It should be possible to actually make that new knowledge. Or at least there should be some indication that it can be achieved. This achievability requirement already asks us to think about the method and the tools that could be used to obtain that new knowledge. Now, the significance and the originality and all the theory and tools and methods that we need to take on a problem, all of these normally come from the existing literature and knowledge in the field. They come from the recorded knowledge in the field, from the literature. This fits in very well with this Chapter's theme that new knowledge can only exist in the presence of old knowledge. Coming up with a good research objective, conceptualizing the research that meets all of these requirements is a tough thing to do. It means that you must already be aware of what is in the literature, and by that I mean everything that is in the literature. This means that by the time you actually have a good research objective, you are probably already an expert at the edge of knowledge. If you are not an expert at the edge of knowledge, then it is difficult to say with confidence that you have a good research objective. If you are doing research at the PhD level or higher, then conceptualizing the research is probably something that you need to do yourself. This is a very tough step because you need to know all that literature in your field, you need to be that expert. So, when working at the PhD level, you need to be prepared to become that expert, you need to be continually reading the literature. This is necessary so that you can bring those three parts together. A significant problem, the knowledge that will address it and a possible way to make that new knowledge. How those three things come together will be different for every person doing research and it will be different in every field, so I can't really give you direct advice on how to do that. But I can say that you need to be that expert and you become that expert by immersing yourself in the literature and knowing about what already exists in your field. However, if you are working on a research project that is of a smaller scope than a PhD, let's say an honors level research project, then conceptualizing the research on your own is possibly too tough to do. You do not have the time that it takes to become that expert at the edge of knowledge. In this case, you really need the help of someone else, typically your supervisor. Your advisor may already be an expert and an active researcher in that field. Then they can advise you on what a good research objective might be. You can, of course, verify that it is indeed a good research objective and you can refine it and you can make it your own, but the tough work of conceptualizing will have been done for you. If you do not have an advisor who is actively working in your field and who can point you in the right direction and help with the conceptualization, that is OK, but you need to be prepared to spend a bit more time to discover where that edge of knowledge is, and bring together the originality, the significance and the do-ability. Of course, if you are not busy with a PhD then the burden on just how significant it should be can be relaxed, and we will talk a bit more about that later on. Alternatively, you might not get to the edge.

There could be something that is not quite at the edge, perhaps it is already known or partly known and you are going to strengthen the knowledge in that area. Then, you can go it alone and you will probably meet success. The reviewers of an honors level project are probably not expecting the same significance and originality that they are with a PhD. However, the message to take away here is that it is good to have an advisor who is at the edge of knowledge. If not, then find someone who is actively publishing in that area and chat with them about your research. An established researcher in any field should be able to immediately point you to the landmark literature that you should be reading first. This makes your life a lot easier in the sense that you can get some casual advice about that field that otherwise you would need to have spent a lot of time reading the literature to discover.

Conceptualizing Research

Not all research work needs to have the same scope and significance of a PhD. This segment gives some thoughts on this. We have seen that conceptualizing a research objective is a tough thing to do. It needs to be significant, original and also do-able, and all this comes from the literature, the knowledge that already exists. Conceptualizing the research is certainly something that needs to happen at the PhD level. In this course, we have been concentrating mostly on the PhD level, but I am often asked what about an honors or MSc project.

What does "significant" and "original" mean in this context? To try and understand this. Let's consider an honors level research project in the field of information technology, in IT. Let's say that we want to find out if the users of a new piece of software find the user interface easy to navigate and to use. This is important because the software developers would want to know about this to improve the user interface design. Is finding out about the software user's experience, research? I would say, maybe. Let's say that we are going to use a survey to ask the users what they think. Before we do the survey, we don't know how they are experiencing it, and afterwards we do know something about the user's experience. So, we have made some knowledge. We could consider this observational knowledge. We saw that something is the case. Can we call this research? To try and help answer this, let's consider another very trivial example. Let's say that I am busy with an extended experiment in the lab where I am monitoring the temperature of a process. Every day, I ask my lab assistant to go and measure the temperature. The lab assistant uses the correct instrument to measure the temperature and writes down the reading. Every day, a new observation is made. Certainly, every day a new piece of knowledge is produced, something we did not previously know. Can we call what the lab assistant is doing, research? I don't think that it would be correct to say that the lab assistant has really made a discovery. What the lab assistant is doing is obvious. It may be very important, but any person working in the lab would have done the same thing. So, I don't think that what the lab assistant is doing can be considered research. Now, let's get back to our example of the person doing a survey among software users to determine their experience. Is this different from the lab assistant taking temperature measurements? This is a difficult one. We are tempted to say that they are different. The IT person is doing research. But if it is different, in what way is it different? I think it all depends on what that IT person is actually doing. If they are using a standard survey to ask for user feedback and then processing the data in a standard way and presenting the results, then that is the same as the lab assistant taking a temperature measurement and I would not really consider that research. It may take a long time to get to the final result, but the route followed is obvious.

Standard procedures were followed all along. I won't deny that the result is important. The software developers really want that result so they can modify their user interface. In the same way, the temperature measurement is important to me so I can use it in my work.

Everything we have discussed in this course so far has focused on the idea that we need to make a contribution to knowledge. And we are making that contribution into the field of other researchers, they are the ones who determine if our work is indeed a contribution. They might want to take our results further and build upon it. I don't think that other researchers would be interested that we carried out a standard procedure and found a result. This means that even if you are doing something that no one has done before, but it is obvious, then it won't be accepted as research. The work the IT person was doing is new, no one has ever determined the user experience of that particular software before. But even though it is new, it doesn't meet the significance requirements. So, how do we go about fixing this? What would make another researcher in this field sit up and take notice? Normally, something that departs from what is obvious. Turning this into a research project requires more than just the measurement. It could be that you can challenge the use and effectiveness of the survey that is being used. Possibly modifying it and arguing the validity of your new survey. Remember, in this case the survey is the instrument that you are using to take the measurement. You can ask the question of whether or not that instrument is actually the right one to use. When processing the results of the survey, can we discover something in the data that was not previously visible?

In other words, we are now using a non-standard processing method. Can the results be interpreted in the context of the problem? In other words, can you already say something about why the results are what they are because of the actual software that was being investigated? These are the kind of things that other researchers may be interested in. You can discover the kind of things that other researchers are interested in by reading the literature. So, once again, it is important to be aware of the other knowledge out there in your own field. Now, the consumers of the knowledge are not interested in that at all. The consumers, in this case, are the software developers and they only want an answer so that they can get on with their job of developing the software. They are not really interested in your new knowledge, and that's OK Give them the result they are looking for, but for research you will need to do more than that. We are back to the issue of consumers of knowledge, who might not really be in a position to evaluate it, and other researchers who might be interested in the real new knowledge that you are making. You need to be careful that you are not only a lab assistant doing obvious procedural work. Even if that work is very tough to do. Now often, it is necessary do such procedural work in the course of your research, but don't only be busy with it. And a final word to the engineers out there. As engineers, we would like to build things, and that's good, but be careful of the "I built it and it works" syndrome. Remember, the objective with research is to make knowledge. If your research is about building something, take a step back and ask if you are also making new knowledge. Even if the thing that you are building is new and has never been built before, if it is something that any experienced and competent engineer could have come up with, you run the risk of your work being labelled obvious and it can be rejected as research.

How does this fit in with my research?

What qualifies as a good research project? We have seen that a good project is significant, original and achievable. How can significance and originality be scoped for different levels of research? The significance required for a PhD research project is different from an honours level research project. How can we be certain we have the levels of significance and originality correct?

Chapter 4: Writing as Discovery

Researchers are Writers

The theme of this Chapter is writing. You might say that you already know how to write, and of course you do.But remember, researchers are writers. As a researcher, you will write a research report, you will write a dissertation, you will write a thesis, you will write a paper. It's all about writing. In any research plan there is probably something that says write up results. I am sure that you will agree with me by now that new knowledge is something that can be written down and can be read by someone else. Your writing is communicating your thoughts and ideas and, of course, your new knowledge. As a researcher, you are seen by the community primarily through your writing. You want people to engage with the output of your work, your new knowledge, and they do that through what you have written. So, writing is about communication but that is only part of it. Writing has another, probably even more important, role in research. Writing is part of the discovery process. Writing has these two objectives. The one is communication and the second is discovery.

It is often this second objective, discovery, that is not given enough attention. In this Chapter, I am going to go through the phases of writing and show that writing is not something that should take place at the end when everything else is done. It is an integral part of the research process. If you leave it to the end, you will find that things become very hard and you often do not progress as fast as you would like to. So, why do I say writing is about discovery? I am going to ask you to do a simple exercise. I want you to think back to a problem that you might have done as an undergraduate student or even in high school. Let's say you were busy with a problem in physics and you needed to determine the force in a rod connecting two points. Don't worry, I am not going to ask you to calculate that force. If this problem is foreign to you, you can substitute it with almost any other test or exam or homework question that you might have needed to do in the past. Right, so I want you to visualize yourself back in that situation trying to do this problem. And I am going to ask you what was the first thing that you did after reading the question, when you started to answer it? What was the first step you took? You might say that the first thing you did was to redraw the figure in your exam script, or on a separate piece of paper. Most people I ask say that this is indeed what they did. Now, why is it necessary to redraw that figure? It is already right there in front of you. You didn't need to redraw it. But you wanted to.

Why is that? I am going to suggest that while you are redrawing that figure your brain is starting to solve the problem. The actual act of redrawing it with a pen on paper was part of the solution to that problem. This is important. Your brain needed that to happen so that it can solve the problem. If you just stare at the figure then it sometimes seems to be more difficult to get to the answer. The writing was aiding you in the discovery process. By writing, I mean the actual act of the pen moving on the paper. When you are dealing with a complex problem, something that requires you to consider many different aspects, then your brain has difficulty in tracking them all at the same time. I am going to suggest that with a complex problem it is not possible to track them all at the same time. All the different aspects that you worry about seem to, sort of, jam up in your mind. Writing it down seems to get the thought processes flowing again. So, it may not be correct to say that you solve the problem in your head and then you write the answer down. No, the writing is the problem solving. The physical act of the pen moving on the paper seems to aid greatly. A problem that only has a few steps doesn't need this aid. You can do it quite easily in your head and write down the answer. But when that number of parts to the problem or the number of steps or the number of things to take into account start to get more than about roughly five, then you need to start writing things down in order to solve the problem. In your research, there are probably going to be very many aspects that need to be taken into account and normally the problems that you need to deal with are complex. Writing is a tool that assists in problem solving.

By writing, I mean all the forms of written work such as maths equations, drawings, graphs and, of course, what we are going to concentrate on here, writing with words. Writing is the act of problem solving, the act of discovery. Sometimes, I see research plans that lay out the research process on a timeline and there are a few months at the end for so called "writing up". This is almost always a bad idea and predicts an extended time to completion. Why? Because the actual discovery takes place during the writing stage at the end. Only then, when the researcher is actually writing, does the real problem solving start to happen and only then do the real issues start to appear. And this normally means that the time has to be extended so that those issues can be resolved. So, the whole takeaway message from all of this is that writing is the act of discovery. We are going to look at how to enable writing as a tool for discovery and then connect it with writing as a tool for communication.

How does this fit in with my research?

Have you ever experienced that you “think better with a pen in your hand.”? Sometimes all that is needed is that you are rough sketching something, or doodling. Often the bigger the problem that you are thinking about the more you need to do this. This Chapter is about leveraging the process of writing for discovery during the research process. This is something that is rarely recognized but possibly one of the most beneficial practices to be busy with. Before you carry on with the rest of this Chapters Sections, I will ask you to reflect on: Does writing (in any form) makes it easier for you to think and solve problems.

Discovery: The Free Write

Never write and edit at the same time. So if writing is part of the discovery process, let's get to see how we can go about actually doing this. A lot of people consider writing to be something that is hard to do, and by writing I mean reports and assignments and, of course, your dissertation or your thesis. Perhaps you don't agree with that and you find writing very easy to do. If this is so, then please share your thoughts and techniques with us. But very often, when we need to write something, especially something a bit big like a thesis or a dissertation, we sit in front of the PC with a blank screen or we sit with an empty piece of paper and it just looks intimidating. We might write a few sentences and then we look at them and they just look wrong and we erase them or we look at them and then don't know what to say next. Or, we rearrange the words to make it sound better. And then we start with the next sentence, and so on, and we progress slowly and painfully through the assignment. Why is this process seemingly so difficult? If you consider what is happening in our minds when we write like this, then there are two separate processes taking place. The first is the creative part, the part that is trying to say something, and the second is the critical part, the part that tells us that what we have just written doesn't sound quite right. Or, that critical part of our mind is telling us that things aren't going well or they are going too slow or that we are no good or that we should start over. Now, these two processes are in conflict with each other, the creative one and the critical one. The bad news is that the critical part of our mind normally always wins. It is much easier to criticize than to create. But the research process is about creating. We are trying to make, to create new knowledge. And writing is part of that discovery process. It is a vital part of the process and we do not want that creative part, the problem solving part, to be shut down by our critical minds. So, how do we go about optimizing this creative process? I am going to suggest a technique called free writing. This is writing that you do for yourself. You normally wouldn't want to show anyone what you have written. This is generative writing where you are being creative and you are discovering what is in your mind and combining your thoughts to create new ideas. If the new ideas are complex you probably cannot formulate them completely in your mind. The actual act of writing will help to crystallize them and bring them to life. This free writing process is about writing your thoughts down as they are flowing and you do not evaluate or criticize or do anything to stop that process. Your thoughts are very non-linear and they are all over the place and trying to streamline them in your head normally does not work so well. So, don't try to streamline them. Just let your thoughts pour out. Later on you will evaluate them. The thing to remember is that you are writing for yourself. Nobody else will see this. And because nobody else will see this, it gives you the freedom to not have to be critical. So, you can shut down the critical part of your mind and let the new ideas take shape. This free write process that I am describing may initially sound a bit flaky. And you might be tempted to say that this isn't really for you. However, this technique normally gives surprisingly good results and I would urge you to give it a try before dismissing it. Right, so what do you physically do? You get comfortable wherever you are with whatever tool you prefer to write with. Tablet, laptop, pen and paper. The tool doesn't really matter. You choose the topic that you want to write about, let's say the experimental results of the day or perhaps the relevance of a new paper that you have just read. You take a deep breath and you start writing. Write down the first thing that pops into your head. Don't say to yourself that it is not relevant or it is not a good place to start. You want to write what is in your head and you don't want to evaluate. If you don't know what to write, then surprisingly I am going to suggest you write down: "I don't know what to write". You literally write that on the paper or type it out. This is going to release that thought from your mind and it will free up your mind for something else. Why do I say this? Just think about what happens in your head when someone gives you a telephone number to remember. You recite it to yourself and you try to keep it in your head.

You actually can't think about anything else because you are worried that you might lose the number. But the moment that you have written that number down it is gone from your mind and you are no longer trying to keep it locked up inside. When the telephone number is gone your mind can start working again on the next

thing. The same happens with our free writing process. The moment the thought is written down it is released. Then the flow of ideas can start to happen at high speed. So, if you have junk thoughts in your mind, write them down physically and release them. As soon as they are gone the other more sensible ones will flow in to take their place. Then you keep on writing your thoughts. You do not want to assess the work that you are doing. You want to keep that critical part of your mind away. The critical part will have its chance later.

How does this fit in with my research?

Set up a writing routine. As a researcher you want your writing tools to be very well practiced. You want to be able to use that tool very well and make a difference with it. It has often been said that one should "write like an athlete" this means that you keep yourself fit from a writing perspective. An athlete, irrespective of their specialty will keep fit by perhaps jogging every day or working out in the gym. As a researcher you keep yourself writing fit by following the same kind of routine. Set aside a time every day for keeping writing fit. 10 to 20 minutes is all that is required. Choose a topic and do a free write on any topic that comes to mind. It certainly does not need to be on your research work, but it could be. The most important part is to get into the habit of doing this so that when you are called upon to write for real, it just flows naturally because you are fit. Set up a routine for free writing every day, normally at a certain time and in a certain place. Guard this jealously and make it your time. Don't let anyone intrude on it. You might be able to achieve about 500 words in this time. But it is not really about the number of words it is more about the practice. *Can you commit to this and become writing fit?*

Mining for ideas

The free writing process produces a lot of text. Now the good ideas and thoughts need to be extracted from all that text. We saw last time that this so called free writing exercise can be useful to generate ideas and discover what you want to say. Because you are not being critical of what you write, it allows you to be creative and let your ideas take shape and crystallize. You are not worried about what someone else will say about your writing because they won't see it. If you allow this process to happen, you will find that you can generate a lot of words in this way. Depending on yourself and how you are writing and the flow of your thoughts, it can be that you can generate perhaps between 500 and 1000 words in half an hour. Remember, this is continuous writing and you are not stopping to edit or to consider what you have written. You are just writing. Now, after you have produced the words and they are written down on a paper or typed into a computer, let them rest for a while.

Maybe for a few hours or a few days, but not much longer than that. Then take them out again and read those words. Now comes the difficult part, the bad news. When you read those words that you wrote during the free write process, you will discover that they sound terrible, absolutely awful. But don't despair, this is normal. Your thoughts are very much non-linear and they are all over the place and normally the work will not read very well.

So, what you do now is you start to unravel what has been captured. Now, you pull out that red pen and you start to be critical of the work. You are not in the editing stage yet, you are mining for ideas. In between all those words are the real ideas and thoughts and breakthroughs. Now, you apply your critical mind and assess what is good and what is not. If something that you read is really no good, delete it or draw a line through it. If it is good, keep it and note the main idea. If there is repetition in a big block of text then group all the text of the same theme together. If there is just a small part of an idea but it looks promising, note that down for further investigation. In this way you unscramble and sift through the text and extract what is good. Now, you might ask: "What if there is nothing that is good? What if everything that was written during the free write stage is all meaningless?" I don't think you will encounter that situation. Even if you are trying to write on a topic that you don't know much about yet, you will find that questions arise during the free write. These questions point the way to things that you might need to find out more about, normally through reading more on the subject. Even if there are only questions arising, those questions are probably the right questions to be asking. So, in that way the free write process is still giving success. And just because you have done a free write on a topic, don't think that you can't do another one on the next day, on the same topic. You can find that the outcome can be substantially different with other thoughts and ideas and questions coming out. When you discover that you are eventually completely out of ideas on the topic and you have written many free writes on the topic and eventually nothing new comes out, it is time to recharge that process. Normally, you do that by reading more on the topic. And then start the process again. Now a word of caution, with this process you tend to generate a lot of text and a lot of ideas and a lot of questions. The free write process lets you create a large volume of work Not all of it will be good, but it will be a lot. You want to create some sort of system, some sort of indexing arrangement to keep track of all of that writing. Remember, it is by nature jumbled and all over the place. If you are writing only 30 minutes per day then you can generate in excess of 20 thousand words in a month. Develop for yourself an indexing or filing system to keep track of all of that and the ideas that have come out of it. Right, so now you have this body of text, your raw thoughts and you have mined it to find the good thoughts and ideas and questions. All the writing up to now has been for yourself to discover what it is that you want to say. Next, we will look at drafting that into something meaningful that can be read by others.

How does this fit in with my research?

A large amount of text can be produced with the free write process. The mining process will identify the good thoughts and ideas from the huge body of text. However it is easy to loose those good ideas in the clutter. How do you keep track of your writing? Do you have a system for doing this or is the writing in a big pile of papers or a big folder on your PC. Do you think it is a good idea to have an indexing system to keep track of the writing that you do? Your writing is your discoveries and you don't want to let a potential breakthrough get lost. Keeping track of all the bits of writing that you do is very important. Develop a system that works for you of tracking your writing. Ask yourself if it is easy to use and if it keeps track of those good ideas?

Drafting for the Reader

Your ideas need to be communicated to the reader of your work. For this the ideas need to be supported with relevant surrounding work. OK, so you have gone through the free writing stage. This was where you were creative, where you let your thoughts pour out onto paper. This was about you discovering what you wanted to say. Then you tried to make sense of everything by trying to unscramble it all and you were mining that free write output for the main ideas. Both of these two phases were for yourself. No one else will see this work that you have produced. Now, we come to the part of the writing process where we start to take the reader into consideration. Why is the reader important? The reader is important because they are the ones who you want to communicate your message to, your big ideas. You want someone to read your work and comprehend what you are saying. Normally, we would like our reader to be convinced by what we say and to accept the message that we are trying to get across. In a sense, we are educating the reader on our message. You will hear me talking about the message a lot in this segment. It could be that while you are reading the literature, you have come across a good paper that is relevant to your work and you want to communicate the message that it is a good paper and that you are going to build on those results. You want the reader to be convinced that this paper really is relevant. Or you may be writing about a result that you got in the lab and the message is that the result shows something interesting. You want the reader to be convinced of this. So, the important point is that your writing will have a message, sometimes a small message and sometimes a big message, and you want the reader to be convinced of that message. For this you need two things. You need to understand what that message is that you are trying to get across and you want to understand the reader. Put yourself in the reader's position and ask if they will be convinced by what you have to say. Finding the message is normally not too hard. When you analyse what came out of the free write and the mining process, the core message normally comes out quite easily. Now, you focus on that and only that. From the free writing process there is probably also a lot of supporting material around that message. That's good. You are going to need that supporting material but make sure you identify the core message. If more than one message came out of the free write process, concentrate on only one at a time. Now that you have that message, you want to put yourself in the shoes of the reader and continually ask if the reader will be convinced. Now often, to convince your reader of your message, you will need to provide good reasons. There probably needs to be some supporting work that helps the reader to come to the conclusion that you want them to. As I said, most of this supporting work will already be present in the output of the free write process. The supporting material normally does one of three things. If the material directly supports the message, keep it. It could be that there is material that is correct and relevant, but it does not really support your message. This could be something like extra background material that you thought was really interesting and you want to include it. But be cautious of this. Even though it is not wrong, it is not specifically supporting your message.

This tends to dilute the message because the reader now has to deal with extra material that they will need to mentally weed out to get to your real message. The third type of material is actively working against your message. This, of course, you need to get rid of at all costs. It is confusing the reader and taking them off track. So, you want to analyse every section and every part to see if what you are writing is contributing to your actual message. You can do this paragraph by paragraph and sentence by sentence. At each stage you need to ask what your reader will think. If something that you write will raise a question in your reader's mind, then you need to be answering that very soon after the question arises. In this way, you can lead your readers to accept what it is that you want to say to them. You probably need to go through this drafting stage many times and each time you tweak the structure so that you eliminate the work that leads them away from your main message. So in summary, the output of the free writing process is the message that you want to get across. And now you are formulating that message in a way that will convince the reader. This sounds very simple and obvious, but we often ignore the reader in this step, so keep the reader in mind. Now normally, I would stop here and we would go onto the next topic. But I am going to add something in at the end of this Section segment. This short Section segment had a message. A message I wanted to communicate to you, the course participant. I will ask you to go back and analyse this Section segment to see if I am following my own advice on communicating the message. Do you think I am doing a good job with this? Is there something you would have done differently?

How does this fit in with my research?

As an exercise take a piece of your own writing and analyse it from the point of view of what was discussed in the Section. Choose a section or a paragraph (not more than a page) . Can you identify a single theme that you want the reader to walk away with? It should be possible to write down this theme as a single sentence or statement.

Then read through each sentence of the work. Categorize each sentence as one of:

- Build and supporting the statement
- Interesting but not directly supporting
- Actually something else all together

Can you reformulate the piece of writing so as to eliminate everything that does not contribute directly? (Note that it is often necessary to lay down background so that other work is put into context. Naturally, this means that there are two different messages, the context and the main one. You would not want to eliminate the context one.)

Editing It

Once you have completed your writing and have the message that you want to convey. It is vital to present it professionally and get it to look almost perfect. We have seen that your writing is about communicating an idea, a message to the reader. It could be a really big message, like the outcome of a thesis or dissertation or it could be a much smaller message like an interesting result from an experiment. We have seen that we need to keep the reader in mind because we actually want that reader to be convinced of our message. The drafting process we discussed last time was about arranging the material in such a way that it leads the reader to the conclusion that we would like them to make. Now, the last stage of this writing process is what I will call the copy editing stage. This happens after you have all the material in the right place and you have said it in the right way to convince the reader. Now, you need to make it look good. This might seem obvious again. However, this stage is very often overlooked. You don't want to have any errors in the actual presentation. Sometimes, we think that our message is so good that it will speak for itself. Sometimes this is true. If you have discovered something amazing, something like a unified theory of the universe, then you may be tempted to think that what you have done is so great that even if you wrote it on the back of an envelope, everyone will be excited to read that envelope. Now, most of the time it doesn't happen that way. Remember, we discussed the values of the research community back in Chapter 2. That research community will want to see the form of the writing in a way that they will accept. Often, if the work contains language and formatting errors it will be rejected out of hand and your message, your new knowledge, will not be seen by the reader. You want to avoid this. This means that before the written work goes out, you analyse it very carefully to see if what is there looks really good. This means that every detail of the presentation is near perfect. Everything from the font sizes and headings to the grammar and the spelling. The readability of the labels on graphs and figures. The links and references to the figures and other literature need to be correct. In short, every single detail must be in place. If this is not done the reader will certainly see this and they will come to the conclusion that if you were sloppy with the care of the final document that you sent out, then you were probably also sloppy with the details of the actual research as well. Now, while that might not be the case, you don't want to create that impression. During this copy editing stage, you might want to show your work to someone else, someone who was not involved in the preparation of it, to read through it and find those errors. Now, most probably the language that you are using to communicate your ideas in will be English. We could have a debate about the dominance of English and if this is a good thing. However, the reality is that you are probably going to need to present your work in English. You are already familiar with English otherwise you won't be taking this course. However, English may not be your first language. This makes it a bit more difficult. What you write may not be perfect English. However, if your presentation is not perfect, your message will not be as strong as it could be. You might need to get the help of someone with the copy editing to get that language right. And even if English is your first language and you are quite convinced that you can do a good job of writing it, I would still recommend that you send it out to a language expert and ask for feedback on what you have written. They might not understand any of the detail of the research or the message you are communicating, but they will be able to get the form correct. The bottom line here, is that you do not want to send out work to the final reviewers of a journal or your examiners of a PhD or MSc that is not very well copy edited and where all the details have been crafted to near perfection.

Telling a story

Writing a research article is very much like writing a story. You want your readers to be engrossed by what they are reading. The biggest element in storytelling is change. With your research you want to show how the world is changing. We have seen how to do the free write and then the mining and then the drafting and then the final editing. We have seen how important it is to be able to focus on the main message and next Chapter we will see how to construct the argument that we need to defend our claims or our messages. But for now, as part of the writing process, we are going to take another look at the reader of our work. I am sure that you would like to see that your work that you have written is actually read. It is not good that when your work is finally published, whether a thesis or dissertation or an article in a journal, it is not good that nobody reads it. Let's say that it has made it through the review or the examination process and there has been success. This is of course, great, but you actually want more than just that. For your work to make an impact, it needs to be seen by more than just the reviewers or the examiners. Of course, the reviewers and the examiners are the first hurdle and you need to keep them in mind when you are constructing your writing. You need to be continually asking if what you are doing will meet the expectations of those examiners and reviewers. However, you also have a broader audience. The general research community out there. Now, the average reader in the research community is quite different from the reviewer and the examiner. The reviewer and the examiner have been tasked with reading your work. If they start reading and it is boring, then they normally do not have the option of tossing it aside. They are tasked with reading the work in detail, whether it is good or bad. And they normally do that so that they can write their reports and make their recommendations. This is not true of the general research community. They are free to engage with your work or toss it aside if they don't like it. Now, these are the actual folk who will one day build on your work. They will use it and cite it in their own work. You want these readers to be impressed and to be captivated by what you are saying. Now, I am sure that you will have encountered a great deal of literature in your field. And there is a very large number of papers that you can choose to read, and you cannot possibly read them all. So, how does a reader go about selecting and engaging with your paper? Remember, you want them to be excited about your paper so that they will actually read it in detail. What makes your readers want to engage with your writing and actually want to read it? Now, before we continue with what makes a paper interesting to read, we are going to take a step back. I am going to give you some homework. This is fun homework. I am going to ask you to go and watch a movie, or read a storybook. A good story. A story that captivates you has certain characteristics that engage the audience. We are going to have a look at those characteristics. It doesn't matter what type of story it is, whether a murder investigation, a love story or science fiction, and as we will see in a moment, your research is also a story. It doesn't matter what type of story you look at, in all of these stories there is often a very clearly identifiable characteristic. That characteristic is change. A typical story outline might follow the following structure: opening, challenge, action and resolution. This is a standard framework for telling a story. The opening is a description of the state of the world. For example, in a fantasy movie we might see a small village hidden away in the mountains somewhere. Then comes the challenge, there is something wrong, the village is being terrorized by dragons. And there is a small boy who is the only one that can save the village. Now comes the action. The boy is doing a whole lot of things and fighting off the dragons and devising plans. This normally takes up the bulk of the story time. Then, right at the end there is the resolution. The resolution of the story is that the world is now a different place. The dragon threat has been eliminated and the boy who was perhaps disregarded at the beginning is now a hero. So, this is a typical story outline. The main thing that happened was change. I will ask you to look for these elements in any movie you see or storybook that you read. Especially where afterwards you say: "I thought that was pretty good". So, this was a chatty description about stories, but how does it relate to our research? When writing your research you are also telling a story.

You want your audience, the readers of your work, to also be gripped by what you are saying. You want them to really want to read your work. Your research has the same elements as a story. The opening is the background and context of the work. The state of the world as it currently is. There is a challenge. Something in the world is not right. This is your research problem. Then there is the action. This is the way you went about the research, the methods you used, the data you collected, the analysis of it. And then there is the resolution. The world is now a different place, it has changed because of the work you have done. This is, of course, the actual new knowledge that is presented. So in this way, writing about your research is not that different from telling a story. It is about how the world has changed. How the knowledge makes a difference. It is very important to really show this change. This is what makes someone want to read your work. It makes for a gripping story. Of course, I do not mean that we can now go and make up stuff as we go along. We still need to be doing good research and meeting the expectations of the field that we work in and doing things right. But that by itself is not good enough to make an impact. That is just the action part. You also need to focus on the change that has come about because of all that action. When next you read a research paper that you think was very good, ask yourself if these elements are present. I am sure you will be able to identify them. Right, so how does all of this relate to our actual writing? The part that makes your work attractive is the change part, how the world is different because of your new knowledge. And this starts with your title. When you are scanning the literature that exists out there, and it is a huge amount, you probably start by reading the titles of the work. You probably read a great many more titles than actual complete papers. So, that title is extremely important. It is probably the most important part of the paper from the perspective of getting someone to read your work. The title should contain the change that will be discussed in the paper. As far as possible, the title should contain the problem as well as the new knowledge. So, the title hooks the reader and draws them in. What part is read next? What do you read next after you have selected a paper? It could be that you look at the abstract. This expands on the title and the abstract needs to draw the reader in even more. In the abstract it is vital to show that change. To expand on the problem and the new knowledge that is going to be presented. You want to show that the world is a better place because of this paper. What part of the paper is read next? If an expert is reading the paper, then probably the problem that you describe will already be understandable to them. They might go straight to the conclusion section to see what the new knowledge looks like. In that last section, the conclusion, you want to be very sure to clearly show what the new knowledge is and how it makes a difference in the world. Now, you have that change part that everyone likes to see. If this change makes a difference in the world of the reader, they will engage with the rest of the paper to see just where this change comes from and if it is something that they can indeed accept. Now, all the rest of the work is going to be read, and of course that part must show good research, otherwise it will still be rejected. In summary, your research work is a story that shows how the world has changed. To capture your reader and draw them in, you need to present this change as clearly as possible in the title, the abstract and the conclusion sections.

How does this fit in with my research?

We have seen that good storytelling is about a change that happens. In our research, we would normally need to describe the background and context and show how the world is a better place because of the research that is being done. This is of course not very different from showing the significance of the research problem which we discussed in the previous Chapter. So what makes research and new knowledge initially attractive is its significance. While this seems obvious, we sometimes miss this when we are writing and then the new knowledge falls a bit flat. We need to really sell the significance of the work. But at the same time, we can not claim more than what we can actually back up. If we claim too much it will be discovered and we will lose readership fast. Can you sell your work to a reader?

Chapter 5: Argument

Reason to Believe

As researchers we use argument to convince others as well as to plan our actions. Every argument has a foundation that we must accept without being given reasons. In this Chapter of the course, we will be considering argument. Argument is one of the core tools that we as researchers use to be able to make our new knowledge as well as to convince others that what we have done is good and should be accepted. We will use the definition of argument as the process of giving reasons to believe a conclusion or a claim. We will see that this process is important not only for communicating our research to others, but it is also very fundamental to how we design the actual research process that we are going to follow. Argument, logic and reasoning is a very well-studied field and this topic could easily fill an entire course. We are going to consider the basics of argument in a pragmatic way, in a way that is useful for our research. We will look at it lightly and bring it into the context of our work. But if you have the opportunity to take an introductory course on argument or reasoning, normally from a department of philosophy, then I would encourage that. They will delve into the finer details in much greater depth than what we can do here. Now argument, also has another meaning in common language. We won't be considering that here. Sometimes, argument can refer to a disagreement between people, such as two motorists who were involved in a collision were having a heated argument. This is not the kind of argument that we will be considering. For us, argument is about reason to believe something. Something that we might call a conclusion or a claim. So, let's start by considering when do we believe something. Whenever we hear a statement, or even if we make a statement ourselves, there is always a possibility of asking why that statement should be accepted. I might make a statement that a new material that I am investigating has a very high density. This could be challenged and I might need to give reasons for why I make that statement. I might say that I have compared the density of my material to that of others and the comparison shows that the density of the new material is high. So, I have given a reason for my original statement. But now, my reason can be challenged. How do I actually know what the new material's density is? I might say that I have measured the mass and dimensions of the material and calculated the density. This can then be challenged again. And I can respond by describing how I measured the mass and the density. I can describe the instruments and the process. Again, this can be challenged, and again I can give reasons for it. Every reason I can give can be considered to be a statement that itself can be challenged again.

Now, the bad news is that formally this process has no end. Formally, it ends up that we can never have complete justification for believing anything. This is something that the folk in philosophy like to discuss at length, but as I said, we are going to look at argument pragmatically and our first step is to see when this infinite regression of asking why I should believe something, might come to an end. We know that in real life we do accept and believe many things, and this infinite regress comes to an end normally quite soon. So, this now leads to the question of: "when do we accept a statement or a conclusion?" The conclusion, in our case, might be a claim of new knowledge and at some point we will need to stop asking for justification. Let's first look at some simple cases of when we ourselves might accept a claim without asking why. You might accept something when it comes from an authoritative source. Let's say that there is a report from the weather service that there is a storm approaching and you need to make preparations. You might recognize the weather service as an authority on these matters and you accept what they say and you believe them. You might not have seen all the weather data, or how they got to their conclusion and you might not have verified their methods. However, you might still be worried about the coming storm. Likewise, you may reject the same warning if it comes from your neighbors down the road who claim they can feel it in their bones.

They are not an authority on these matters so you reject what they say. In our research, when reading the literature we might not be reading every paper in detail, and we might accept the claims of the paper based

only on where it was published. We might be more ready to accept claims if they were published in a reputable journal than if we see them on a blog post. We recognize that journal as an authority on the subject and tend to accept what is there. There are, of course, no guarantees that what the authority is saying is good, but we are more likely to accept that it is. This is also the case when we recognize the author of the paper that we are reading as an established expert in the field. We are more likely to accept what that person is saying, because we accept them as an authority. Again, there is no guarantee that what they are saying is indeed good. Sometimes we also accept something because it fits in well with what we already know about our field.

Let's say we are working in the area of chemical coatings and someone claims to have a paint with a very good reflective property and they obtained this by using a certain additive. If you already know about paints and additives then you might be willing to accept that that kind of additive could very well lead to a more reflective paint. This means that you accept this based on your own knowledge in that field.

It fits in well with what you already know. Related to this is a claim that you could very well believe something because everybody knows that. Let's say that an object was placed in a hot oven and the claim is made that the temperature of the object increased. You could very well say that that is obvious. Of course the temperature of the object increased. Everybody knows that. This is common knowledge. You would not actually want to see proof of that claim. So, we have these three sources of claims that we accept without asking for justification. Something that comes from an authoritative source, something that fits in with what we already know and something that we can call common knowledge. However, we often cannot rely on these alone. Often, when claiming new knowledge these will not be good enough and our new knowledge will need to be defended much more rigorously. It needs to be defended to the community of other researchers so that they accept it. And this leads to the need for a good argument. Now, this thing called argument will have two aspects. The first is evidence and the second is how that evidence is arranged. And we are going to look at these two aspects in a bit more detail.

How does this fit in with my research?

There are many things that you question, and also many things that you accept. At some point, we always need to stop asking the question why. In your research environment when do you stop asking this question? If you think about it carefully, we tend to accept very many things without ever questioning them. This is something to be cautious of because we also fall into this practice and think that just because we believe and accept something, then others will think and accept it as well. Our own authorities that we trust are not necessarily the same as that of other folks. *Take careful note of the things that you do automatically accept in your research environment. Ask yourself **why** you accept them.*

Graphical Arguments

Arguments are vital in research. This segment introduces a way of describing arguments graphically. A higher resolution PDF of the diagram used in the discussion can be found here. We have seen that the argument process is about giving someone reasons to believe a claim or a conclusion. A good argument will be able to convince someone of something. In our research we would like to construct these arguments in a robust manner so that the reader is indeed convinced, and so that the claim that we are making is not open to challenge. Now in everyday life you are already making arguments and giving people reasons to believe what you are saying. However if we look closely at how we argue in everyday life then there are many cases where our arguments are not very robust. And even though they may be accepted in everyday life they might not be good enough for our research. Our objective is to build good arguments that can withstand scrutiny. To get started we are going to take a look at a very simple argument and see a way of constructing it. Later on we will move to a more complicated example based on a real piece of research. Now there are many ways of constructing arguments, but the approach I will use is a graphical one that I have found to be quite useful. The example that I will use is almost trivial, but it illustrates quite well how the argument construction process could happen. Let's consider a scenario where I come into the office and I speak with a colleague and I make the claim that "it is raining outside". This is a piece of knowledge and it is telling us something about the world around us. My colleague might not be convinced and challenges this. My colleague doesn't accept this and asks for reasons to be convinced. Now, I need to construct an argument that will be convincing. There are different ways doing this and you might take a different approach to me. We are going to look at two different ways in this segment, and I challenge you to come up with a better one. We are going to start with the main claim that we want to support. In this case we want to support the claim of "it is raining outside". Now this claim is being challenged. My colleague is asking me for reasons to believe this claim. I now need to supply these reasons. I need to supply some evidence to support this claim. The evidence I supply could look something like this. I could start with making a statement, "I was outside" Then I could add to this the statement "I got wet". Then I could add to that a final statement "Rain makes you wet". All of these statements are needed together to be able to supply a reason for the claim so I am grouping them. Note that each of these statements by themselves, I was outside, I got wet and Rain makes you wet, each of them by themselves would not be sufficient to believe that it is raining outside. They need to be presented together. That's why they are being grouped. Now, is this a good argument? Let's analyse this bit closer. My first supporting statement is "I was outside". This is an observation and is giving us some data. The second one, I got wet, is also an observation and is giving us more data. My last statement "rain makes you wet" is not an observation. Here I am relying on common knowledge, everybody knows that rain makes you wet. Now is this a good argument? Do you think that my colleague has reason to believe my claim that it is raining outside? I present this evidence to my colleague but he raises an objection. The objection is that sprinklers also make you wet. In this way he is attacking one of the base statements that I gave for trying to convince him that it is raining. It could be that my observations are correct, but there are other possible scenarios that will cause my argument to fail. Perhaps I did indeed walk through the sprinklers and because of that I am wet. I can refute that objection by stating that no sprinklers were in operation. This is again an observation. Now my argument is good again. The objection has been countered. However my argument is still weak. There could be a large number of other possible causes for me to get wet other than the rain. There could have been a burst water pipe or someone might have spilt coffee on me. It is difficult for me to refute all of these objections, so perhaps my approach needs to be rethought. Lets start again with the main claim that I want to support. The claim that it is raining outside, and we are going to do things a little bit differently this time. As evidence for this I am going to make the following statements. I am going to use the same statement as before "I was outside", But now I am adding in a different one. Now I add in "Water was falling from clouds"

And finally I add in "Rain is water falling from clouds"

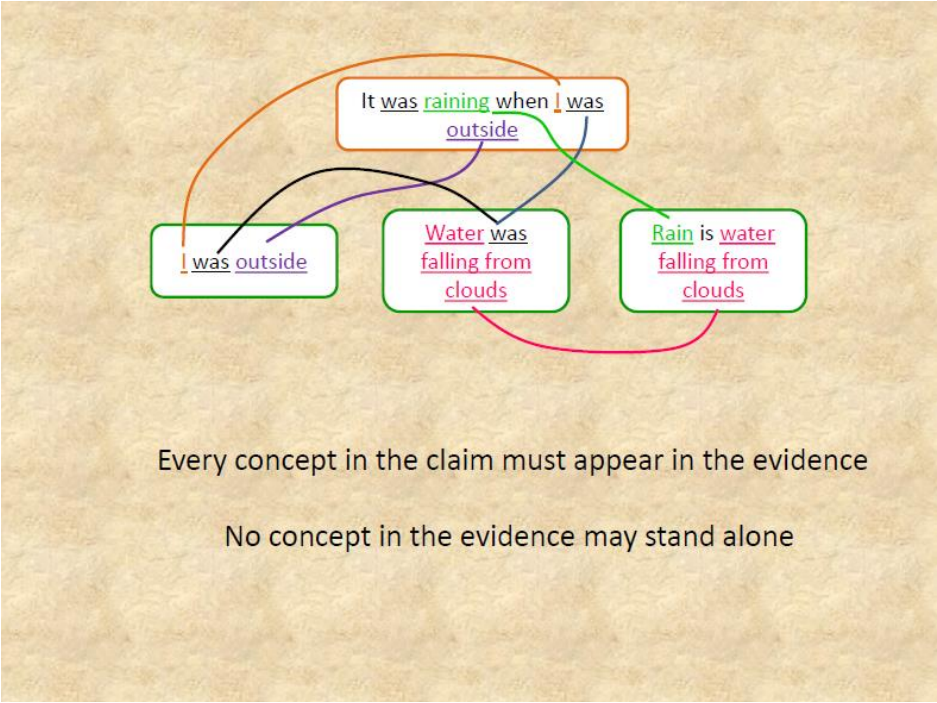
Again all three of these statements need to stand together to form a reason to believe that it is raining outside. Now let's go and delve into these statements a bit more and see if our argument will hold up. Each of these three statements can be questioned again to see if there is any evidence to support them by themselves. Let's see how this might work. Firstly let's look at the statement "I was outside". This is being questioned. I will state that "I am able to determine my position". This is an ability that I have. I am not going to defend this ability further. This is something my colleague needs to accept. I am asking him to accept that I am competent to determine my position. Then I can add in the actual observation of my position. "My position was outside." Together these two give a reason to accept the higher statement that I was indeed outside. Now both the ability and the observation can be called into question, but for my argument, I am going to stop there. Now let's look at the second statement, that "Water was falling from clouds". "I am able to recognize falling water". This is an ability that I have. I add to that the actual observation, "Water was falling". To that I add the statement that "Falling water comes from a origin". For this I rely on common knowledge. To this I add the statement that "The origin was clouds", which is an observation I finish off with the statement that I have the ability to determine the origin of falling water. All five of these statements together form a reason to believe that water was falling from clouds. Now the final statement I need to support is the one at the end that says, "That rain is water falling from clouds". I am going to state that this is a definition and I will quote an authoritative source for this. Right so there is my complete argument structure to support my statement that it is raining outside. What do you think of this? Is it open to attack? Ok so there we have an argument for trying to convince my colleague that it is raining outside. Do you think this is a good argument? Is it convincing or is it weak? The foundation that I have have built this argument on comes from my own abilities to observe, the actual observations, common knowledge and an authoritative source. Each of these can be questioned but that is where I will stop for now. I will ask you to look at this argument very carefully and see if you can find flaws in it. If you can then we can look at ways of fixing them, or we might need to modify that final conclusion of "It is raining". You might not need to give such a detailed description to tell someone that it is raining, but for your research you will certainly need to be able to do this. Your new knowledge will be continually challenged and you will need to build a very strong argument. This argument structure is very useful, not only in convincing someone else, but probably even more useful in actually designing the process of making the new knowledge yourself. You will be able to reason out what needs to be done and what evidence you need so that when you are finished you will have a conclusion that is good. Now a final word. This argument supporting my claim of "It is raining outside" has a flaw. It actually has quite a big flaw. A flaw that invalidates the claim. I am going to ask you to look for that flaw, and tell us about it in the forum.

How does this fit in with my research?

I am sure that you are already using an argument of some form in your work. When you are trying to convince someone of something how do you go about it? It may be that you draw out an argument map as we have just seen, but it could also be that you use another method. It would be interesting to see how you construct your own arguments and analyze those of others. Do you just do what sounds right or is there another strategy that you use?

Argument Construction

In any argument there is a claim that is supported by some evidence or other reasons to accept the claim. The different concepts in the claim and evidence need to follow certain rules for a good argument. A higher resolution PDF of the diagram used in the discussion can be found here.



Chapter 5 Argument, Research Methods An Engineering Approach

We have seen what a possible argument structure could look like using a graphical approach. In the last segment I presented this argument structure without much description of why I chose the statements that I did. This is ok for analysing an argument, but the question now is, how do you go about choosing the correct statements that can combine to form the argument? We are now going to look at how I arrived at those statements I did choose for the rain example. There are many other possible argument structures that we could use and I do not mean to imply that my one is the best or only one possible. You may very well come up with something better. But for now let's consider what is in that example. So let's start again with the main claim that we are trying to defend. "It is raining outside". Looking carefully at this claim there are two major concepts here. The one is rain and the other is outside. We are going to need to treat both of these concepts in the evidence that we supply. These two concepts need to be present in the evidence statements that will support this claim. Now there are many different ways of giving evidence for this claim, but the main context of my claim is that I came in from outside and I made this statement to my colleague. I came from outside. So let's start with that. I can introduce that statement I was outside. So now I have one of the concepts of the main claim in the evidence statement as well. I can emphasize this by actually showing the linkage between these two concepts. Now I am going to deal with the other concept. Rain. And I bring in the definition of what rain is. I am showing the linkage again between the main claim and the evidence statement. Good, so now I have the main concepts from the claim taken care

of, rain and outside. But if I look carefully at the two statements that I currently have then these two evidence statements together don't really say anything meaningful. If I look at these two statements “I was outside”and “Rain is water falling from clouds”, if I make those two statements there is no way that anyone will believe me that together they infer that it is raining outside. The problem is that with each of these two evidence statements that I wrote down, I also introduced new concepts. In the first evidence statement there is the concept of “was” and in the last one there is the concept of “water falling from clouds.” These concepts stand alone. Now a rule to follow is that there may never be any concept that appears by itself in the evidence statements. So this concept of water falling from clouds and this concept of was, need to be dealt with somehow. So let me bring in the statement of “Water was falling from clouds”. This new statement is going to allow me to link all the concepts together. And I can link the concept of was from evidence statements one and two. And I can also link the concepts of water falling from clouds from evidence statements number two and three. So now I have no isolated concepts anymore and I have a possible good argument, although there is no guarantee. My argument must meet at least these two rules. Every concept in the claim must be visible in the evidence, and secondly that no concept in the evidence may stand alone. Those are the two most important rules for constructing an argument. Now, is this a good argument? Have we actually met those two rules? Let's go and have a look at what we haven't taken care of in all those statements. I have circled the words that I have not dealt with yet. Are these important words? They seem to be small words that don't carry much meaning, but let's have a much closer look. In the statement “Rain is water falling from clouds”, the “is” is part of the definition. This is not something that we need to be worried about. It’s in the definition. This we can ignore. However the other two are going to give us trouble. These other two are concepts are concepts in their own right that have not been dealt with properly. These leave our work open to attack. Both of these are violating our rules. The first one is in the claim, this “it is” is a concept that was not dealt with in the evidence. It’s something in the claim with no evidence to support it. The “I” in “I was outside”, that evidence statement has also not been dealt with properly and this “I” stands alone. Both of these are problems with our argument. It means that the claim and the evidence do not match up. Let's look at this carefully. The claim is that it is raining outside, that means that it is something that is currently happening. Right now, at this instance. However in my evidence there was the observation that I was outside. Was, implying in the past. So right now I am claiming a current event but I only have evidence from the past. So my claim that it is raining is not supported. And we can see that by the fact that that concept in the claim is not present anywhere in the evidence. So this argument is no good. Is there a way to reformulate this argument to tighten it up? I am going to suggest the following. I have reformatted the claim, but kept the evidence the same. The claim is now different. “It was raining when I was outside”. By reformulating the claim in this way I am eliminating the untreated concepts and I am applying the two rules. Do you think that this is a better argument now? Remember these two rules for formulating the argument. If there is a concept in the claim it must appear in the evidence. And no concept in the evidence may stand by itself. These two rules will help you formulate arguments that are very robust and very solid and not open to attack. Now for me to make that original claim that I had, the claim that “It is raining outside”, I would need to have different evidence in place. Could you come up with an argument structure that would be needed to be able to make that original claim that it is raining outside? I am going to ask you to give this argument construction technique a try and see if you can come up with your own argument that can be formulated in a very solid manner.

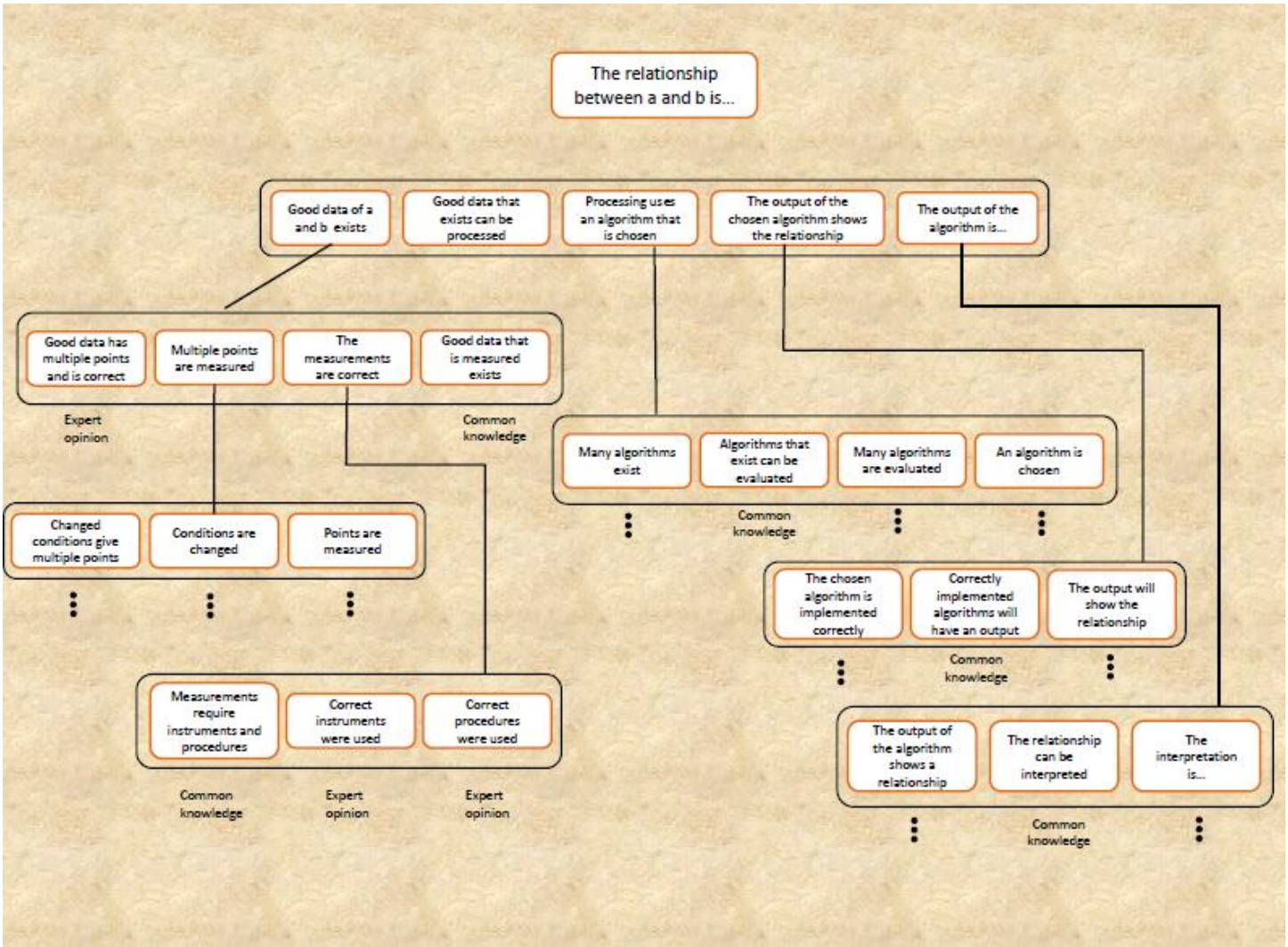
How does this fit in with my research?

In your research there are many arguments. Start small, for example, why a certain paper should be included in your reference list. Start with a simple claim that you would like to argue for. Then apply the rules and write down some evidence statements that are relevant to the claim. Work with the evidence statements until the

rules discussed in the Section are met. Do you think that you have a solid argument? Can you write that argument in a paragraph using full sentences and does it make sense? *Practice this form of arguing and always try to see where the argument might fail and where it needs strengthening.*

Research Example

This segment shows a piece of research described from an argument point of view. A higher resolution PDF of the diagram used in the discussion can be found here.



Chapter 5 Argument, Research Methods An Engineering Approach

We have been discussing several aspects of argument and we are ready to see how this can apply to an actual piece of research. The example I want to use is that of a metal bar expanding when it gets hot. From this we can

draw the conclusion that metals expand when they are heated. Of course this is a known result but it is useful to consider something that we are already familiar with. What would the research objective look like, that would lead to this? Perhaps it could be phrased as: I want to know what happens to the dimensions of a metal object when its temperature increases. Can this be written in an abstract form? I think it can. What would that abstract form look like? Perhaps how is parameter (a) affected by parameter (b). Parameter (a) is the dimension of the material and parameter (b) is the temperature. Now what would the knowledge look like that we would need to be able to answer this? This is of course a model. It relates two parameters to each other. It shows a relationship between things and will help us to understand what is going on when the temperature of metals change. So the conclusion, in other words the knowledge that we are looking for, will have the form of "the relationship between (a) and (b) is...something" This something might be in the form of a trend, an equation or a graph. We don't know what the relationship is yet, but we do know the shape of the knowledge that we are looking for. Ok so now we know we are looking for a model. If I were to ask you how we would go about this. In other words we want to find this model, this relationship between the dimension of the metal bar and the temperature. What would need to be in place? Often when I ask this question I get a response that sounds something like the following: We would need to measure the length of the bar when it was cold and then heat it up and measure the length again. Then we would compare the two measurements and if we saw that the measurement when the temperature was hot was bigger than the measurement when the temperature was cold we could say that the dimension increased because of the heating process. We might want to heat the metal to several different temperatures and then make the conclusion that there is a direct relationship between the expansion and the temperature. Now that seems reasonable, but this description that I just gave was a description of actions.

Things that need to be done. Now certainly all those things do need to be done. However this description of getting to the model what we are looking for is not based on argument. It is based on actions. We are listing the actions based on what we think needs to be done in order to build the model. This leaves the possibility that the argument that we will finally make to support the model will have flaws and be open to attack. I am going to suggest that when planning this research we should not plan it from an action perspective but rather from an argument perspective. What we are going to do now is look at this. We are going to look in detail how to construct this research argument. Ok so here we are with our objective we want to be able to make the conclusion that there is some relationship between (a) and (b). This is of course the relationship between the expansion and the temperature of the metal. However for our argument we will use only the abstract form of (a) and (b). Now we need a good argument, in other words, reasons to believe, that the conclusion can be accepted. I am going to write down some statements that will hopefully be able to support our conclusion

that we would like to make. Here they are. Let's go through them one at a time. Let's start with good data of (a) and (b) exists. Presumably that means we are going to get some data from somewhere. Then we have good data that exists can be processed. I think that is pretty obvious. And we are probably going to rely on common knowledge for that. Then we have processing uses an algorithm that is chosen. Fair enough so we are going to have to choose some algorithm to do this processing of our data. Then we have the output of the chosen algorithm shows the relationship. That sort of makes sense and then we have the output of the algorithm is... something.

Right so there we have some statements that I am suggesting will give reasons to believe and accept the conclusion. Now does this meet our two rules for argument construction? If we go through all those statements, are all the concepts dealt with? Let's have a look. Right so let's have a look at that here we have good data and good data. Good data exists, it exists. The good data can be processed and there it is being processed by an algorithm that is chosen, by an algorithm that is chosen. The output of that algorithm, the output of the

algorithm is something. There is our relationship and here is data of (a) and (b). So we see that all the concepts in the this argument have been dealt with correctly. All the concepts in the supporting statements as well as the concepts in the actual claim itself. So I think we have potentially a good argument here. Now what that really means is that each of these statements themselves are defendable and we have reasons to accept them then we also have reasons to believe the main claim. So now each of these statements that we have here becomes a claim in its own right and we have to give good reasons to accept and believe each one of those claims individually. This is because each one of these statements could be challenged. Here we have a whole lot of challenges to our statements. First of all we can say for the good data (a) and (b) did we do it right? The processing algorithm that was chosen, are we using the correct one? Then the output of the chosen algorithm shows the relationship. Did we implement it correctly? And then when we actually start talking about the output of that algorithm. That actual final shape of the knowledge. We can ask did we interpret it correctly? So we have many challenges and we need to deal with them. Let's start with our data. We need to give some support for the claim of good data of (a) and (b) exists. For this I am offering the following support. Good data has multiple points and is correct. Multiple points are measured. The measurements are correct. Good data that is measured exists. Now each of these statements in their own right also needs support. To start with I am going to say that good data has multiple points and is correct, this I am basing on expert opinion. Let's say I have read this in the literature somewhere. And this last one, good data that is measured exists. Of course that is common knowledge. I am not going to take that one any further. These other two are going to need some attention. As support for multiple points are measured, I am going to offer these three statements. Changed conditions give multiple points. Conditions are changed. Points are measured. Now each of these can be supported again further. However for this discussion I am not going to take this any further. For the statement, Measurements are correct I am going to offer these three. Measurements require instruments and procedures. Correct instruments were used. Correct procedures were used. Now for this first one I am going to rely on common knowledge, of course measurements require instruments and procedures. Then I am going to rely on expert option that I used the correct instruments and that I used the correct procedures. This is probably something I might want to discuss as part of my foundational knowledge. What instruments should I use and what is the correct procedure to use. So for now this branch of the argument stops. And the only way to attack it is to attack my expert opinions or my references. So in this way we can build up this argument diagram with the claim at the top and we give a whole lot of supporting material for each next level of claim. We can move through the others in a similar manner. We can continue to build up this argument until each of the legs of the argument ends with an expert opinion, which is what the literature contains, in other words existing knowledge. Or it ends on something which is obvious, in other words common knowledge. Take care that normally when we write this argument in our final work we don't explicitly state the common knowledge aspects, because very often they are obvious. So we won't actually write them down. So now by looking at this argument diagram you can start to identify things that actually need to be done. For example here we have something that says points are measured. Ok so that points to an action. But we see how the actions are contained in the overall argument structure and they are not what drives the research. With this argument driven approach we end up doing the correct actions. Also note that in this whole discussion I have not made any mention about the fact that

this research is actually about metals expanding. That is the power of abstracting the research objective. We are now concentrating on the argument structure and not on the specifics of the actual research question. Of course you will need to bring the actual research context with all the details in soon enough, but for the argument you don't actually need them. I could have the same argument structure if I was looking at research into the effect on let's say the insulation properties of composite materials because of the addition of nanoparticles. That also has the form of the relationship between (a) and (b) is... something This way of

representing an argument can be very powerful. Both from the point of view of convincing someone that your conclusion is good as well as for yourself in planning what needs to be done.

How does this fit in with my research?

In planning your research do you plan from the perspective of actions or from the perspective of argument? I would encourage discussion on this in the forum. When we plan using actions, are we not already keeping the argument structure in the back of our minds, and that is what guides us in choosing the actions? *Which is a better approach?*

Inductive and Deductive

Some arguments can be proven with certainty and some can only have strong conclusions. We have been looking at some quite sophisticated argument structures and we have seen how the graphical representation of arguments can be useful both in evaluating the argument as well as in seeing what kind of evidence would be needed to support a claim. We have been looking at argument pragmatically and we have discussed ways of constructing arguments without much concern for the underlying theory of argument. Now I don't want to get into the theoretical discussion of argument, but there is one aspect that we need to discuss, because it relates to the kind of claims we are entitled to make, based on our evidence. We have been considering argument as the process of giving reasons for someone to believe or accept our claim. At no stage have we ever used the word prove. Is it correct to say that a good argument proves something? The answer is maybe.

We are going to deal with that word prove. There are two types of arguments that exist. The one has a conclusion that can be considered proven and the other has a conclusion that can only be considered strong.

Let's illustrate this with an example. I have two statements and a conclusion. Here it is: The first statement is: I have a phone without an audio connector. The second statement is: Only the gPhone doesn't have an audio connector. Conclusion: I have a gPhone. Now I want you to look at this carefully. First of all is this an argument? Yes I think it is. There is a conclusion, I have a gPhone, and there is a reason to try and convince

us to accept this conclusion. This is an argument. Now is this a good argument? Is it convincing? I want you to look closely at this argument. Let's say that the two statements I have given, I have a phone without an audio connector and only the gPhone doesn't have an audio connector. If those two statements are indeed correct, does it logically follow that the conclusion can be accepted? Can you think of any scenario where those two statements are correct, but the conclusion is false? I will ask you to try and think of any situation where that could be the case. You can pause the playback now and really try to see if it is possible that the evidence

statements are correct but the conclusion is incorrect. Of course it could be that the evidence statements are incorrect, then of course the conclusion will be no good. It could be that I don't have a phone, then the conclusion that I have a gPhone will be incorrect. But that's not what we are looking at here. In this case if the evidence statements are correct, then it is impossible that the conclusion can ever be wrong. The form of this argument guarantees it. This is an argument where the conclusion can be proven. There is no possible way that this argument can be wrong, if the evidence statements are correct. This is called a deductive argument. Deductive arguments can be proven and they can only be attacked by attacking the evidence statements. The other type of argument that we will consider looks like this. Here is an example. The lab assistant said that the temperature of the oven is 300 degrees. Conclusion: the temperature of the oven is 300 degrees. Is this an

argument? Yes it is an argument. There is a claim and we been given a reason to accept this claim. This is indeed an argument. Now is this a good argument? Is it convincing? We can go further with this argument.

We can say. The lab assistant says that the temperature of the oven is 300 degrees. We can add in. The readout of the oven panel says 300 degrees. Conclusion. The temperature of the oven is 300 degrees. Now we have a second evidence statement and we have more confidence in the conclusion. Can we say that those two evidence statements prove that the oven is at 300 degrees? We might be quite convinced that the oven is indeed at 300 degrees, but we can never be certain. As more evidence is introduced the strength of the conclusion becomes bigger. We might gain confidence because we might add in additional evidence for example that the thermometer has recently been calibrated. Now we have an even stronger conclusion and more of a reason to believe that the temperature really is 300 degrees. However with this type of argument it is never possible to be completely certain about the conclusion as with the example of the gPhone.

This is an inductive argument. With this type of argument the conclusion can be made stronger with additional evidence to support it, but it can also be weakened with the addition of different new evidence. Most of the arguments we make will be of this inductive form. The conclusions can never be proven. But the conclusions can be made strong. A classical example of this is again Newton's Second Law. This law is the conclusion of an argument. It is a model, a piece of knowledge that is telling us something about the world around us. It is a claim that says the relationship between the force and the acceleration is the mass. Do we have reason to believe this claim? Yes we do. We have a whole lot of measurements that support this. With each experiment that we do we gain more confidence in the correctness of the claim, but we can never be completely sure that it is correct. It will only take one additional experiment that shows that this relationship is not good to shake our confidence of this claim. Newton's second law, and indeed most of the natural laws are claims made by inductive arguments. An inductive argument can only be strong, and it gains strength through the addition of evidence. But we should not claim absolute certainty with our conclusion. It is not possible to prove Newton's Second law. So there are these two types of arguments. The one type is where the internal structure of the argument makes it possible to prove the conclusion, this is the deductive argument and the second type is one where it is never possible to prove the conclusion, but the evidence to support that conclusion can be strong.

Now before we go, in this segment I gave the deductive argument example of the gPhone. Here we saw that there is no possible way in which the conclusions can be wrong if the evidence statements are correct. I am sure that you will agree with me that the conclusion of that argument is a good one. However I will challenge you to look at it very closely. The claim that I am making with that argument is good, but it needs a slight modification to make it perfect. We can discuss this in the forum. You might want to try drawing that argument graphically and applying our argument rules to see where that modification might lie.

How does this fit in with my research?

In your research, is the new knowledge that you are aiming to make going to be supported by an inductive or a deductive argument? Or a combination of both? This is very important to know as it will affect the kind of a claim you are entitled to make. It will also affect the bounds of the claim and how general it can be.

Argument Pitfalls

With research arguments the three most common pitfalls are, an insufficient foundation, irrelevant material and not matching the scope of the claims to the scope of the evidence. Right so with your research you are making this new knowledge. And you have an argument that you are using to convince everyone in the research community that what you have is good. Now these folk are going to scrutinize your argument and they are going to try and poke holes in it and they will try and show that your claim, your new knowledge is no good. Now the argument supporting new knowledge can fail on many counts, but probably the most common ways it can fail are these three that we are going to discuss now. Firstly, the argument is built on a foundation that is not solid. As we look at the graphical argument structure we see that the argument must stop at some point. We cannot be continually asking for more evidence for everything that exists. At some point we need to stop and lay down that foundation. This foundation is now open to attack. Is it the right foundation and it is good? If the foundation is attacked and fails, then everything that was built upon it will fail as well. The foundation statements could be from the literature or from an authority or from common knowledge or from some data. If any of these are shown to be no good then the whole of that argument that is supported by it is also no good. Let's say that as part of your argument structure you have made reference to a particular piece of theory or you are making use of a particular tool. And it turns out that that theory or tool is actually no good. What happens then? Everything that you have built on that piece of theory or tool is then also no good. You want to build that foundation on the most solid existing and well accepted knowledge that you possibly can. The second problem that you might have is that the argument fails, not because of the foundation or anything else that is wrong. It could be that the foundation and everything else is good and correct, but it might be irrelevant. For example, I might make the claim that the temperature of the oven is 300 degrees and base this on the fact that the sky is blue. It is certainly true that the sky is blue and I can offer good and convincing evidence for this. However that the sky is blue is not relevant to the claim that I am trying to argue.So the work might not be supporting the claim in the correct way. This then also causes my argument to fail. You want to be guarding against doing the wrong things very well. The third problem that causes your argument to fail to be convincing, is when the bounds of the claim are too big or too small. I will be making a claim and I would like to make that claim as big as possible. I would like to generalize my new knowledge and make it applicable and relevant to as many cases as possible. This normally means that it will be very significant. Here’s an example. Let’s say that I have done some work on modelling and predicting the water services that an expanding city might need. This is a useful model and will enable city planners to make provision for services. Now I might have done this by considering a specific city, the one where I live. I might have a very good model. However, I need to be cautious to claim that I also have a good model that works for a neighbouring city. And I would be extremely cautious to claim that I have a good model that works for any city in the entire world. If I was to claim too broadly then my claim will be rejected because nobody will think that the same work applies everywhere. My claim might need to be smaller, because the evidence that I have is limited. I do not have sufficient evidence for a claim that big. In that case I can reduce the scope of my claim and not claim too much. In this way the evidence might be sufficient to support my claim. But it is now a reduced claim, and that means a smaller significance. So we don’t want to reduce the claim too much. The scope of the claim and the evidence needs to be very well balanced. So in summary, the most important and common pitfalls with a research argument are an insufficient or a weak foundation. Good evidence that is irrelevant and a mismatch between the scope of the claim and the scope of the evidence. These three need to be guarded against.

How does this fit in with my research?

While I generally tend not to like tick boxes in approaching any aspect of research, these three pitfalls that have been described, are what normally sink a good piece of research. When working with research arguments always be sure to check for: A solid and defendable foundation (literature) Relevant reasons to support the claim. Matching up the scope of the evidence and the scope of the claim. Also when reading the literature and other people's arguments, look for these flaws. Most often the last one, the scope of the claim, is what might be a bit off.

Chapter 6:Planning

Non-linear Planning

The research process is inherently very non-linear. It cannot be planned using linear planning tools. We have been discussing research for several Chapters now and have seen the major aspects that need to be taken care of. Last Chapter we considered the argument process and from this it was possible to see the kind of evidence that is needed to lead to the conclusion, to the new knowledge. This evidence is normally not trivial and is where a lot of research activities lie. From this argument structure you can start to plan the kind of things that need to be done. This Chapter we are going to look at this planning process in a bit more detail. This planning is important because irrespective of what research you are actually busy with, you will probably have a limit to the amount of time that you can spend on it. If you are busy with a formal qualification, the rules of your institution might dictate a time limit, or you may only have funding for a certain period, or you might just want to get on with the next thing. If you chat with other experienced researchers they might tell you that research always seems to take longer than anticipated. Let's try and understand why this is and let's see if we can get a strategy in place to try and prevent the research from taking an excessively long time. As part of the knowledge production process you will be doing a great many things. There is literature that must be read, background to be learnt. You will need to get evidence via lab work or in the field. You will be analysing results and developing models, and writing down the work and presenting it to the community, and many other things. So there are a lot of activities that you need to do to get to your final result, to your new knowledge. Now the one thing that I can almost guarantee, is that it is not a straightforward process. There are many twists and turns and dead ends and there are moments of despair and there are moments of enlightenment. And sometimes progress is fast and sometimes it's slow. It is very non-linear. This is something that you can expect and prepare yourself for. If you are already nearing the end of your research, I am sure you have a lot of stories to share with us about this process. Making knowledge is a very complex process. However, as I said a moment ago it could be that this process has a defined and fixed ending time. And we need to be able plan to achieve that. Now almost every research proposal that I have seen and most books out there on research have insisted on using a Gantt chart to plan this research process. Now let me say up-front that I do not think a Gantt chart is a good tool for planning research, and I am going to explain why. The Gantt chart is pretty much a timeline with activities listed on it. This is a typical Gantt chart that I have arbitrary generated. The Gantt chart lists activities and there are nicely defined starting and ending dates and there is a logical order to the activities, for example the experimental results are obtained before they are analysed. That makes sense, and it is quite easy to generate a chart that looks much like everyone else's. With this approach the primary planning variable is time. Time is on the horizontal axis and progress can be measured against time. This Gantt chart is a linear planning tool and I think it works very well when doing procedural work such as running a production line or making widgets that you have made before and you already know how long certain activities take and you can plan it out in this way. But remember research is certainly not about procedural work. We have just seen that research can be very non-linear with many twists and turns. With research you are going into the unknown and there is a great deal of uncertainty. It is because of this uncertainty that I don't think you can squash the research process into a linear Gantt chart. For example, what happens when the outcome of your lab experiments points to a problem with your theory? There may have been a flaw in your reasoning and you need to go back and change things and test it again. You were certainly not planning to introduce that flaw, but now it has thrown your timeline out completely. Now you need to go back and revisit a section that was supposed to have been finished a long time ago. Or suddenly there appears a new paper in the literature that that proves what you are trying to do is impossible. This throws everything into disarray as well. These types of difficulties are almost to be expected, and they completely mess with your carefully prepared Gantt chart. So what I am saying is that using a Gantt chart or any other kind of strategy that uses time as the main planning variable is probably not going to work,

and we are going to need to look at a different way of planning. Now before we leave linear time planning and Gantt charts behind us, I will just want to say that there are times when they could be useful. If there is a procedural part to your research then of course the Gantt chart works very well. Let's say that you are setting up a complex experiment and you need the input of several different folk, and you need to arrange that you have the right material are there at the right time and you need to make sure that a piece of equipment is available. This is all very procedural things and yes it certainly makes sense to use a Gantt chart, but only for that specific procedural part. And a final word of caution. When we started I said that most research plans call for a Gantt chart. And it could be that you need to prepare a formal research proposal that will be assessed,

as is normally the case with most PhD and MSc work. It could be that that formal proposal is required to have a Gantt chart with milestones and the assessors are going to look for that. In that case give the assessors what they want, but keep in mind that the research process probably isn't going to work out that way. We will look at a different way of planning in the next segment

How does this fit in with my research?

As has been discussed in this segment, the research process is not straightforward. I am sure most experienced researchers will be able to share many stories about this. If possible, track down someone who has recently finished, or is nearing completion of a Ph.D., or some other research. Ask them about the process and what their plan looked like at the beginning of the work. Then ask them about how it eventually worked out.

Planning for the Objective

With research we would like to make a contribution to knowledge. Therefore, these two concepts, the *new knowledge* and its *significance* should drive the research planning. In the last segment I said that the Gantt chart is not a good tool for planning something as uncertain as the research process. So let's look at a possible alternative. Let's take a look at our actual objective and see if we can make sense of planning to achieve it.

Time by itself does not drive the research process. If the time allocated to a certain activity has come to an end, it does not mean that that activity has been completed and is finished. For example if the time allocated to lab experiments has run out, but you discover inconsistencies in the measurements, you need to go back and redo them. So the time does not dictate that you are finished. Time is certainly a resource, a very precious resource, and we should optimize that resource, but it doesn't drive the process. So what does drive the process? With research we are trying to make that contribution to knowledge and that comes from two things, the actual new knowledge and its value to the community, the contribution. So I will suggest that we use these two things as the actual things to track and worry about. Rather than using a linear time based approach we could represent what we are doing on a two dimensional plane. On the horizontal axis we have the new knowledge that we are making. It extends from a small scope near the origin and gets larger as we move to the right. Small scope might mean something like a single observation and larger scope might mean a generalized theory or model. On the vertical axis is the significance of the work, its contribution to the community. How important your work is as judged by others.This extends from weak significance all the way up to earth shattering significance. On this two dimensional plane we could map our research. When we start out we are at the origin. We have done nothing and nobody cares. As we progress we make new knowledge and that increases in scope and significance. Ideally we would like to be up at the top right, where we have a large scope and large significance. I am sure that we could probably map out the regions of this plane where the PhD and the MSc and honours projects might lie. Now quantifying the scope and significance with actual

numbers might not make too much sense, but this view of what is happening in our research can guide the process. It also forces us to think about the significance and not just the knowledge that we are making. If you are already busy with your research, then I will challenge you to think about where you actually are on this plane right now. With the research process, as we progress we will move around this plane and we can drive our work in the right direction. We move to the right by increasing the scope of our new knowledge and we move up by testing our knowledge against the community to see if it is significant. We are going to see next how we might actually use this representation of the research process to plan the activities that will allow us to move in the right direction.

How does this fit in with my research?

Do you think that this 2D plane can be used to describe your research? If you are already busy with some work, are you able to estimate where you currently are, and where your final objective is? (A black and white PDF of the plane is here) If you can point out your position, how do you have confidence in your estimate? (The next segment will help with this) If you have your current position and ending position, are you planning the correct activities to move in that direction?

Feedback Processes

To exercise control over any process and drive it forward, regular feedback is required. Feedback for the new knowledge comes from our writing. Feedback on the significance comes from showing our work to others. We have seen this 2 dimensional plane of describing the research that we are busy with and we have seen how it can clearly track our objectives which are both making knowledge and the significance of that knowledge. But how do we actually use it to plan our work? How can we judge where we are on this plane on a regular basis, so that we do indeed know that we are progressing towards our final objective? With a traditional research plan which is driven by time we normally only know where we are in terms of knowledge and significance, right at the end. Let's say that we have done a lot of new work, made the new knowledge and sent it out for review or examination and we have received the feedback. In that case we could indeed place our work on that research plane. However this is normally too late to do anything about it. We have received the feedback only at the end of everything. With this approach it takes much too long to get the required feedback. What we would like to do is to see ourselves moving incrementally, Chapter by Chapter or month by month towards our goal. We would like to track our discoveries and their significance continually, so that we can adapt to changes as we progress and learn. Now our discoveries are coming from our writing and the significance is coming from the feedback of the community. So let's look at these two, writing and feedback from the community. When we look at the knowledge production process then it certainly starts with a problem, which gives rise to the requirement for new knowledge. Then we do a whole lot of actions, the actual research work, and then we end up with our conclusion, our new knowledge. When we look at the traditional linear research plan there is often that section at the end that says write up. But as we have said writing is the discovery, and the new knowledge is only made during the writing process so you want to be writing continuously and not only at the end. This will enable you to use what you are learning and discovering to guide the knowledge production process as it unfolds. This is how you find flaws and problems with your work and where you see the different directions that might need to be taken. If you leave the writing to the end, you will almost always end up extending the time you have allocated to the research because this important feedback, from yourself , comes too late. Now after the new knowledge has been produced, it then goes out into the community for that important peer review process. Others get to see it and this is where the contribution and the significance are determined. Normally this is done right at the end again. Now, if the outcome of the peer review process is anything other than a complete success, it means that the work will need to go through another iteration, as the peer review process is fed back into the knowledge production process. So we can see that there are these two feedback paths in this process. The knowledge production process which we get from our writing and the acceptance path which we get from the peer review process. The problem of leaving the writing and the peer review process too late is that the time it takes before you get feedback is too long. You get feedback at intervals that are far removed from each other. If there is something wrong with our work, with either the content or the significance, then the feedback processes will show it, but it takes a very big amount of time to realize this before we can make a correction. We would like to enable these two feedback processes as much as possible so that we can know sooner rather than later if there is a problem with our work. Then we can make an adjustment to what we are doing in good time. A problem we sometimes have as researchers is that we are quite happy with our progress as long as we don't write anything down or as long as we don't show it to anyone. In our heads everything seems fine and we are doing everything right. But without writing it down and showing it to others we actually don't know where we are on that two dimensional research plane and we actually don't know what our new

knowledge really looks like and what its significance is. So the message here is that you need to be writing and showing your work to others continuously throughout the time that you are busy with your research, so that you can get those feedback processes working. Next we are going to look at a way of making sure that we stay on track with this and that we do not need to wait too long before getting this important feedback.

How does this fit in with my research?

Will your work benefit from these two kinds of feedback? If not can you say why? Is it possible to be sure on your own without obtaining feedback? Is your advisor sufficient to get feedback from? In your environment, can you identify opportunities for getting this kind of feedback? *Can you schedule feedback opportunities so that you get the feedback required to track your progress?*

Incremental Construction

Make a small piece of knowledge and then grow the scope and significance, rather than trying to do it all in one go. So what we have seen is that when you are busy with your research and you are going into the unknown, you need to be getting regular feedback. You need feedback from both the creative knowledge production process as well as from the research community, so that you can determine if your work is indeed good and on track. Obviously this feedback is important because it guides you in the direction that your research is taking and in everything that you do. It is important to have this feedback quite regularly. This is so that we can chart our position and our progress on the two dimensional research plane. And so we can see what the scope of our knowledge and what its significance is. So what this means is that we need to commit to write regularly and to test our work often. The biggest problem that you have is that the feedback normally comes too late in the process. So how do we go about doing this? I am going to suggest a technique that you might initially think sounds a bit crazy, but I am going to ask you to consider it carefully before dismissing it. Every Chapter, or perhaps every two Chapters, you completely write your paper, dissertation or thesis. Now what do I mean by that? But that I mean you actually write, let's say a research paper, from start to finish. Starting with the objective and going all the way through and ending up with the new knowledge. Naturally if you have only one or two Chapters to do this then the scope, the size of that new knowledge will be small. But that's ok. You will grow it as time goes by. However after one or two Chapters you will have a finished product. A piece of knowledge that exists, that can go out into the world and can be shown to others. It is important that the knowledge be completely formulated, even though it may be of very limited scope. You want it to be completely understood by those looking at it. You want those looking at it to be able to understand it and give good feedback. They can only do that if the work has been well formulated. Now every few Chapters you update to a newer version of your research paper, or your thesis or your dissertation. You make the scope of the work slightly bigger, you add in parts that make it more significant and you expand it and you generalize it more. At the end of every few Chapters you have an actual working copy of your paper, or your thesis or your dissertation, that you can show everyone. And it is formulated completely, start to finish.

Now you might say that this is not possible. You might have a long experiment to run and process data that will take a long time before you get the results that you need. That may be true, sometimes experiments do take a long time or you need to wait for data to be collected or you have some other long procedural activity that must be in place. However, the longer you have to wait before having a working draft, even if it is of very

limited scope, the bigger the risk becomes. What happen if after running a long experiment, you discover that there is something wrong and you need to go back and repeat something? That puts you back a great deal.

And that means you are going to need to extend the time that it is going to take. Sometimes this approach is called exploratory research, you do a quick experiment or some simple work to see if there is anything meaningful in the direction that you are thinking of moving in. You get feedback quite fast and that gives you guidance on whether you should continue in that direction or not. Now I am suggesting taking that idea of exploratory research to the limit as far as your work allows it. Make everything aspect of it exploratory. That is what research is all about, exploring. Now you can take that argument diagram that you have produced, or at least an outline of it and what you do is you ask yourself, in this whole argument structure what is the smallest piece of knowledge of the most limited scope that can be defined? Ask yourself what is the minimum viable argument that you can define? And you shed any parts of the big argument that are not vital. Of course you are now weakening the argument greatly and you are limiting the size of the claim tremendously. But that is ok you just want to get a small core piece of knowledge to start with. Once you have it and once you have written it down and formulated it properly

from start to finish, you can show it to someone else, then you can start to expand that argument and strengthen it and build it out and increase the size of the claims. The whole idea behind this approach is that you always have your knew knowledge ready to show the community. In this way you can see it developing and you can get the vital feedback about whether it is good or not. You are not waiting until the end to discover if what you are doing is good and meets the expectations. The advantage of this is that you always know where you are on that research plane of knowledge scope and significance. Then at some point all what you need to do is stop. Your thesis or dissertation or research paper is already finished there is nothing more that needs to be done. But now you might ask, what if you are just starting out and you are still trying to conceptualize your research, after the first two Chapters of a PhD you might not actually have a good research objective yet. And that's probably quite normal. You won't have anything that resembles your final work yet, but you will probably have read some literature and from there you will already have learnt something and formed opinions, you may have articulated the relevance of that literature. So you do have some new knowledge. I agree that the scope of it might be quite small and the significance won't be very large. But it is something and you can build on that. Now this might sound a bit simplistic and it is not the way most research plans are laid out, but remember most research plans do not work out at all, they are hugely off target because they try to lay out the complete path before anything is known. The uncertainty is too great. However with this incremental approach you have the ability to adapt quickly as you learn and discover more. With this approach you are only making a small piece of knowledge and testing it to see if it good, then as you progress you can increase its size and significance as you gain confidence. However, always be sure to write it down in a completely well-argued form. The knowledge does not exist until it has been written down.

How does this fit in with my research?

This approach of making knowledge incrementally and growing its significance and scope is a bit new and novel. Do you think it can work? Our time resource is often limited and we do not want to overrun the time. To deal with this risk of a fixed resource something else must be flexible. Either we overrun on the time if the outcome is fixed or we limit the outcome if the time is fixed. This approach tries to reduce the risk of overrunning the time.

Course Closing

We have come to the end of the course, thank you! We have come to the end of the course. I would like to say thank you for sticking with me until the end. I really do hope that it has been beneficial for you. If nothing else I hope that you have seen things from a slightly different perspective. What I have presented in this course is not that new. There is almost nothing here that you will not find written down in other places. There are many books on research out there, but they are often written from the perspective of a certain field of study, such as the humanities. That's ok, but that sometimes makes the work in those books inaccessible to folk who are not in those fields. What I have tried to do in this course is strip away all of the terminology and jargon and make the core fundamental principles visible. These fundamental principles I think hold in any field of research. What is most important is that you see how these principles apply to your own field and in your own environment. I do think that all the principles that we discussed, are going to be part of your own research.

Applying these principles correctly is of great importance in achieving your objective, which could be your qualification or your research paper. I do hope this happens and I do hope that you achieve that goal. I have said that there are other books on research out there. Please do also read one or two of those books on the subject. But after doing this course those books might be a bit more meaningful. I am sure you will be able to see our principles in those books. Now this is the first time I am delivering a course in this manner and I suspect that it could be strengthened in many areas. I would value your input on what your impressions were of this course. Back in Chapter 2 when we discussed the peer review exercise, I said that it was very important

to use every opportunity to get feedback. I am going to actively use your feedback about this course to make improvements to what comes next. There will be a short survey at the end of this Chapter's material. I would really like you to engage with that to help us change the course and develop it to better serve the needs of what is required. The material presented was only a short overview. The topics that we discussed each Chapter could easily be expanded on greatly for a more in depth treatment. It would be useful for me to know which topics you think need strengthening. The survey is split into two parts, the first is on the content of the course and the second part is on the presentation. And I would really appreciate it if you could engage with that survey. In closing I would like to wish you well with your research and I hope that you really do achieve the success that you are aiming for.

Reference

- https://courses.edx.org/courses/course-v1:WitsX+ELEN7070x+1T2019/course/