Introduction to Scientific Research Projects

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Contents

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Short Biography

Dr Graham Basten is Associate Head of the School of Allied Health Sciences at De Montfort University (UK). He holds a PhD from the UK government's Institute of Food Research and has researched and lectured extensively over the past 10 years on clinical biochemistry, nutrition and folate at the Universities of Sheffield and Nottingham (UK). He is a De Montfort University Teacher Fellow and has been nominated for the Vice Chancellor's Distinguished Teaching Award. As a senior lecturer in Clinical Chemistry and as leader of the undergraduate Projects module, this expertise and experience is transferred to the concise introductory textbooks written for Bookboon.

Select research publications

1. Blood folate status and expression of proteins involved in immune function, inflammation, and coagulation: biochemical and proteomic changes in the plasma of humans in response to long-term synthetic folic acid supplementation. Duthie SJ, Horgan G, de Roos B, Rucklidge G, Reid M, Duncan G, Pirie L, Basten GP, Powers HJ. J Proteome Res. 2010 Apr 5;9(4):1941-50
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4. Effect of folic Acid supplementation on the folate status of buccal mucosa and lymphocytes. Basten GP, Hill MH, Duthie SJ, Powers HJ. Cancer Epidemiol Biomarkers Prev. 2004 Jul;13(7):1244-9

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Introduction to Scientific Research Projects

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Preface

This book is primarily aimed at undergraduate students undertaking scientific research projects as part of a programme in medicine, nursing and midwifery, subjects allied to health and biological sciences, although it is generally applicable to all project work. It will also be useful to professionals undergoing continuing professional development (CPD) or changing to study at MSc masters level and who need revision on scientific research methods. Since the book uses "example boxes" to explain complex terms in lay language, it should also be accessible to patients and people with a non-clinical background but an interest in the subject.

As this book is an introduction to the area, you may be inspired for, or want, further training and reading. There are many excellent resources within institutes and online, too many to list here, although I would recommend starting with your own institutes' library, support or academic teams for further information.

Expert boxes are provided as cues for further reading, as this text is an introductory overview it is not conducive to all readers to cover all aspects in considerable detail.

Example boxes will provide worked examples or case studies.

Disclaimer

This book provides an introduction into the key areas that if addressed comprehensively will ensure a sound research project. Certain examples given in the example boxes may not be suitable for your Institute or sponsor and the reader should check local rules specific to your project requirements.

1 What is an undergraduate scientific research project?

The undergraduate project allows the student autonomy to design, plan, execute, analyse and finally disseminate their research ideas. As this autonomous element is usually unique, compared to other assessment modules with didactic lectures and examinations, the project has significant currency in scientific employment as it is the foundation of a research career.

1.1 How is it different to other types of assessment?

University assessments fall broadly into two categories "formative" and "summative". Formative assessments are to inform learning and to allow you to receive feedback on a piece of work that carriers no formal mark. Summative assessments are a sum of work to date and feedback is provided with a formal assessed mark that will usually count towards the overall degree classification.

Most undergraduate scientific research projects are summative and provide a substantial amount of marks towards the final year and subsequent degree classification. Therefore it is vital that students fully prepare and plan their project work for maximal effect. Since most projects by definition do not have an unseen public examination element they can be highly productive source of credits, particularly to candidates who find examinations difficult.

In addition to the project, undergraduate students are tested by a variety of assessments including unseen examination, open book examination, essay, presentation and practical classes (table 1). The clear difference between these assessments and the projects is that of ownership, support and outcomes. The final outcome of the project is often unknown and it is an opportunity for the student to sample research and to bring personal ideas and philosophies to the work. Therefore, it is important to think about your own hopes and expectations and how they relate to the reality of the project which will be further discussed.

Assessment type	**Based upon (typically)**	**Duration (typically)**
Unseen examination	Lecture material	2 to 5 hours
Essay	A set and defined question	2,000 words
Presentation	A set and defined question	10 minutes to 60 minutes
Practical classes	A set of defined instructions	3 hours with practical report
Project	Expertise of department	200 hours with a 7-10k thesis

Table 1: Different types of undergraduate assessment

1.2 How is different to other types of research projects?

An undergraduate scientific research projects fits into a progression of scientific research and is therefore often seen as the start of a research career or pathway. Figure 1 shows a typical research pathway from left to right, with undergraduate (U/G), MSc, PhD to post doctoral research. The cards underneath represent a well known card trading game with scores out of ten (ten being the most) to represent typical attributes of a project. Scope is how much freedom and broadness is allowed to research a hypothesis, whilst depth is how much detail into the area is investigated. The figure also demonstrates that the undergraduate project is a balanced introduction to research.

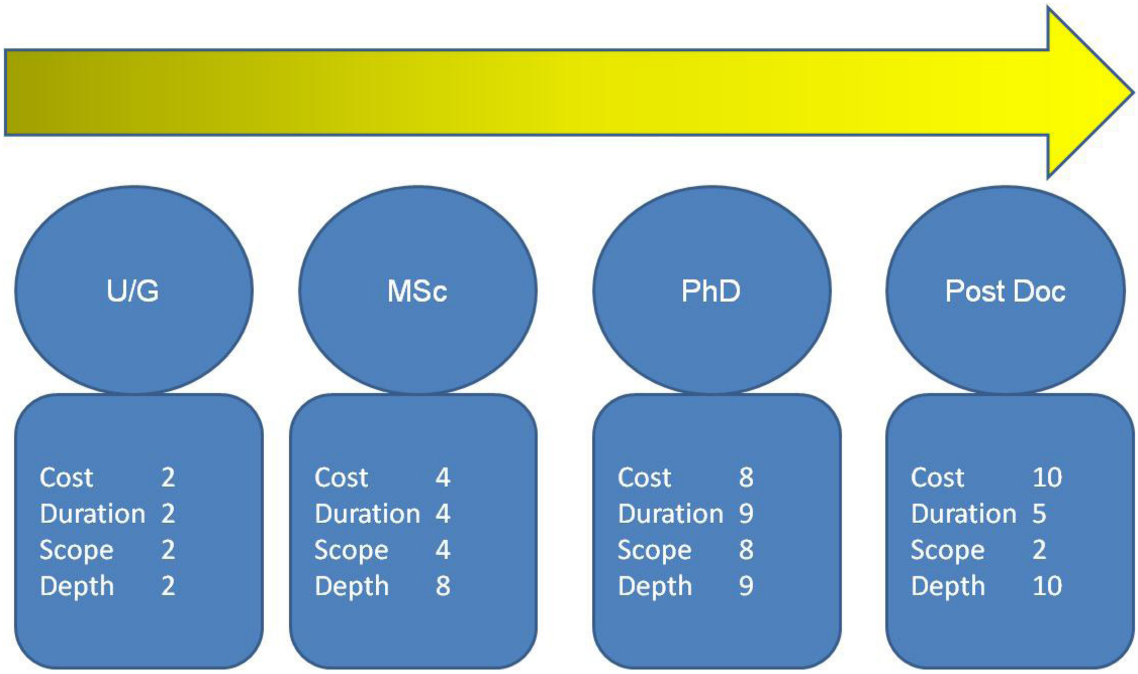

Figure 1: A typical research pathway.

Hypothesis: A statement which is tested by research and subsequently accepted or rejected.

1.3 What types of research projects are there?

There are several types of undergraduate research projects common examples include laboratory, literature, meta-analysis, intervention, questionnaire and data handling. A brief description is given below and the projects should allow the reader to identify personal strengths and assist in project choice (see chapter 1.4).

Laboratory projects are typically based in a laboratory environment. Types of projects that are typically done will have some element of repetition, sample preparation and analysis for example measuring glucose in provided urine samples in order to accept or reject the hypothesis.

Literature projects review existing studies by collating data and conclusions to create a consensus data set and conclusion. These projects are often wrongly viewed as having less worth, particularly if there is little or no data manipulation or analysis.

Meta-analysis projects are a literature project with complex models applied to reach a conclusion. These projects, by having data manipulation and analysis have considerable research currency. An example could be "Does Viagra work".

Intervention projects are when the student recruits volunteers to part in a piece of research, for example taking vitamin C tablets for 6 weeks and providing urine samples. At undergraduate level will often be very limited and poorly powered (see power calculation) with only a few volunteers but will give an insight into ethics and will look impressive on CVs, although they are high risk because of volunteer recruitment and compliance.

Questionnaire projects involve collection of data from volunteers, rather than samples, and are lower risk than intervention projects but still require ethics and recruitment. A typical project could be a food frequency questionnaire to determine nutrient intake in a cohort.

Data analysis projects are lower risk as the data will already have been obtained from a previous study and using statistical tests, hypotheses are tested. An example project may be to look at case control data from a prostatic cancer study of 10,000 men which has data on cancer marker concentration, symptoms and lifestyle.

Power calculation is the minimum number of volunteers or patients needed to make the results statistically significant.

A cohort is a group of people being investigated in the research.

1.4 What project will best fit my personality?

As a very simple guide you may choose to complete a personality test, many are available, but a basic one is outlined below. Each box contains a description of a person type, whilst most people have a mixture of all these types, think about which description colour best fits your personality in a work environment and then use in table 2 to match a project. This is not meant to be definitive but it should make you question what type of project best suits your style of learning and working.

Red: Self confident, critical and outspoken, very confident and gets results by any means.

Yellow: Highly organised with a priority for fine detail, a perfectionist.

Green: Very outgoing and friendly and prefer to be part of a team.

Blue: Dependable, practical and paced in a methodical way.

My personality colour is:

Project Type	**Typically suits personality colour**
Laboratory	Blue
Literature	Blue
Meta-analysis	Yellow
Intervention	Red, Green
Questionnaire	Red, Green
Data-analysis	Yellow, Blue

Table 2: Matching project type with personality colours

1.5 What will I be expected to do and learn?

Each institute will have different assessments within the research project, the following are examples of what you may expect and they are covered in more detail in subsequent chapters. As outlined in figure 1 they are "mini" versions of what you would be expected to do in more in-depth and advanced research projects.

1.5.1 Critiques

Critically review key papers in the area you have chosen to do a project in. This enables the researcher to design experiments based on the suggested improvements of previous work and it also development of key skills such as writing and data presentation, but most fundamentally it will allow researchers to overcome the perception that all published work is correct and true.

Example: If someone had found the cure the cancer would this really be published in an obscure agricultural journal in South America?

1.5.2 Research grant

You may be asked to either write or review a research grant or patent claim. The aim of this assessment is to help the student to understand how research is funded and managed.

Example: Find out by internet engine search and talking to your supervisor who the key sponsors of research in your area and your country are. These sponsors are an excellent source of information to assist in the writing of this assessment.

1.5.3 Literature review

This allows the student to gain a broad knowledge of the subject and is the key to a great introduction and subsequent discussion.

Example: Register with a library and online peer reviewed manuscript databases to gain access to key papers.

1.5.4 Oral presentations

Typically a summary of your work in a presentation format, usually using PowerPoint and taking the style of an oral communications as seen in conferences. Timing and keeping to point is the key to a cool presentation. Remember, you did the work, so you should know a fair bit about the experiments so don't be nervous!

Example: Use internet search internet engines to find video clips of good and bad presentations!

1.5.5 Poster session

There are three ways to disseminate results, one is by writing a journal article, one is the oral presentation and the other is by poster presentation. A common misconception is that the poster presentation is like a "wanted" or advertising poster. Instead it is a summary of all your work summarised into panels.

Example: Ask your supervisor for good examples of research posters.

1.5.6 Notebook, diary or blog (online diary)

Keeping a record of your work is vital to show progression and how your work has evolved over time. It may also come in handy to prove you did invent something amazing!

Example: A hardback notebook is most suitable for laboratory projects, a blog site or paper diary would best suit projects in which you interact with volunteers or team members.

1.5.7 Thesis

The thesis is the complete written summary is often viewed with most fear by students. It should be relatively straightforward to put together as it has set and well defined sections and should be worked on throughout the project.

Example: DO get a copy of the rules about how to write the thesis and get previous examples of good work, but DO NOT attempt to copy a previous thesis as they are written in your own style.

1.5.8 Oral viva

Often viewed as the gold standard research assessment, you will expect to do a viva at PhD and sometimes at MSc level. It is an interview in which you will be asked questions about your work to judge your understanding. If you are confident and don't like writing the thesis they are great, if you are a naturally nervous and forgetful person they can be problematic.

Example: Practice the viva as often as possible and use summary cards. How you write the thesis can also affect the flow and questions asked at the viva.

1.6 Summary

The chapter summarised where the undergraduate sits in the hierarchy of scientific research projects, it discussed the types of projects and assessments and introduced a method of choosing your project based on your personality profile.

2 Choosing your project, hopes and expectations

Well, to begin I'd like to quote Einstein, which as a fellow Scientist seems a logical place to start:

"Logic will get you from A to Z; imagination will get you everywhere."

"If you can't explain it to a six year old, you don't understand it yourself."

"Education is what remains after one has forgotten what one has learned in school."

These **three quotes** succinctly summarise my philosophy to research and projects, which is:

1. Students should understand the *concepts* which provide educational capital and societal gain, not the information to simply pass an exam.
2. Know your ability, start simple and (hopefully) inspire future scientists with *relevant* new techniques.
3. You'll provide yourself with the tools for self directed, research lead learning and not the answers. The seeds, the spades and the soil but not the spinach.

Which can be further summarised into **three words** central in human evolutionary biology; Performance (try a project idea), Feedback (review literature, ask tutors, is your work viable?), Revision (refine idea) and repeat process.

This may seem a bit extreme but I passionately believe that students undergo this biological process in a University setting, they can't help it, they are hard wired through evolution, and if we better understand these three concepts you'll potentially perform better during your project.

Since your project will take a substantial amount of time choosing a project that inspires and interests you is vital for success. Constantly revisit performance, feedback revision during the entire project process starting with the pre-planning stage, choosing a project.

2.1 When to chose your project

Each institution is different regarding when and how projects are allocated. Some are allocated in your final year, some during your penultimate year. Regardless of when your institution formally allocates project you should be thinking about your project from year one.

Year	Action
1	Whilst taking general lecture notes, make additional notes about the **topic** areas which really interest you, thinking if you'd like to do some independent work on this area.
2	• Start to collate research review papers from journals on the topics which interest you, this will save time in year three as these will form the basis of your introduction. • Read the articles published by the staff in your department, this will give insight into areas of research expertise. These are often very different to the subjects formally taught in lectures! Talk to the staff about their work. • Visit grant funding websites like the Medical Research Council and look at the latest challenges and key areas • Finally, think of a problem which solving.
3	

Table 3: Planning for your project, based on a three year undergraduate degree.

2.2 Hopes

There is no doubt (hopefully) that your initial idea will be "blue sky" this means without limits and is the ultimate goal for researchers. So you already deserve full credit if your project is "to cure cancer" as this shows a variety of positive personality attributes. However, if you start the literature base you'll find that the reality of "to cure cancer" is manifest in numerous "jigsaw pieces" of work with titles like "uracil misincorporation in DNA is increased in smokers" which together progress the field of knowledge to the ultimate goal "to cure cancer". It is inevitable that your hopes will be tempered somewhat by the expectations and reality of the institute you are studying at.

2.3 Expectations

Your expectations may be different from those of the institution. The main reasons for this are twofold, logistical and theoretical.

Logistically the project has a defined time frame, usually a few months, and it will certainly have a financial limit. The laboratory will have a set equipment list; think about what equipment you'll need. A good tip is to download any instructions or method files from the manufacturers of chemicals or kits you plan to use. Ask your tutors about these, or they could be cited in the literature you have collated in your review papers. Again, this is not wasted work as they will help you to write the materials and methods section of the thesis.

The theoretical challenge that you set yourself may be very worthwhile, but remember that your project is part of a wider and much deeper set of research projects (see chapter 1). Try to make your work achievable with specific aims, whilst keeping the nucleus of a (great, world changing) idea for you to address in larger projects

2.3.1 Refining your project

Figure 2.1 shows an example route taking into the account points discussed thus far. The time frame of the pathway will vary between institutes but the refining in this manner should allow for a well planned project. You may want to buy a hard backed note book or create a blog site to input these entries and thoughts over time. Some institutes offer assessment credits for this type of pre-planning thought.

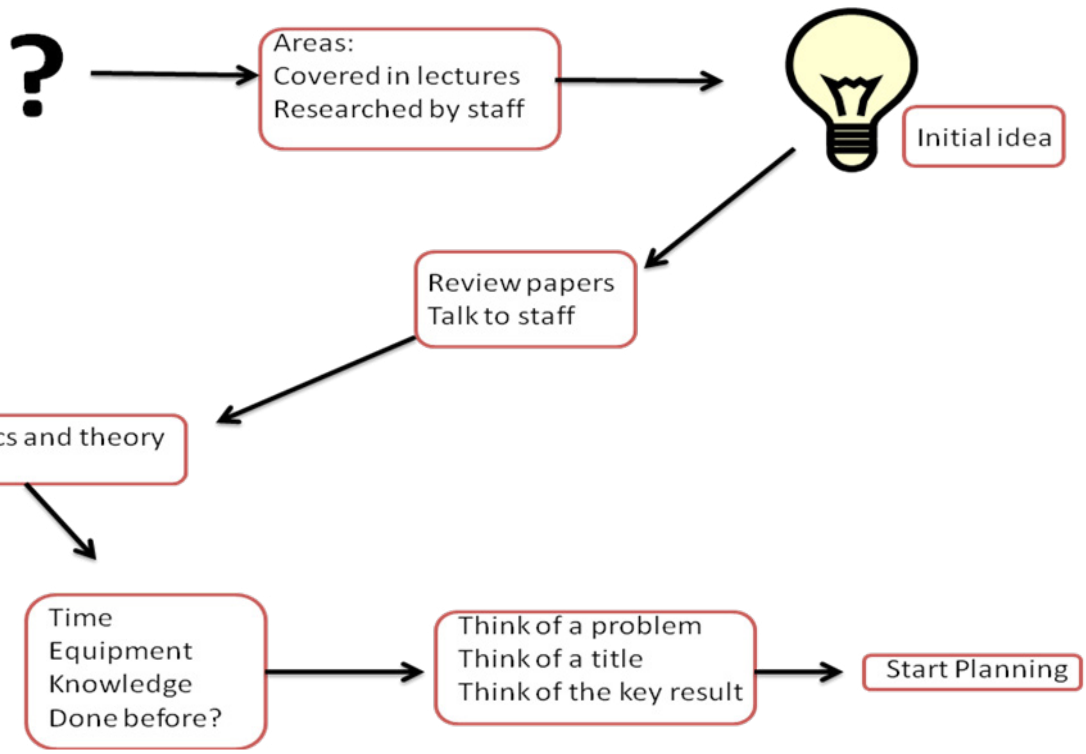

Figure 2.1: A flow diagram to showing an example of how to refine your ideas from initial thoughts to planning for the experiment with a final idea and working hypothesis.

2.4 Summary

After reading this chapter you should have the nucleus of a research idea, take ownership of it and nurture it. Planning ***what*** project to do can be as important as how you do perform in the project assessment itself.

So, now you have picked your project you'll need to successfully design and plan experiments, analyse the data and write a thesis and disseminate your findings.

3 Planning your project

It may sound obvious but planning your project will produce better results. Take the time to think about your work and most importantly own it, it is ***your*** project.

3.1 Time management

Good time management is always a good idea in all applications and there are many excellent resources and software available. However, when undertaking a project with an end point which seems a long time away, it is best to break the project down into smaller "milestones" which you should agree with your supervisor. Other good techniques include:

- Use e-mail to communicate with your supervisor who will be very busy. Please do remember though to write a clear and concise comment in the subject field and include as much information and if possible a specific question. You can even use e-mail to corral the more elusive supervisors!
- Have clear objectives for each activity, whether this is reading a research paper and making notes, or undertaking a piece of practialwork.
- Use online storage resources, they are an excellent free, and most importantly reliable alternative to USB storage pens, CDs etcetera.
- Write a blog, to plan and self reflect. Complete these or your laboratory note book "live" or in other words don't do this retrospectively.
- Don't be tempted to use a large and complex "project management" software you could spend more time learning how to use it and keeping it updated than time spent on the project! They are almost certainly superfluous for undergraduate projects; a simple Gantt chart using a word processor table option could be an alternative if you rely on steps for completion (see Table 4).

	Week							
Task	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	X		X		X		X	
2		X		X		X		X
3		X	X	X	X			
4						X	X	
5								X

Table 4: An example of a simple Gantt style chart. The tasks are listed in rows with the weeks in columns. In this example task 1 repeats fortnightly, task 2 is dependent on task 1 completing, task 4 follows task 3, whilst task 5 can only be done in week 8.

Reflect on how you manage your time, make a list of improvements and then try them for a fortnight.

3.2 Student supervisor responsibility

The undergraduate project is probably the first time you will have encountered a student supervisor relationship. In the traditional lecturer and student model the transfer of information is from the former to the latter. However, in the project, partly due to you owning and doing the work some new and novel (hopefully) information is transferred to your supervisor and the field of knowledge is progressed by your work.

Some institutes will have a contract between student and supervisor which details the roles of each party. Even without one the basic principles should be considered to ensure a smooth project.

The ***supervisor*** will almost certainly have time allocated to them by the department for the supervision of projects, so do not be afraid to ask for meeting. To make the meetings as productive as possible have one or two clear questions for discussion, and inform the supervisor in advance. Ask yourself do I really need a meeting, could I used e-mail or ask my supervisor to read my blog or watch a video clip of work instead, this could often be more productive. If you do decide to use e-mail clearly write in scientific English and attach the relevant data, too much information which can be ignored is better than mystery one line messages. The ***supervisor*** will have some research experience and be able to give advice on logistics and theory as discussed in chapter 2. They will also advise on safety and ethics with which the student agrees to follow.

The ***student*** should raise problems quickly with the supervisor and document this. If over time you feel that your supervisor is ineffectual then you'll have some evidence to take to the module lead or department head to affect a change in supervisor or to provide evidence for your assessment mark review. However, please be aware that this is two sided and most institutes view the student's main role as initiator, so poor student engagement will probably result in a poor project.

3.3 Research personnel

In addition to other students and your supervisor there may be other personnel in the laboratory with you. The principal investigator or PI is a person who has funding to undertake a specific project, these are often heads of department and are worth talking to informally about your work as they often have other funding opportunities like PhDs ongoing. Remember, courtesy to your supervisor and reserve methodological discussions for their discretion. It is important to learn who the safety manager, lab manager and technical teams are as they can help enormously.

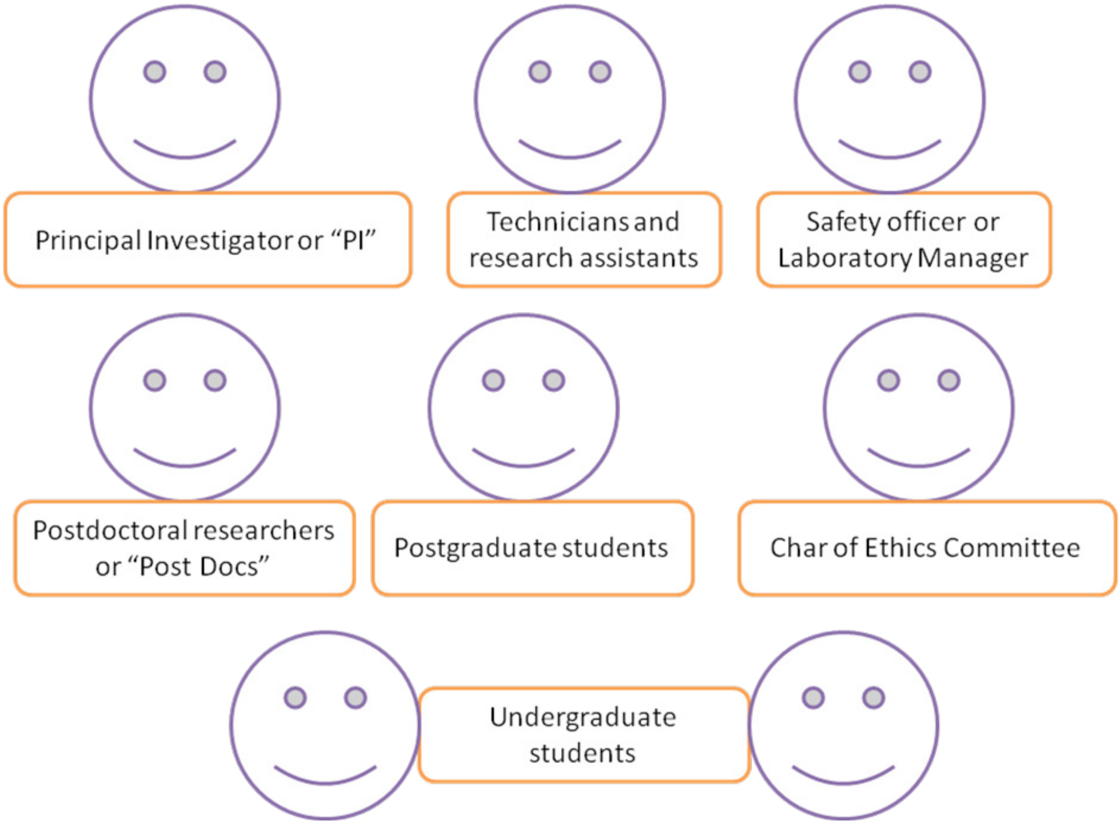

Figure 3.1: Research personnel which an undergraduate student may encounter during their project.

3.4 Etiquette and survival tips

During your project engagement in the key and enjoyment and success should follow. To you, your project could the most important thing in your academic career or something to worry about in the fortnight of the year, either way to get the best results from the people around you plan in advance to avoid last minute crisis and fire fighting.

In the first session in the lab or in the field: introduce yourself to anyone present; set up your area and familiarise yourself with the surroundings and systems for ordering, cleaning etcetera; if possible do a small simple experiment to break your fear of the unknown; write down any helpful advice to avoid asking again and again. Ask if there is lab or field tour to meet the team and look around.

The first time in the lab or on the field is also when first impressions are made so try not to: do anything dangerous; play computer games or other time wasting activities like using the area as a social club; be over demanding and finally it is vital not to upset the lab or field manager!

3.4.1 Supervisor meetings (journal clubs)

The meeting with your supervisor is key to a successful project, but as discussed try to be imaginative about whether you need a formal "in office" meeting. In a formal meeting provide an agenda of items to be discussed, this facilities the meetings, allows you to collate the relevant materials and indeed may induce not having a meeting at all. Take notes during the meeting if you wish (you may want to podcast them with your supervisors consent) but before you leave agree on action points of what will be done by whom and when, you may want to refer to your project plan or Gantt chart.

Journal clubs, usually informal, are when results from relevant paper are discussed in a group, these may be a great way to meet a busy supervisor, gain the knowledge of other people and gain relevant papers.

3.4.2 Notebook or blog

The notebook or blog is a key for recording exactly what you did in a chronological order. This is done for two key reasons, to prove you did the work and when, and so that the work can be repeated by you and others. Your institute should have clear guidance on how to complete a notebook or blog of work as these are often assessed. These should never be compiled after the event as you will forget information or lose the piece of toilet paper you wrote your great idea upon. A good tip to keep an updated record is to use them in your supervisor meetings as a notebook. Increasing technology allows for electronic storage of this information on free storage sites and increasing institutes are less understanding of "lost" notebooks.

3.4.3 Hours and requesting equipment

Your institute may have allocated specific hours in the laboratory or field for undergraduate projects. Plan how long the work will take ***before*** starting work, as invariably as you turn over the instructions page it will read "incubate for 3 hours" and it will be 5pm and you'll have to abandon the work. Plan to arrive early with your day planned ahead, making space for breaks and lunch.

If you will need equipment check what in advance how much notice is required, don't be surprised that you cannot do any work because the equipment you suddenly need is being used elsewhere.

3.4.4 Dress code

Most institutes will require a similar dress code to that as worn in timetabled practical sessions; the only difference in a project setting is that there may not be a staff member present to tell you what to wear. Check what safety equipment is required to be worn and what the dress code is.

3.5 Staying alive and not being sent to prison (safety and ethics)

It is very, very unlikely that you'll either die (dangerous working) or be sent to prison (ethical malpractice) as there are strict procedures in place to avoid these serious outcomes. However, before starting any work check with your supervisor about what safety forms you need to read and sign.

> Ask your supervisor to see the risk assessment and Control of Substances Hazardous to Health Regulations (1988), COSHH form and Risk Assessments before starting work.

The law expects you, as an adult, to take all reasonable precautions to ensure your personal safety; however, as an individual whose training has not yet been completed a certain amount of responsibility for your safety rests with the staff. It is essential that you discuss with your supervisor and, if necessary, with the technical staff, your experimental plans to highlight potential hazards and to devise ways of overcoming them. Under no circumstances should students to undertake unsupervised experiments without appropriate training.

You and your supervisor must discuss whether your work requires ethical approval; your supervisor will advise you (figure 3.2)

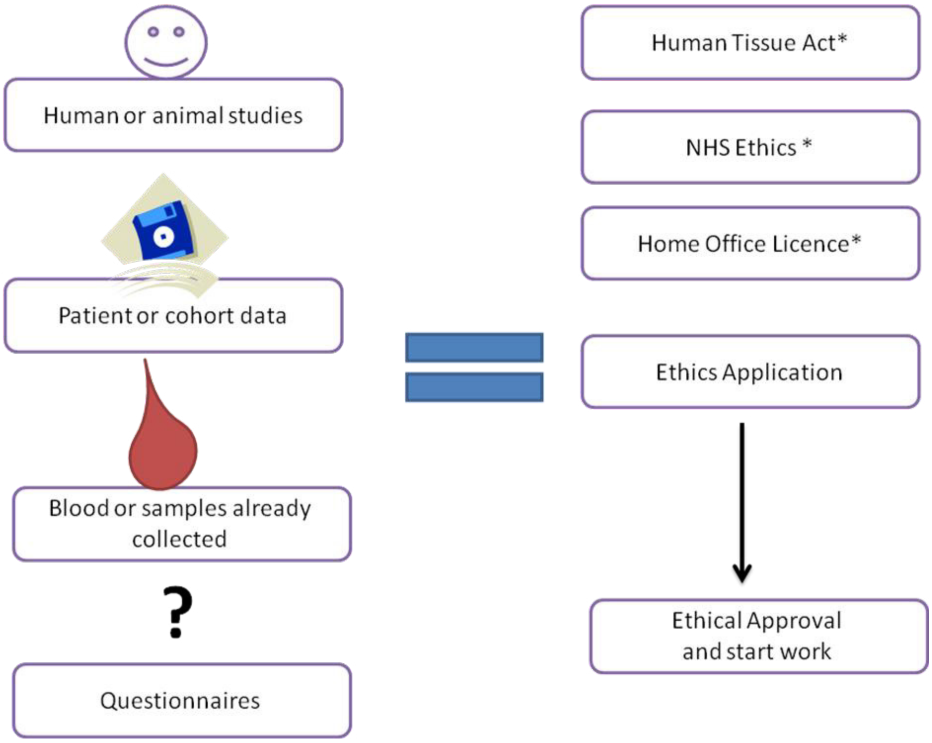

Figure 3.2: Typical flow chart for considering ethical approval. If your project involves any activities listed on the left of the equals then you'll need to consider gaining ethical approval before commencing any work. On the top right are some additional considerations to be made (* or your country's equivalent) before gaining approval. Your supervisor will advise on these.

3.6 The library and other planning resources

Your library will almost certainly contain more than just books; they are increasingly a resource for writing and learning skills.

There are numerous excellent online resources which can assist your project, ask your supervisor, fellow students and use search engines to find out more.

3.7 Plagiarism and academic offences

It is strongly advised to read the regulations about plagiarism and academic offences at your institute. If you are unsure about referencing in your project you should speak to your supervisor and the library staff. It is very tempting when writing the thesis to copy and paste sections from (online) resources, but most institutes will use plagiarism detection software and if found guilty the consequences of failing such a large final year component could be catastrophic. To avoid the temptation of cut and paste, start to write the thesis as soon as you start work, and if you really have left it until the last minute then a mark of 50% for a part effort is still preferable to zero marks and serious consequences of submitting even partly plagiarised work.

3.8 Summary

Planning what to do at the start, middle and end is crucial for a successful project. The key is not to waste any work or processes, it may have taken two months to get ethical approval, but this is a valuable commodity to then place on your CV that you have "completed an ethics process". Table 5 summarises the points thus far.

Journey	Points to ponder and discuss with your supervisor
Start	• Discuss a title, equipment needs, ethics approval. • Advice and guidance on ways of organising your time, on finding the right types of information and even on reading and how to take notes • To "plan the dissertation methodically" be kept "on the right track". • Agree supervision communication and recording methods • Supervisors should be aware of the students' initial perception of the enormity of the dissertation task and tailor their support accordingly.
Middle	• Given help on how to "breakdown the project into achievable tasks" and to "plan the workload". • Some students had gained this advice from their supervisor whilst others had obtained this from the Library or their faculty's academic guidance centre. How to use your time "efficiently" to meet the demands of the assessment • Set up regular meetings with your supervisor to help keep you on task. Most students are aware of the significant amount of work that the dissertation would entail and wanted guidance that would help them "make the most of 'free time'" and enable them to also be able to "concentrate on other module assignments". • They had all been expected to produce a timetable of work for the whole project or had been helped to produce a Gantt chart. Some students had used a weekly journal to "guide and plan tutorial sessions".
End	• Towards the end of their project the students should be enthusiastic about the levels of support and supervision they had received from their tutors. • How to write the thesis and what type of feedback will be given.

Table 5: Summary of project planning framework which may help in constructing the agenda for supervisor meetings.

4 Critiquing existing research

The ability to critique your own research and that done by others is a key skill. It is vital that you understand you are asking questions of the RESEARCH and NOT the paper style. If done well it can help you plan your own experiments and help in writing the thesis.

4.1 Choosing a paper to review

Your supervisor will help you choose, but use you should register with the relevant manuscript database for your area, for example NCBI Medline and enter some keywords to find the key papers. Your aim should be to assess the quality of the work and the validity of the conclusions. You are allowed, even encouraged, to disagree with the authors if you can justify your point of view.

Reviewing papers of the project subject could be a good place to start, or why not critique a paper written by your supervisor?

4.2 Writing the critique

Your supervisor will help you write the critique which may be in the form of a written paper report; highlighted and annotated notes on the research paper itself; a blog discussion or journal club; or to write an alternate abstract after reading the paper (table 6).

Why you have chosen this paper/how does it impact upon your project?	Does it refer to relevant, recent literature?
Very brief outline of what the paper is about (three or four sentences)	Are the error bars/standard errors shown? How wide are they?
Did they use the most appropriate methods?	Are the controls shown? Are they convincing?
How were the methods validated?	What conclusions do the authors draw?
What controls did they run?	Do you agree with them?
How many times was each experiment repeated	What journal is published in? A cure for cancer is unlikely to be in an obscure journal
Results are they convincing?	**What ideas can you expand upon or make use of in your own work?**

Table 6: Example parameters to discuss and explore when critiquing the work of others

4.3 Critiquing a research grant

You may be asked to either critique or write a research grant. Most research is funded externally and the selection process is very competitive. Reviewers will assess and critique grant applications for suitability. You should critique the grant objectively and decide whether you would fund it. Your critique should include **discussion** – you must explain your answers using sentences, read around the subject, investigate the researchers on Medline, suggest additional ideas etc.

It can be a powerful tool to narrow your literature searches because they often contain good review material. If you are not formally asked to do this assessment then ask to see one from your supervisor, or you can get examples from most Research Funder's website. Write a short report and try to answer as many of the following as possible:

- Do the researchers have the relevant expertise? If so why? If not why?
- Who else is known in this area? Are there claims correct?
- Is it unique work, do a literature search on the area?
- How could the study be approved, did it need ethics?
- Any ideas to improve the study, have they thought of everything?
- Is it value for money? Think about how much your project will cost in comparison.
- What problems could you see, any bottlenecks? Think about any hold ups you may face in yours.
- Finally, would you fund this and why?

5 Experimental design

The ability to design your experiments before your start is one of the key attributes to a successful project.

A powerful technique is to draw one or two key graphs which you would like to see as your final outcome. These are an ideal world scenario to accept or reject your hypothesis. On the X-axis are the variables which you have changed or manipulated and on the Y-axis are the observation as a result.

Figure 5.1 is an ideal theoretical graph. Ask yourself what data will I need to construct the X-axis, how many people will be in each category, will they be the same age, etc., for the Y-axis how many times should I measure the observations etc.

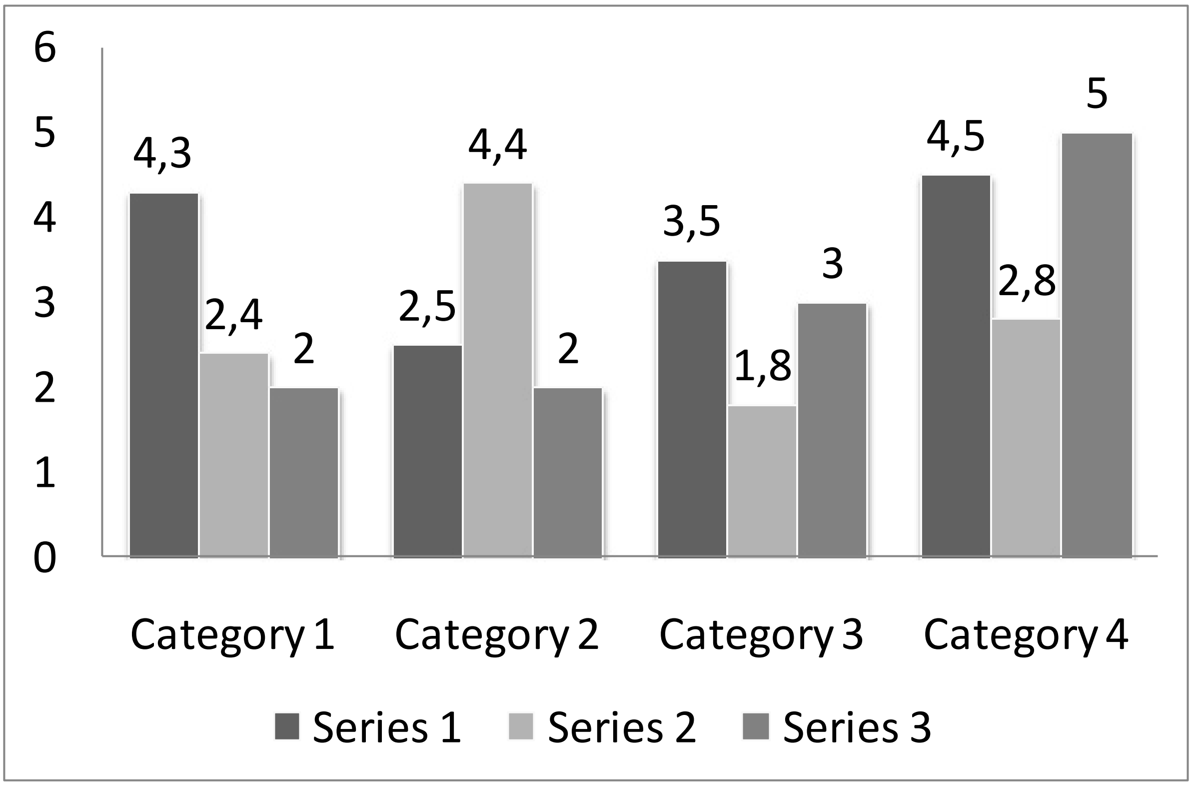

Figure 5.1: An example of a theoretical graph drawn *before* work has become to assist in the planning of the experiments by asking what data will I need to be able to draw this graph at the end?

5.1 Planning the experiment

Now you have defined the question with a specific (achievable) hypothesis and you have thought about "ideal" graph and data that is required, it is now the time to plan your experiments. Your supervisor will advise you on how to design your work but background knowledge will expedite the process.

Experimentation usually comprises of the following components, variables, controls, replicates and statistics. Variables are things like time, age and temperature, think about what variables are important for your field by reflecting on the review papers and your critique of the area. Replicates are how many times you repeat a measure, once, twice? See what other people have done in similar published work. Finally, consider what statistical test you may wish to employ, a power calculation will tell you how many people or measures you'll need to make your results statistically significant. The general rule is the more people the more significant and accurate your data will be, although these will need to be tempered by the logistics discussed in chapter 2. If you have only managed recruit 4 people onto a study and you needed 400 from the power calculation, where you ever going to get that many people in the time? Probably not, with careful discussion in the theses, without making exaggerated claims, show that you know about the power calculations and discuss improvements and limitations of your work. Don't forget your CV, remember, you've just recruited 4 people to a research study!

List the variables, replicates and statistics needed to achieve your ideal graph.

5.2 Controls

A control is basically to address the question of "what would have happened if you had not done anything" or "does the liquid you dissolved ingredient X in also have the same affects without X in?" They provide stability to your findings and you should explore all the control variables with your supervisor. (Table 7)

Control	**What is means**
Experimental	These are also called primary controls and demonstrate the experimental process has worked. Example: A known chemical dye which moves 3cm in the gel matrix Another example is a "spike" where you can place a known amount of the chemical you are interested into the sample at the beginning of the process to check that the experiment itself does not change the chemical. This is often seen in extraction studies.
Treatment	These are separated elements of an experiment. Example: Does lemon and lime juice prevent cancer? Treat with both, but also test with just lime juice and just lemon juice.
Positive	This is usually an experimental control to check that something positive always happens. This tests the positive response of your experiment. Example: When I place a tent pole inside my tent it raises. If it did not rise when I used my tent pole then I would be unable to test whether a stick has the same effect as a tent pole because the system is not performing with a known variable.
Negative	This is usually an experimental control to check that something negative or no response always happens. This tests the negative or background response of your experiment. Example: When I take a tent pole from the centre of my tent, it falls. If it did not fall when removed then I would be unable to test anything because the system is not performing with a known variable
Time	This will inform if things change over time (or you may choose temperature etc). Example: Take a sample of pond water every 5 minutes for 24 hours. You may only need to do this experiment once to determine the optimum time for collection, which all subsequent experiments will be fixed at.
Zero	What happens at the baseline or the start or the experiment?
Random	Ensure that your data is randomly collected for example if comparing male and female do you have equal numbers, or are the men older, the women all smokers etc?
Observer	Of more importance in non-laboratory based projects, this looks at the affect the questioner. Example: A volunteer may give different data to a researcher in a suit from a government health agency as they wish to impress or please them.
Follow up	What happens if you repeat the experiment a week later or year later? In non-laboratory based intervention projects this could be seeing people are still drinking the lemon and lime juice six months later.
Exclusions	Samples, chemicals or people you may want to exclude from your project. These fall into two groups, before and after. Example: In the former you may wish to exclude pregnant women from taking part in your rollercoaster study. In the latter you get a strange result from a blood sample which is making your data non significant, but the sample used is bright green, if documented you may be able to exclude this data from your results.

Table 7: Common controls used in undergraduate projects

What controls would be relevant to your experiments?

5.3 Performance, feedback, revision

Plan the timings and equipment needs as discussed thus far and have quick dry run through in your head. Make notes in your notebook or blog as you do the work and make questions and comments about what worked and what did not. Periodical show your supervisor draft results to confirm that the right path is being followed. At each repetition of this process your research skills should improve.

5.4 Summary

Research can be like a rollercoaster ride with peaks and troughs, the peaks can be exhilarating but short lived whilst the troughs can seem long and arduous. Yet, in the same way you would not go on a rollercoaster after a heavy meal, if you were ill or wearing a giant onion costume, so too can you plan your experiments for the best outcomes.

The key concept is to plan from accepting or rejecting the hypothesis and working backwards determining what data I need to collect.

Further reading to broaden knowledge could be directed towards research methods, meta-analysis and the classics of research such as Mentor, a Greek god entrusted with the care and stewardship of Odysseus's son, hence the use of the word mentor.

6 The scientific poster presentation

You have planned your work, done the experiments and analysed the data. You now need to tell people about your work and this is usually done in one of three ways, poster, oral or thesis. The poster (Figure 6.1) is an overview summary of the journey from start to end, similarly the oral session is a summary presentation usually done using a slide software like PowerPoint. Whilst the thesis is a considerable more detailed piece of work detailing all aspects of the projects. Presenting and defending your work at a conference is a key skill. Some institutes will ask students to present a 10 minute (5 minutes for questions) presentation on their project and be prepared to answer questions from an appointed panel of staff and students. The oral presentation will often be in the form of a conference style poster presentation with the student explaining, defending and feilding questions whilst standing next to their poster. You should spend the time guiding people around your poster in a logical manner starting with the introduction. The audience looking your poster could consist of other students, programme and Faculty staff who have been invited and are there because they are interested to hear what you have to say. External examiners and visitors may also be invited to this session.

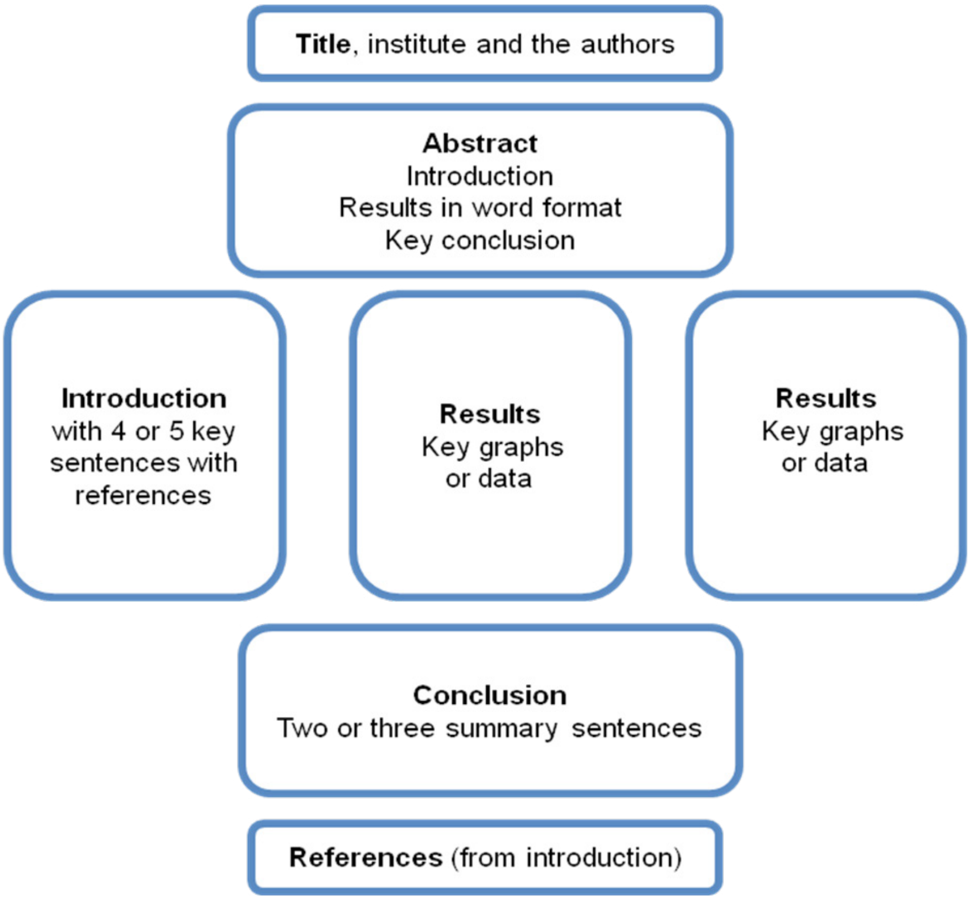

Figure 6.1: A typical poster layout.

To create the poster (Figure 6.1) your institute may have a template and you will get help from your supervisor, however the key sections are now discussed. Start with the title, your institute and any authors (some supervisors like to be mentioned here). In the introduction write a few sentences which summarise the key papers you have read on the work and reference each entry in the reference section. If you are referencing your supervisor's work, make sure it is accurately summarised! In the results section place your key findings, one or two key, accurate and well drawn graphs will help you to describe the work easier that a clutter of numerous tiny graphs. For the conclusion one or two summary statements, with a sentence about how the work could be improved will assist you and the reader to convey your ideas and findings.

Advice for the presentation:

- Keep it simple.
- Use your poster as a cue, start and the title and work around the poster to the conclusion.
- Practice this before the session.
- Introduce the topic carefully; although all the audience members are professional scientists they may not be familiar with your particular topic.
- Explain your method briefly.
- Show your data. The audience really do want to see it (even if you don't think it's very good).
- Talk about your conclusions and suggest further work which could be done in the area.

In the question period:

- Don't be shy. Tell the panel what you really think.
- Often questions are asked because the panel are interested to find out the answer, there should not be any trick questions.
- Don't forget that other than (maybe) your supervisor you will know more about your work than anyone else in the room! So, be confident in you and your work.
- It is OK to say I don't know to a question that you really don't know the answer to; you could ask the enquirer to rephrase the question if you did not understand.

7 The scientific oral presentation

You may be asked to present you work as an oral presentation (Figure 7.1). In chapter 6 we discussed how to construct a scientific poster, the oral presentation is very similar. It is an effective way of telling people what you found and is a key research skill to develop.

7.1 Constructing the presentation

Before jumping on the PC to start with your slides imagine that you are stopped in the street by a live news crew. The presenter asks you to discuss your work for 30 seconds before they move to the next item. Visualise what you need to say, what is are key messages? You'll need to explain the problem, the background, what you did and what you found. It is important to get the balance right and keep it fun and interesting. Write down each of these key messages and they will form the nucleus of your slides (Figure 7.1).

Tips for a putting a good presentation together:

- The 7 / 7 Rule (Figure 7.2): This says that you should have about 7 words in each row and a maximum of 7 rows. This also aides in the selection of an appropriate font size
- Slide design: Consider that some people in the audience may be colour blind so try avoid red and blue designs. There can be some truly garish, complex templates and backgrounds, your work is the star attraction so don't be tempted to get fancy, keep it clean, eloquent and easy to read. Have a look at the venue, if it is large then try to keep you graphs and figures as large as possible for people at the back.
- One minute per slide is a best guide of how long it should take to read through it, or spend on, especially if you use the 7/7 rule.
- Practice using the timer facility in your slide show software
- Use the slides as cues and try not to read from hand written notes. You did the work and know the work so don't be shy. It is very difficult in a stressful setting to read from paper, slides, and talk and operate the PC and pointer all at the same time!
- Ask a friend to video you (most mobile phones now have video cameras) to watch for anything repetitive like saying "yeah", or "you know what i mean" at the end of each sentence.

Figure 7.1: A typical template for a ten minute oral presentation.

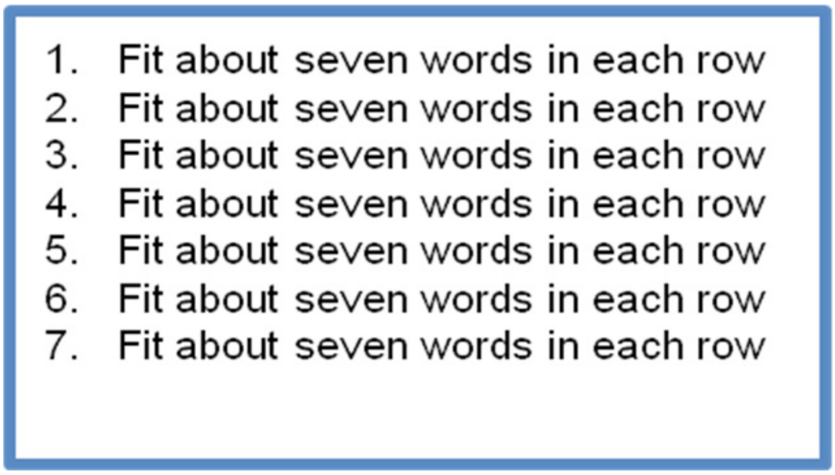

Figure 7.2: An example of the 7/7 rule

7.2 Navigating the session

On the day you are bound to be nervous, but as with most things if you have prepared then the oral session should a fun experience of telling people what you have done. Be yourself and allow your personality to come across, otherwise it will just be a stuffy reading session.

Advice for the actual presentation:

- Keep it simple.
- Use your slides as a cue, start and the title and work through the talk to the conclusion.
- Practice this before the session.
- Introduce the topic carefully; although all the audience members are professional scientists they may not be familiar with your particular topic.
- Explain your method briefly.
- Show your data. The audience really do want to see it (even if you don't think it's very good).
- Talk about your conclusions and suggest further work which could be done in the area.

In the question period:

- Don't be shy. Tell the panel what you really think.
- Often questions are asked because the panel are interested to find out the answer, they should not be any trick questions.
- Don't forget that other than (maybe) your supervisor you will know more about your work than anyone else in the room! So, be confident in you and your work.
- It is OK to say I don't know to a question that you really don't know the answer to; you could ask the enquirer to rephrase the question if you did not understand.

7.3 Viva Voce

You may also be asked to complete a viva voce, which means live voice, and is a more assessment of your work than the oral presentation with slides. It is usually only done for MSc projects and above due to the complex nature and in depth subject analysis. It is typically based on your thesis and not on a slide show, with the panel asking you specific questions about your work.

Tips for the viva voce:

- Keep your thesis to a minimum, especially in the introduction, less material means less to question.
- Tabulate your thesis with post it notes that stick out the side with "introduction", "key graph" etc. written on them, allowing you to quickly navigate around the thesis.
- Unfair questions from the team may be political and internal and not your fault. If you feel a question is unfair ask for it to be re-phrased, or look to your supervisor for help. A good defence is to ask for the viva voce to be recorded, that way you have a record of proceedings.

7.4 Summary

Well done! You have successfully disseminated your research ideas, in chapter 9 we'll discuss how you can use these events to enhance your CV. Consider keeping a blog for reflective learning and discuss how you could have improved the session, this powerful tool will grow with you over time.

8 The thesis and scientific writing

A thesis is the key way to disseminate your work in detail and to convey your depth and understanding of the project. If you have written scientific report before, then you will recognise the components of a thesis, they just have more depth and detail. They usually include Abstract; Introduction; Materials and Methods; Results; Conclusions; Further work and References used.

8.1 Preparation

If you start to construct your thesis as a working document which grows along with your project then it will be an onerous task to be completed at the end. Table 8 shows how once you complete a task in the progression of the project then you can add that information into your thesis; this avoids last minute of the entire work. Hopefully you can see how keeping a good notebook or blog and reading the background can really help when putting the thesis together.

Start of project – **Experimental planning**	**Put in this part of thesis**
Collate review and specific papers to see what other people have done	Introduction References
Read other people's materials and methods	Materials and methods
Plan your own materials and methods	Materials and methods
Middle of project – **Execute your experiments**	
Note any change made to existing methods	Materials and methods
Creation of new methods and protocols	Materials and methods
Do your standards and controls work before continuing work	Results
Initial results are produced	Results
Mistakes or improvements to the experiments which could have been made if more time	Conclusion
End of project – **Final results analysis**	
Analyse results	Results
Compare these with other results	Conclusion

Table 8: An example template of how the thesis can be constructed throughout the project in stages.

Do as much background reading as you can before you start; your critiques and literature review should help with this. Table 8 shows an example template starting at the beginning and writing until they get to the end; you may choose to write the materials and methods, or the results sections first, but be careful to do this as procrastination strategy which could lead to deadline problems.

8.2 The thesis sections in more detail

The thesis usually consists of several components; your institute may have a template and guidance on font size and word count.

It may be helpful to think of your thesis as a recipe book (example boxes).

8.2.1 Title

The title should adequately describe your work. Try to make it interesting, whilst still scientific, using as few words as possible. Consider using a colon if your want to use two sentences.

Example use of colon in the title would be "Fruit and vegetables intake: An investigation using dietary analysis."

Recipe book analogy: the title would be "Italian cakes made simple"

8.2.2 Dedication

You may wish to thank friends or family or anyone (or being) that you feel has supported and helped you.

8.2.3 Acknowledgements

You may wish to acknowledge the help of your supervisor or other staff in the institute.

8.2.4 Authorship

Your institute may wish you to state that the work was yours.

8.2.5 Abstract

The abstract is the short description of the work, usually not more than one page, it will be a mini version of the thesis components. It will include introduction, results and conclusions, in one easy to read summary. Depending on the timing of the oral session or poster you may want to write the abstract first to help you distil key ideas.

8.2.6 Contents

A contents page will allow you and the reader to find information quickly. You may wish to list tables and figures in the contents section, often the reader would like to read a figure or chart independently of reading the thesis from cover to cover.

8.2.7 Introduction

The introduction is the place to say what other people have done and why. Start by discussing your problem or hypothesis and place this in context. Remember that you'll refer back to the key papers in the conclusion to compare and contrast you results with those of other researchers. It should make reference to major publications relevant to the field, some description of previous findings and any hypotheses derived from them. All statements of fact made in the introduction should be supported by references from the literature.

For the recipe book analogy the introduction would include a section of Italy itself, then discuss cakes, and why Italian cakes justify a recipe book and why they taste delicious. There may a description of the type of cake.

8.2.8 Materials and methods

This section is strictly an "instruction manual" of how to repeat your work. Therefore, do not include any comments about the study you took the methods from; they will belong on the introduction.

Part	Contents
1	Describe all the materials used; it is a good practice to identify the suppliers of all chemicals, consumables and equipment used. In a study using animals or humans you would list how many were recruited, from where, mean age etc,
2	Describe the experimental protocol, or what you did so that another person could repeat your work. What equipment did you use, what where the settings, any information that you feel would be helpful. Look at other published work and see how this section is written in your field. Take photographs of the machines and chemicals and add them if you think they will add colour and context to your work.
3	You will need to explain what statistical tests you have chosen to do and why. You may cite a power calculation or say p value you have chosen as significant.

Table 9: An example template of the contents of the materials and methods section.

Some people find it helpful to think of this section as the recipe itself, so a list of ingredients followed by cooking instructions, followed by substitutions and amendments for vegans etc.

8.2.9 Results

This section should contain the results only, a common mistake is to make detailed discussions on the data, instead put those in the conclusion. Think about how you want to display your results, photographs, testimonies, narratives, graphs and tables can all be used. Raw data, if relevant and not already in the notebook should be placed in the appendices, transformed and analysed data should be placed in the results section. For each graph or piece of summary data clearly label it so you can refer to it in the text with a concise summary statement. If relevant also say whether the results in the graph are statistically significant. Some templates ask for symbol like * to be placed directly on the part of the graph which is significant. Refer to your papers used in the introduction to see how data is presented in peer reviewed work in your area. You can also ask you supervisor to look at a draft section of the results.

For the recipe book analogy the results section could just contain photographs of the cakes with a short description of the cake underneath.

8.2.10 Conclusion

The key role of this section is to compare and contrast with what you introduced at the start in the introduction. Do you agree with the consensus or your does you study disagree, you can then discuss. How would you improve the work if you could so it all again? What worked and what did not? One common mistake is to introduce new ideas, they belong in the introduction, so an example would be: Jon D found this (detailed in the introduction) and I agree (conclusion, a summary will suffice because you have already explained Jon D's work in the introduction)

For the recipe book analogy, this section would not be in the book. It is done by you after you have baked the cakes. It may look identical to the cake in the book, but does it taste as described, how could you improve it, more fruit, less sugar? It may look nothing like the cake in the book, but still taste wonderful, why is this? The final possibility is that it looks nothing like the picture and tastes horrid, the reason may be obvious or not but you will be able to discuss what remedial action you would take to improve the cake.

8.2.11 References

All the statements of fact and studies you cite should be listed in the references section. Your supervisor will tell you what form they should be in and your institute's library will be able to help you with this section.

8.2.12 Appendices

The raw data is often found in the appendices, along with ethics applications, volunteer information sheets; some even have the instructions from chemical kits and equipment. Do not put any personal information here such as consent forms or actual patient data; they should be kept in a secure site file.

8.2.13 Assessment Scheme

Check how your institute assess the thesis and ask for a marking scheme (Table 10). This can help you to allocate time effectively on each session.

Assessment section	% of total mark
Student's attitude to research work (attendance, organisation, commitment)	10
Layout, structure, English grammar, scientific prose, use of diagrams and flowcharts	5
Abstract	10
Introduction	20
Scope of references – these should be from peer reviewed journals, mostly recently published.	5
Materials and Methods	5
Results	15
Discussion	20
Referencing – correct referencing in the body text and in the references section	10

Table 10: An example marking scheme for the thesis, one from your institute could help to allocate time in writing the thesis. For example, in this one, twice as many marks are given for correct referencing than for the materials and methods.

In this example, where do you think the following texts should be placed in the thesis.

Text	Placed where?
Chemical #42 was bought from Buffalo NY	?
John D found that	?
John D found that, but the results found this project did not agree	?
Was heated for ten minutes	?
Due to time limitations the bacteria were incubated for 10 minutes, instead of the optimum of 20 minutes as determined by experiment 2a	?
Figure 1a: A response element and cancer induction? Figure 4c: Response to bacteria when exposed to chemical	?
The results from this study suggest that bacteria incubated for 10 minutes are resistant to chemical #42	?

8.3 Summary

Probably the largest piece of assessment you will complete, your undergraduate thesis can be joy to write if done as your project progresses and an arduous task if done at the last minute. Take care to use a suitable level of scientific language as the audience will be scientific, so be objective and formal, writing in third (impersonal) person, past tense. For example "25 litres of milk was used" or "patients were recruited to the trial" or "Jon D found that".

9 Summary

We have discussed some key concepts in this textbook. Each section provides an introduction to the key areas with example boxes and cues for further reading. The following strategy could aid learners further:

1) Read the book
2) Complete the example boxes and seek advice from your tutor or other more in-depth textbooks for the answers
3) The headings for the further reading should allow specific additional information to be gained. Use reputable sources such as recommended text books and validated internet resources. The idea with further reading is to build your knowledge in layers, only adding a layer once you have tested your knowledge at that level. A key understanding of the basics is fundamental allows for more engaged and complex thought.
4) Put your knowledge into action, write a reflective blog, and make drafts for your supervisor.
5) Use the undergraduate project as a taste for a research career.

Make a list of the skills you have gained during the project, from literature searches, to practical skills, to writing and speaking skills and make the most of these in CVs and applications. The ability to undertake high quality independent scientific research is a sought after commodity.

As the text is introductory, it is not possible to cover all aspects of scientific research; however the following could be subject to further reading:

- Meta-analysis studies
- Advanced statistics
- Randomisation techniques
- Placebo controlled trials
- Case, control studies
- Ethics, consent forms, governance, volunteer information sheets and posters
- Good laboratory practice

As the undergraduate project develops with changes to technology enhanced learning, automated scientific equipment and a more homogenous student population the understanding of the underlying concepts of research must remain sound to secure an innovative future.