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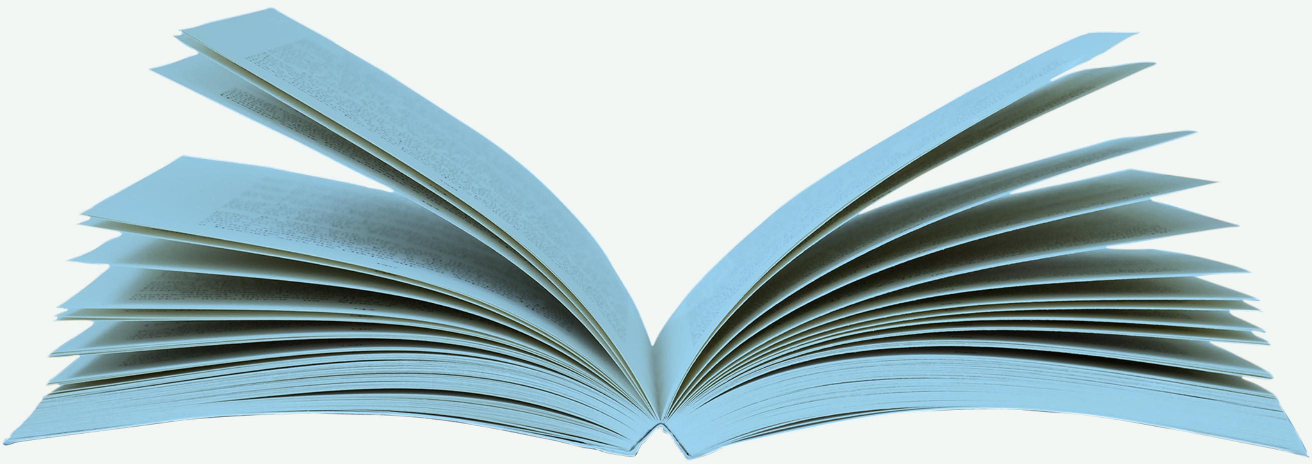
SCI S330
Scientific Research Methods
(Free Courseware)



香港公開大學
THE OPEN UNIVERSITY OF HONG KONG

Contents

Chapter 1 Fundamentals of scientific research

1.1 About this module

Welcome to this free courseware module 'Fundamentals of scientific research'!

This module is taken from the OUHK course *SCI S330 Scientific Research Methods (http://www.ouhk.edu.hk/wcsprd/Satellite?pagename=OUHK/tcGenericPage2010&lang=eng&TYPE=CI&CODE=S330)*, a five-credit, higher level course that is part of the the Bachelor of Science in Applied Science (Biology and Chemistry) degree programme offered by the School of Science and Technology (http://www.ouhk.edu.hk/wcsprd/Satellite?pagename=OUHK/tcSubWeb&l=C_ST&lid=191133000200&lang=eng) of the OUHK. This course introduces you to the basic principles of scientific research methods, and enhance and develop your ability to understand and perform independent scientific research.

SCI S330 is delivered via a blended approach to learners and comprises five study units. Each unit contains study content, activities, self-tests, assigned readings, etc for students' self-learning. This module (The materials for this module, taken from the print-based course SCI S330, have been specially adapted to make them more suitable for studying online, and multimedia elements have been added where appropriate. In addition to this topic on 'Fundamentals of scientific research', which is an extract from Unit 1 of the course, the original Unit 1 also includes the topic of 'Constructing hypotheses'.) retains most of these elements, so you can have a taste of what an OUHK course is like. Please note that no credits can be earned on completion of this module. If you would like to pursue it further, you are welcome to enrol in *SCI S330 Scientific Research Methods (http://www.ouhk.edu.hk/wcsprd/Satellite?pagename=OUHK/tcGenericPage2010&lang=eng&TYPE=CI&CODE=S330)*.

This module will take you about **six hours** to complete, including the time for completing the activities and self-tests (but not including the time for assigned readings). Owing to copyright issues, textbook and assigned readings are not included in the free courseware.

Good luck, and enjoy your study!

1.2 Introduction

Research plays a vital role in addressing questions. Through research we can develop results that can help to answer these questions. Scientists — as well as science students — must learn that conducting scientific research requires an understanding of the whole research process. This module focuses on the fundamentals and the beginning steps of the research process, including identifying research problems, asking research questions and formulating hypotheses. It will help you to understand what research is, and the many forms it can take.

This module is subdivided into four sections:

1. **The fundamentals** This section illustrates what science and research are, and explains each step of the research process. You'll also be introduced to the tools that researchers typically use to achieve their research goals.
2. **Identifying problems** This section discusses ways of setting up research projects; in particular, we'll focus on the skills you will need to identify research problems, as well as how to break down a research problem into subproblems.
3. **Asking questions** This section highlights the basic considerations and skills you need to ask research questions.

1.3 What are science and research?

When you look for the definition of science, you will find various results. You might conclude, however, that none of them is fully satisfactory. The following presentation will try to answer the basic questions 'What are science and research?'

The fundamentals (Part A)

Click this link to watch the video: http://www.opentextbooks.org.hk/system/files/resource/10/10643/10647/media/The%20fundamentals%20%28Part%20A%29.mp4

I think we all have all had the experience of getting sick. What do you do when you are sick? Sleep? Go to see a doctor? I think we all have different answers to this question.

And if you asked your friends or relatives the same question, they would probably give you different answers, too.

Some may suggest taking vitamin C because they believe it can help you become stronger to fight against diseases, or even prevent them. Some may suggest drinking Chinese herbal tea…this is a common practice for Chinese people. You may also be advised to do more exercise, or to get more rest. Of course there are still many other different methods you might try, but how do you decide what to do?

Most people follow the advice that makes the most sense to them, and if they find they still feel terrible, they try another method. In fact this kind of testing of ideas, and discarding ones that don't work, is a kind of 'everyday Science'.

But…even if you feel better after trying a new cold treatment, you can't know if your recovery occurred because the treatment was effective ,or because the cold was ending anyway! You can't prove it, can you?

How about scientists? How might they decide what treatment to try? How would they determine which advice is the best? Learning to understand scientific research is not always easy. Scientists have developed specialized steps, processes and language for planning, conducting and reporting their research.

And – you will know their answer by the end of this lecture!! Ok. Let's get started learning about scientific research.

Discussion of science and research is all around us. You may see the results of scientific research reported in local newspapers, and hear about recent findings from scientists through the Internet. You may even consider scientific findings when you decide which new mobile phone to buy!

We all know the word 'science', but it is difficult to define. When you look for the definition of 'science', you will find various results. You might conclude, however, that none of them is fully satisfactory. The word 'science' is a derivative of the Latin '*scientia*', which simply means 'knowledge'. But you can easily imagine a person with great knowledge who is *not* necessarily a scientist. Another way of defining 'science' is as a system of acquiring knowledge through scientific methods, and then organizing the body of knowledge gained through such research.

No matter what definition you choose, you should bear in mind that doing science does*not* mean memorizing what is already known about the world, but does mean discovering something new and previously unknown.

In general, scientific researchers start with simple questions. They then seek to gather data and conduct experiments to answer the questions they pose. Science is therefore not just a collection of facts, concepts, and ideas about nature, or even the systematic investigation of nature; even though these are common assumptions about science.

For example, when you think of science, you may think of formulas and facts to memorize. You probably studied DNA molecules in a biology class by memorizing the terms of the four nucleotides – that is, adenine, cytosine, guanine, and thymine. Or maybe you learned about velocity in physics class by practising with formula such as $V = d/t$; that is, velocity equals distance over time.

Such knowledge is an important part of science, but it does not cover *all* of science! In addition to a body of knowledge that includes formulas and facts, science is a *practice* by which we pursue answers to questions that can be approached scientifically. But then what is *research*?

Research is actually a process of steps used to collect and analyse information – in this case course we mean data – in order to increase our understanding of a problem. We can say that research consists of three main steps:

- first, asking a question;
- then, second, collecting data to answer the question;
- and finally presenting an answer to the question.

There are definitely a few more steps researchers must complete when they conduct their research; this short list simply provides an overall framework for research. As you learn about the steps in the research process in the following slides, you will become more familiar with the process, but you will find that these three steps are the core elements of any research study.

To keep things simple, we can simply combine our conceptions of science and research to remind us that the 'scientific research method' is basically a systematic process that comprises steps that scientists use to solve problems and acquire knowledge. Scientists use the scientific method to search for cause and effect relationships in nature. We will talk more about the **cause and effect** relationships in later when we discuss how to construct hypotheses.

Although you now know that 'knowledge' is the goal of science, remember that the knowledge described here is not 'static'. Instead, it is a dynamic process!

Imagine if scientific knowledge did not change: if that were so, we would spend most of our available time reading the literature rather than gathering new data from hands-on experiments. For example, how would we know about the four nucleotide bases A T C G contained in DNA molecules? These were not revealed by chance, but through the work of many researchers and scientists collecting data, evaluating the results, and putting together a comprehensive theory that explained their observations.

1.3.1 Activity 1

Based on what you've learned so far, see if you can define the differences between basic research and applied research. Use your own words and give examples if possible to illustrate the concepts.

1.3.1.1 Activity 1 feedback

Basic research is conducted for the purpose of developing or refining a theory. Applied research is conducted for the purpose of applying or testing a theory to determine its usefulness in solving practical problems.

1.3.2 Self-test 1

1. The scientific research method is:
   - A. simply another way of presenting ‘knowledge’
   - B. a logical method that people try to use to understand nature
   - C. a collection of facts, concepts, and ideas about nature
   - D. a systematic process that comprises steps scientists use to solve problems and acquire knowledge
2. ‘Basic research’ is:

   A. conducted for the purpose of applying or testing a theory to determine its usefulness in solving practical problems
   B. conducted for the purpose of developing or refining a theory
   C. conducted without data collection
   D. a type of research that does not involve any complicated steps

3. ‘Applied research’ is:
   A. not a scientific research
   B. any research conducted with the use of computers
   C. conducted for the purpose of applying or testing a theory to determine its usefulness in solving practical problems
   D. conducted without data collection
4. Which of the following is NOT a characteristic of research?
   A. research originates with a question or problem
   B. research is cyclical
   C. research is restricted to information gathering
   D. research accepts certain critical assumptions

1.3.2.1 Self-test 1 feedback

1. D

2. B

3. C

4. C

1.3.3 The steps in the research process

The next presentation describes the research process and the steps involved.

The fundamentals (Part B)

Click this link to watch the video:
http://www.opentextbooks.org.hk/system/files/resource/10/10643/10650/media/The%20fundamentals%20%28Part%20B%29.mp4

You should now have a good understanding of what science and research are. Next, you need to become more familiar with the process of scientific research, i.e. the series of steps researchers use. You'll also see how these steps can help you to conduct your own research projects.

When scientists conduct a study, they usually follow a series of steps that provides them with a framework that helps them to organize and conduct their studies. These steps that were first identified as the 'scientific method' are based on the procedures used to conduct research in the physical sciences. The scientific method is a process for experimentation that is used to ask and answer scientific questions by making observations and doing experiments.

Scientists use the scientific method to search for cause-and-effect relationships in nature. In other words, by making use of their observations, scientists design an experiment so that a change to one item causes something else to vary in a predictable way.

For example, let's say a scientist observes that the growth of bacteria slows down at a low temperature. The scientist may then speculate that the growth rate of bacteria is affected by temperature, and he will design an experiment to try to prove his idea. For example, in this case he could measure the growth rate of bacteria in various temperatures.

Even though you now know that the scientific method contains a series of steps, bear in mind that it is an *iterative* process. This means that new information or thinking might cause a scientist to back up and repeat steps at any point during the process.

In addition, different types of research have their own specific purposes, so they may use various steps and parts of the scientific method differently.

As you can see in this diagram, the research process is cyclical; this is what I meant by the word 'iterative'.

Research begin with Identifying a research problem, just like the example we used of how temperature affects bacterial growth. Once we have identified a research problem, then we can search for more information by **reviewing the literature** to give us a better understanding of the topic, and especially so that we can sub-divide our research problem into sub-problems. I will talk more about this later. Then we need to **specify a purpose for the research.** This is also called **forming questions and hypotheses.** In our example, the hypothesis could be 'the growth rate of bacteria is affected by temperature'. Then we need to **design the experiments and collect data**, and finally we'll need to **analyse the data and interpret the research.**

Please keep in mind that the research process is cyclical – scientific research is an *iterative* process.

This means that new information or thinking might cause a scientist to back up and repeat steps at any point during the process.

Just as this diagram shows, you need go through these steps when you perform your own research, remembering that the process is iterative.

After finishing the eight steps, you may find that your research results either support or reject your hypothesis. No matter what your result is, you may find it beneficial to start the process over from construction of hypothesis again.

These steps in fact provide the foundation for scientific research today. Although not all studies include all eight steps, researchers use this overall process as a framework whenever they undertake a research study.

To make it easier for you to understand the steps of the scientific method, I've summarized the key steps involved in the process:

1. Identifying a research problem
2. Reviewing the literature
3. Specifying a purpose for the research; that is, forming questions and hypotheses
4. Experimental design and collecting data
5. Analysing data

6. Reporting results
7. Interpreting the research
8. Disseminating and evaluating the research

Please note that the steps for scientific methods described in various sources or textbooks may be slightly different from each other. For example, some descriptions of the scientific research process say there are nine steps because they add a step called 'prediction' after the forming of a hypothesis. Therefore, please bear in mind that the eight steps I describe here are only the generalized key steps for a typical scientific research project.

Now let's take a look at an example.

Imagine one day that a boy Tom does to a beach and observes that there is a lot of sand there. Of course there should be sand on a beach! No big deal! But he comes up with a question: 'where does the sand on the beach come from'?

Now Tom has identified a research problem, and has asked a question, that is, 'where does the sand on the beach come from?' His next step is to try to get more information about his topic so that he can refine his question; that is, he needs to break the problem into sub-problems. Besides searching the literature, he may simply look around the environment to see if he can get some clues. Let's say Tom notices that there are rivers flowing from the nearby mountains to the beach. This triggers him to refine his question and ask himself 'does the sand come from the mountains by the way of river streams?'

So now Tom could make up a hypothesis such as 'the sand comes from the mountains.'

Now we get into experimental design. Can you think any method for testing Tom's hypothesis? What Tom might do is to examine and compare the mineral content of sand from the river streams, beach, and rocks from the mountains.

Let's say Tom collects this kind of data, analyses them, and comes to a conclusion. If the mineral contents of the sand extracted from the three places are the same, then he could accept his hypothesis. Remember, however, that this really doesn't mean that the hypothesis is *true*. More experimental tests should be done before it can be proposed as a theory.

On the other hand, if the mineral contents of the sand extracted from the three places are not the same, then Tom could reject his hypothesis. He would then to figure out a new hypothesis by repeating the steps again. Remember this is a cyclical process.

Before we end this section, I would like to introduce you to some research tools.

When scientists conduct a research, they need specialized tools in order to make their research effective, just as a carpenter needs a hammer, a screwdriver and a saw when making a table or chair.

The tools of research can be anything such as:

The library and its resources can help you find more information about your study topic.

- A computer and its software are useful for data storage and analysis.
- Measurement techniques are needed to use the equipment and protocols you need for your experiment.
- Statistics and the human mind are needed for data analysis.
- And even language is a tool for report writing and oral presentations.

Getting to know how to best use these tools will help a lot in your research.

One key point from this presentation that you will have noted is that the research process is cyclical; this is what I meant by the word *iterative*. After finishing the eight steps, you may either find your research results support or reject your hypothesis. No matter what your result is, you may find it beneficial to start the process over from step 1 or step 3. These steps in fact provide the foundation for scientific research today. Although not all studies include all eight steps, researchers use this overall process as a framework whenever they undertake a research study.

You should now be able to identify the nine steps that comprise the scientific method. You also learned that when scientists conduct research, they need specialized tools in order to make their research effective. Several key tools are used by researchers when performing their research. These tools can be effective and helpful — but they must be used correctly. One effective and helpful way of learning about research tools is to work closely with or talk to an experienced researcher in your field. For example, you could talk to your tutor, course coordinator and even the professors in your school about their experiences in using these research tools in their fields.

You can now test your understanding by completing the following Self-test 2 (Page 11).

You have now learned all of the fundamental and universal steps of research. Although you may find not all of these steps are involved in some kinds of research, they provide you with a framework for conducting your own research.

In the next section of this module you will start to learn about the first major step of the research process: identifying problems.

1.3.4 Activity 2

Do you think the order in which the steps in the research process are completed is important? Why or why not?

1.3.4.1 Activity 2 Feedback

The research process is cyclical in that it usually starts with a question based on a problem, and then it ultimately closes the circle by interpreting and reporting the results from the experiment. Researchers usually follow the ordered sequence of steps to perform their research. However, different types of research have different requirements, so it is not always necessary for a researcher to complete all the steps. Moreover, researchers sometime start in the middle steps, for example in a situation in which they are at the end of a previous study, so they know more than they did when they first started. In this case, they may not need to return to the same state (i.e. the initial step) when they go on to conduct further research.

1.3.5 Self-test 2

1. Which of the following orders for the research process is correct?

   a. identifying a problem -> forming a hypothesis -> asking a question
   b. asking a question -> identifying a problem -> forming a hypothesis
   c. identifying a problem -> forming a hypothesis -> data analysis
   d. forming a hypothesis -> asking a question -> data analysis

2. Which of the following statement(s) is correct?
   (i) The research process is cyclical.
   (ii) The research process usually starts with a question based on a problem, and then it ultimately closes the circle by interpreting and reporting the results from the experiment.
   (iii) Researchers usually follow an ordered sequence of steps to perform their research.
   (iv) Different types of research have different requirements, so it is not always necessary for a researcher to complete all the steps.

   a. (i) only
   b. (i) and (ii) only
   c. (i), (ii) and (iii) only

d. All of the above

1.3.5.1 Self-test 2 Feedback

1. C

2. D

1.4 Identifying problems

The next presentation explains how researchers define their research projects, and what should be avoided when considering a research problem.

Identifying problems

Click this link to watch the video: http://www.opentextbooks.org.hk/system/files/resource/10/10643/10654/media/Identifying%20problems.mp4

In the previous section we overviewed the steps involved in a typical scientific research process. You should now have a very good understanding of the process and steps involved in scientific research. In this lecture we will take a deeper look into the identification of research problems

You might wonder: why do some research projects produce such important results, while so many others fail to do so? The fact is, many researchers owe their greatness not to their skills in solving problems, but to their wisdom in choosing their problems in the first place.

As you should recall, the first step of scientific research method is to identify a research problem.

Please note that the 'research problem' I describe here is *not* a problem that you encounter while you are conducting your research. Instead, the 'research problem' means the topic of your research study. Every scientific research study is aimed at solving a specific problem or question. In other words, scientific researchers typically begin conducting a research study by identifying a problem in their field that needs to be resolved. By specifying a research problem, the researcher limits the subject matter and focuses attention on an important aspect of a broader topic or field of study.

Finding a topic may be the hardest part of a science project. One of the most important considerations in picking a topic for your study is to find a subject that you consider interesting. However, researchers do not find their research topics randomly.

Although problems in need of research are everywhere, researchers usually find their research topics by following their curiosity within their specific areas of interest. Besides curiosity and interest, what else?... What can you think of?

To find a good research project, you have to know what a good research problem should look like.

It should be interesting – it's hard for you to work on something that you don't like it.

It should be researchable; that is, you must be able to collect and analyse data on your topic.

A good problem should be significant; that is, it should address an important question and advance the frontiers of knowledge.

Finally, it should be manageable. It must possible for the project to be handled by you. This means you should have the equipment required, find it safe to perform, and so on.

It is often difficult to justify that one choice of a research problem in a given field is better than another. As you've learned, one of the most important criteria is that the problem chosen should interest the researcher strongly. Scientific research is not a routine process. It requires originality and creative thought. An uninterested person is unlikely to produce new ideas and make any significant progress. One famous scientist expressed this idea by saying that the problem should be important in the larger picture of one's view of the world.

If you are a curious and inquisitive person, you may have already have wondered about a number of problems you've encountered in your profession or your research field. This makes sense, since the identification of research problems is usually based on *observation*. You should note, however, that 'observation' does not necessarily mean that you have to see something with your own eyes. Relevant information can be obtained from various sources such as books, articles on the Internet, your own past experience, talking to others, and so on.

In addition to observations, some other starting points when shopping for an idea are your own experience, your needs and your interests.

When these factors are added up they can help you get closer to indentifying a research problem. Of course, there is no magic way to accomplish this.

As a science student, the best way for you to start in identifying a research problem is to read extensively in the literature related to your field of interest. By reading the results of studies conducted by investigators in your field of interest, you can learn what has already been done, and what problems were encountered.

Some other ideas I'll mention here may be useful in helping you to identify 'researchable' problems:

- Try looking around you – this means using your observations.
- Try reading the literature for new information and inspiration.
- You can attend professional conferences to get ideas by listening and talking to other experts.
- You could seek the advice of experts directly.
- Try to choose a topic that intrigues and motivates you; that is, research something you are really interested in.
- Finally, you can try to choose a topic that others will find interesting and worthy of attention. This means that topic is 'hot', so it will be easier to follow.

Let's suppose that a researcher has located an interesting, feasible, and worthwhile topic for investigation. There may still be a serious problem: that is, most research problems are too large or too complex to be solved in one research project.

One of the best ways to handle a major research problem is therefore to break it down into subproblems. This allows researchers to manage their research problems more easily. As you can imagine, it is much easier for a researcher to tackle a series of sub-problems one by one.

So, you may ask, what is a subproblem? A subproblem is a subparts of the main problem that is an integral part of the main problem.

For example:

Let's say we are going to study the effect of a new drug, drug A, on lung cancer. This is a big project, so we can divide this main problem into several sub-problems.

First, we may first investigate the effect of the drug to the growth of lung cancer cells by adding different amounts of drug A to the cells, and then measuring their growth.

Then, we could perform animal studies by setting up another set of experiments to test the effect of various concentrations of the drug on rats induced with lung cancer.

We could also to investigate how drug A might be used to kill lung cancer cells.

There may be more sub problems in this example, but what you can see here is that all the sub-problems are still under the umbrella of the main problem.

To distinguish and set up subproblems, you need to know their characteristics:

First, just like for the main problem, each subproblem should be a complete and researchable unit.

A subproblem must be clearly tied to the interpretation of the data.

The subproblems you choose to research must add up to the totality of the problem; remember, all of these subproblems are broken down from the main problem.

Finally, the number of subproblems should be kept small. You can't handle 1000 subproblems, right? They should be kept to a number that you can handle.

Activity 3 (Page 15) encourages you to think more deeply about the nature of a good research topic.

1.4.1 Activity 3

1. Do you think is it important that the researcher articulate, as clearly as possible, all assumptions that affect the research problem? Why or why not?

2. Do your best to select a study topic. You could start with a theory, a personal experience, a study you already know about that you may want to replicate, or a library or Internet search. Identify the research problem that relates to your area of expertise, and show the way in which you derived the research problem. If you are studying cell biology, for example, relate the general issue to cell biology. If you are in some other field of study, relate the issue to your own discipline.

Then try to list out the main criteria that you use to review the appropriateness of your topic/research problem.

1.4.1.1 Activity 3 Feedback

1. There are some strong reasons why a researcher must articulate the assumptions underlying a research problem. I will point out two of these reasons here, but you may have thought of more, and you can discuss them with your tutors. First, the researcher's assumptions will guide the selection of research questions and the formation of hypotheses, as well as the interpretation of the data. Clearly stating the assumptions will assist someone who is reading the finished research in evaluating the merits of the study, and the conclusions that can be drawn from it. Secondly, the assumptions to some extent can be incorporated into the study design to promote the validity of the conclusions drawn from the study. That is, readers will be more likely to find a study's conclusion to be convincing if they know that the researcher has explicitly addressed and taken into account his or her own assumptions.
2. A vast range of topics are possible grounds for scientific research. Choosing one really depends on your own interests and discipline. Typically, you can identify a research problem based on your observations, on previous studies that you have read about in the literature, or as a follow-up study to one of your own projects. When reviewing the appropriateness of your topic, ask yourself if it is:
    - interesting;
    - researchable and measureable (that is you can measure, collect and analyse data on your topic);
    - significant; and
    - manageable.

1.4.2 Self-test 3

1. When reviewing the appropriateness of your topic, you should ask yourself if : (i) It is interesting (ii) It is significant (iii) It is manageable (iv) It can make you rich
    A. (i) only
    B. (i) and (ii) only
    C. (i), (ii) and (iii) only
    D. All of the above

2. Which of the following statement(s) is correct? (i) A vast range of topics are possible grounds for scientific research. Choosing one really depends on your own interests and discipline. (ii) A researcher must articulate the assumptions underlying a research problem. (iii) Each subproblem should not necessary be a complete, researchable unit. (iv) Breaking a main problem into subproblems allows researchers to manage their research problems more easily.
   A. (i) and (ii) only
   B. (i) and (iv) only
   C. (i), (ii) and (iii) only
   D. (i), (ii) and (iv) only

1.4.2.1 Self-test 3 Feedback

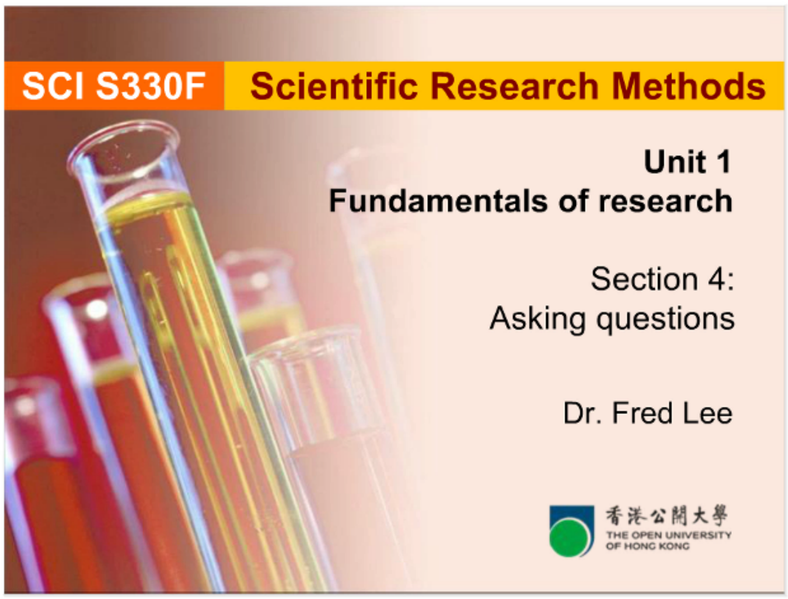
1. C

2. D

1.5 Asking questions

Asking questions is the next step in the research process. The following presentation introduces you to the basic considerations you need to know about when asking research questions.

Asking questions



Click this link to watch the video:
http://www.opentextbooks.org.hk/system/files/resource/10/10643/10657/media/Asking%20questions.mp4

In the previous section you were introduced the methods and skills you need to identify a good research problem. As you learned, researchers start their research study by identifying a broad research problem that they want to address. However, they usually need to narrow down their research problem and identify a specific focus for their study.

Specifying the purpose for research consists of identifying the objective for a study, and then narrowing it into specific research questions, and then into hypotheses.

In other words, research questions are questions that narrow down the study purpose to specific questions that researchers seek to answer. Unlike the single statement found in a research purpose, researchers usually state multiple research questions so that they can fully examine a topic.

After you identify a research problem and find an interesting topic to study, you may start to ask yourself some questions that you want to answer. A question generally starts with: How, What, When, Who, Which, Why, or Where. For example, if you are interested in cancer cell research, your questions might be 'What are cancer cells?' or 'How could cancer cells develop from normal cells?' or 'What is the most effective method for killing cancer cells?' The research and experiments you will be conducting all revolve around finding answers to the questions you are posing.

Let's move on to some basic considerations in asking research questions.

If you are conducting something like a science project, it is important to think ahead. For one thing, you need to think through the potential implications of your project questions. If you can identify and plan for these implications, this will save you lots of time and unhappiness in your later experimental work.

There are also basic practical and ethical considerations that need to be addressed before asking interesting science project questions. Again, if researchers do not consider and follow these considerations carefully, they may waste a lot of time and materials.

What are the characteristics of good research questions?

First, the questions should be interesting Remember that it is difficult to work for months or even years on something that is not interesting.

There should be at least some references on the subject. That is, you will want to be able to build on the experience of others!

A good question should measure changes to important factors – that is, the variables – using a number that represents a quantity such as a percentage, length, width, weight, voltage, velocity, time, temperature, and so on. It should be *measureable*. If you cannot measure the results of your experiment, you're not doing science!

Do you have all the materials and equipment you will need for your research study?

Do you have enough time to do your research study? Remember; for most experiments you may need enough time to do a trial/ preliminary test so that you can work out any problems in your procedures; these are sometimes called 'dirty experiments'.

Most importantly, is your experiment safe to perform? If a scientific research project involves human subjects, vertebrate animals – that is, animals with a backbone – or animal tissue, pathogenic agents, DNA, or controlled or hazardous substances, you will likely need approval from corresponding authorities such as a Scientific Review Committee.

For example, in order to maintain an ethical approach to animal research in HK, local researchers should follow the code of practice developed by Animal Welfare Advisory Group and issued by Agriculture, Fisheries and Conservation Department, AFCD when handling animal experiments. The purpose of this code of practice is to ensure the humane care of animals used for experimental purposes. This is one part of the overall strategy being adopted by local universities, private research laboratories and the HKSAR Government. If you're interested, you can search for an download the 'Code of practice' from the AFCD website.

The questions shown here are good project questions. As you can see, their parameters – such as water purity and surface tension – are measurable! Answering them will be safe to perform. There are tons of references that you can find. And so on….

Now that you know the basic considerations for setting good research questions, the next question that you may ask is: How do you actually make up such research questions? It certainly can be difficult to think of good questions from scratch. Usually they must be triggered by something, and as such they can arise from a number of sources.

If you analyse the questions that scientists typically ask, you will see that there is a generalized form of these questions that can be applied to nearly anything. What you need to do, however, is to refine a general question into a very specific one that fits into your research study. Of course, this approach is not perfect, but it can help you overcome research difficulties that you may be frightened to ask questions about because you may feel you don't have enough knowledge to do so.

All study subjects have arisen somehow, and for some reasons. They must be composed of certain elements, and possess certain characteristics. You can immediately get a better understanding of most subjects for scientific study by asking questions that start with: How, What, When, Who, Why, or Where – the six Ws.

In the example listed here, do you think the questions are good or bad?

I would say both of them are bad...but why?

First, the effect of music on plants is something that is difficult to measure.

Ladies and gentlemen, can we compare an orange with an apple to see which tastes better? Some of you may say an apple is better, and some of you may say an orange is better. The question is too subjective, and difficult to measure!

You can begin to build an understanding of a study subject just by asking research questions based on the skills you have learned – even if the answers are not known to you. Forming good research questions is important for your subsequent experimental design. I hope, therefore, that you have learned some useful tricks for devising research questions that you can apply when you go on to prepare your own project.

Now let's test your ability to spot a good or bad question in Self-test 4 (Page 20).

1.5.1 Self-test 4

1. Do insects suffer from cancer? Why good/bad?
2. What is the effect of talking on plants? Why good/bad?
3. What is the effect of high phosphate concentrations on plant growth? Why good/bad?
4. How does water temperature affect the solubility of sugar? Why good/bad?
5. What is the effect of music on human's emotion? Why good/bad?

1.5.1.1 Self-test 4 Feedback

1. Bad. Although this is a very interesting question, the word *suffer* is unclear and vague. This is typical of a certain type of poor research question because is difficult to define the meanings of terms used in stating the question. For example, does the question mean 'Do insects suffer (i.e. feel pain) when they have cancer?' or 'Is it possible that insects develop cancer?'

2. Bad. It is very difficult to measure the effect of talking because talking itself is something that cannot be measured.
3. Bad. *High* is a vague term, so one can only guess an answer to the question. The question only becomes useful if it is stated more specifically, e.g. 30mg/L rather than *high* or *small*.
4. Good. Both the independent variable (water temperature) and the dependent variable (sugar solubility) can be measured.
5. Bad. Again — *effect of music* and *emotion* are highly subjective terms that are difficult to measure.

1.6 Conclusion

Science and research exist in a close relationship. In this module, we tried illustrate the links between them, and to integrate these ideas into a conception of the scientific research method.

You learned that no scientists achieve success by luck. They must engage in repeated experiments, trials and failure — sometimes hundreds or thousands of times over. If you take a look at any legitimate scientific research projects worldwide, you will find that the common research process they follow always starts with identifying problems, and then goes on to asking questions and constructing hypotheses.

You also learned about some of the fundamentals of research such as research tools and the research process. You have become familiar with several concepts that are crucial in the beginning steps of the scientific research process. In identifying problems, I showed you how to pose a good research problem, and introduced to you the importance of dividing problems into manageable subproblems. In asking questions, you learned the characteristics of good research questions and how to apply the 6Ws.

If you would like to learn more on this subject, especially the procedure of constructing hypotheses, you are welcome to enrol in *SCI S330 Scientific Research Methods (http://www.ouhk.edu.hk/wcsprd/Satellite?pagename=OUHK/tcGenericPage2010&lang=eng&TYPE=CI&CODE=S330)* offered by the School of Science and Technology (http://www.ouhk.edu.hk/wcsprd/Satellite?pagename=OUHK/tcSubWeb&l=C_ST&lid=191133000200&lang=eng) of the OUHK.