Questions for the week

- What is Quantitative Reasoning (the concept and the course)?
- What does Quantitative Reasoning have to do with my studies and career goals?
- What is the Scientific Method?

Welcome to 1015SCG Quantitative Reasoning!

On behalf of the teaching team for Quantitative Reasoning, welcome (back) to University! The course Quantitative Reasoning is intended to help you start developing the quantitative skills you will need as a scientist in the 21st century. Virtually every branch of science uses mathematical or statistical arguments to analyse data and draw conclusions. Some of the largest issues currently facing our society – responding to coronavirus, climate change, and population growth – involve questions of a quantitative nature. But so do many of the smaller, more immediate issues – whether it's cheaper to run a car or use public transport and Uber; figuring out the correct dose to administer to a patient, working out what mark I need in the final exam to pass the course.

For all these situations, we need to access and analyse the available information -- in many cases, in the form of numerical data -- and make decisions based on this analysis. In Quantitative Reasoning, you will learn about the skills required to do this.

1015SCG Quantitative Reasoning, as a course, is constantly evolving

This course was re-designed just before COVID struck, and we have made some changes here and there to accommodate the different way we are running this course. Our aim has been to move the focus *away from* the mechanics of performing mathematics, and toward improving your understanding of when and how to applied maths in a scientific context:

- We won't be testing your ability to do mathematical calculations by hand in a small amount of time.
- We will be testing you on your ability to do the right calculations, to get them correct (by hand, calculator, or computer), and to present your solutions in the context of the original problem

Who do I contact if I have a question?

<u>If you have administrative questions</u> (e.g. enrolment problems, applying for deferred assessment due to illness), contact the your **course convenor**.

If <u>you have questions about the course content</u>, you should ask your tutor (during workshops), or your lecturer.

You can check the 1015SCG [course site on Learning@Griffith](#) to find contact details for your campus convenor, and lecturer(s).

Why have I come to University?

It's important to understand why you are doing a course involving maths and statistics, since you might have thought maths didn't play much of a role in the area of science you are interested in. In this course, we'll try to help you see why maths might be relevant for your career goals, and the parts of the course that might be most relevant to you.

Quantitative reasoning plays a critical role in authentic real-world interdisciplinary STEM problems, providing the tools to construct data informed arguments specific to the problem context, which can be debated, verified or refuted, modelled mathematically and tested against reality.[1]

Exercise: To begin, let's consider the following questions:

1. Why have I come to University?

2. What area of science would I like to work in?

3. What style of job would I ideally like?

4. True or False: Getting good grades is enough to get the job I want after graduating.

5. True or False: University will teach me all I need to know before I (re)enter the workforce.

6. True or False: The degree I'm doing will help me meet my career goals.

[1] Mayes, R. (2019). Quantitative Reasoning and Its Role in Interdisciplinarity. Interdisciplinary Mathematics Education. ICME-13 Monographs. Springer. https://doi.org/10.1007/978-3-030-11066-6_8

Where does Quantitative Reasoning fit into science (and more!)?

Exercise: Do any of the following topics involve maths? Discuss with people sitting near you.

- Coronavirus
- Global Warming
- Interest rates and inflation
- Renewable Energy
- Artificial intelligence

Answering most scientific questions requires *quantitative reasoning*:

- *Quantitative*, because the arguments involve numbers
- *Reasoning*, because we want to take a scientific approach to our argument

In this course, you will learn:

- Why and how mathematics is important to seemingly non-mathematical sciences
- How to use mathematical methods to answer scientific questions
- How to present those answers

Exercise: Let's think a little about whether natural disaster events we have recently been experiencing (e.g. major Australian floods, cyclone in New Zealand, earthquake in Türkiye and Syria) are the worst they have ever been.

In pairs/small groups, consider the following points (feel free to look online for information):

- What would it mean for the recent rain events to be the "worst ever"?

- What information would we need to determine whether they were or not?

What do we need to know in order to answer these questions?

- What data do we need?

- How can we source it reliably?

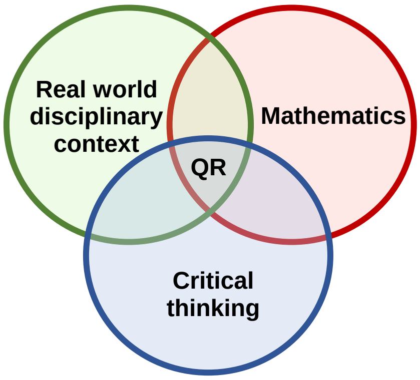
- How do we use that data to answer these questions?

Course information

Much more information on the online study guide https://degrees.griffith.edu.au/course/1015SCG

Why call the course "Quantitative Reasoning"?

The term *quantitative reasoning* is used has emerged over recent years (see, for example, Elrod, S. Quantitative Reasoning: the Next "Across the Curriculum" Movement, *Peer Review* 16:3 (2014)) to describe the use of scientifically structured, number-based arguments in order to better understand the world around us. Quantitative reasoning sits at the intersection of



- mathematics (which we need to when our arguments involve quantities)
- critical thinking (which we use to construct sound arguments)
- a real-world context (since our aim is to better understand that world).

Over the following 12 weeks, we will focus on the first two of these (the *quantitative* and the *reasoning*), in the context of many different real-word problems. We will cover the following topics:

Week 1: Why "quantitative reasoning"?

- Course introduction
- Science, the scientific method, and the role of numbers (maths and stats)
- Maths' role in your chosen field

Week 2: Data (where do my numbers come from?)

- Numbers and measurement
- Units for quantities
- Scientific notion (and intro to orders of magnitude)
- Errors in measurement, and how they propagate

Weeks 3 and 4: Statistics and Inference

- Why do we need to use statistics in order to interpret data?
- Reporting best estimates and errors in repeated measurements
- Measuring correlation between quantities
- Linear algebraic relations ($y=mx+c$) and (straight) lines of best fit
- Subtleties of interpretation (correlation vs causation, interpolation vs extrapolation)

Week 5: Functions: relationships between data

- What is a function? What is a graph?
- Some important functions (and situations where they arise)
  - polynomials
  - logarithms and exponents (re orders of magnitude) (pH)
  - sinusoidal functions
  - other useful functions: sigmoidal functions, bell-shaped curve (Gaussian)

Weeks 6 and 7: Critical Thinking

- Modes of scientific argument
- Skills involved in critical thinking
- Logical flaws
- Critiquing a scientific argument

Weeks 8 to 10: Science Communication

- The structure and language of scientific writing and scientific arguments
- How to represent data (good ways and bad ways)
- How to interpret graphs

During weeks 6-10, we'll also consider a number of case studies, exploring techniques for setting up and solving quantitative problems:

- Setting up the right algebraic problem to solve
- Solving algebraic problems: by hand, calculator, or computer
- Approximation: Fermi problems and orders of magnitude
- Checking your own answer (is it reasonable?)

Week 11 and 12: Data Science

- What is Big Data and Data Science all about?
- Examples of using Big Data to answer interesting or challenging questions
- Big data, fake news, and AI

As we go through this curriculum, we will consider

- How does it relate to your future professional context?
- How do you do good quantitative science in the 21st century?

Learning Outcomes

The learning outcomes for this course are listed in the course profile. By the end of the course, you should be able to:

1. Relate the use of mathematics to your own scientific studies and interests
2. Use computational tools to perform mathematical calculations
3. Communicate scientific arguments effectively in writing
4. Construct and critique quantitative scientific arguments
5. Construct suitable mathematical models of real-world phenomena
6. Solve problems related to mathematical models of real-world phenomena, in order to better understand those phenomena

Lectures and workshops

There will be two hours of lectures, and around two hours of recorded content for you to watch each week between them. Lectures will not just be someone telling you stuff. They will also involve times where you have to think and contribute. This can be challenging, but it is what will help you learn the most.

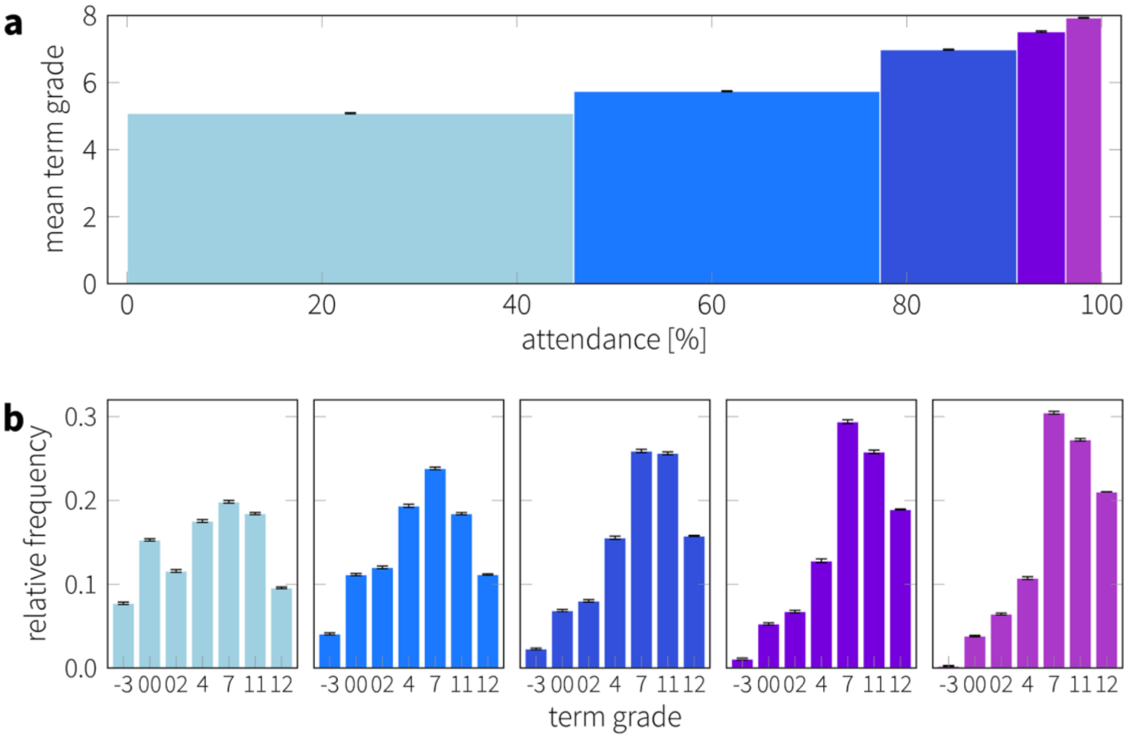
The lecture class is aimed to <u>reinforce</u> the content delivered by recorded content. Content is delivered in the videos. This gets explored and reinforced further in lectures. Then we practice in workshops. All three work together to build up our understanding – so it is important to follow this structure!

You will have a two-hour workshop every even week (starting week 2), where you will

- Do exercises to help you understand course content
- Have time to work on assessment tasks with a tutor to help

You do not get marks for turning up, bu but there is marked component in the workshops ndicator of success in mathematics related courses. The graphs below taken from a scientific journal article[2] show that

- students who attend more have a *higher overall average* mark; and
- the more you attend, the more likely you will have a high overall grade.



(Note the grade numbers don't match ours, but a higher grade is a better result)

Assessment

Through the semester, you will be asked to complete a number of assessment tasks. Here is a summary of those tasks and the weeks they are due (more details will follow):

- **Employability task** [5%, due Week 3 + 5% due week 9
  How does the content of this course align with your science career goals? Highlight work you have done (in the course and elsewhere) that reflect this.
- **Maths and Inference assignment** [30%, due Week 7]
  Perform calculations on data that are relevant for quantitative reasoning, in order to draw conclusions about what the data tell us
- **Scientific critiquing task** [35%, due Week 10]
  Identify a quantitative claim or argument (an article in the press, report on TV, claims made in advertisements, or a scientific article), and present a critique of that argument
- Workshop Tasks [25%, done and marked during the workshops, every even weeks]
  The workshops will be held in the even weeks only, during the workshops we will be working on the report writing taks.

There is no longer an exam at the end of this course.

[2] Kassarnig *et al.*, (2017). PLoS ONE 12(11): e0187078

The University has a policy that you must follow if you need to defer assessment (e.g. because you are sick)

- If you miss an assessment item
  - Apply for a deferred assessment
  - Let us know separately by email that you have done this

- Supporting evidence
  - *Illness* or *temporary disability* – medical certificate
  - *Bereavement* – bereavement notice
  - *Sporting or cultural commitment* at state/national/international rep level – letter from sporting body
  - *Accident* or *other compassionate grounds* (*e.g. work*) – statutory declaration

Academic Integrity

Universities treat intellectual honesty as a very important issue. In particular, don't claim someone else's work as your own.

- Attribute quotes or ideas found elsewhere
- Do not pass off other people's work as your own
- Reference your work, provide a citation if needed

For Griffith policies please check the dedicated student web page https://intranet.secure.griffith.edu.au/student/academic-integrity

Communication

- Make sure you follow the announcements on the course site
- Check your University email regularly

I need help – who should I turn to?

For help on **coursework**: ask your *tutor* or *lecturer*

If you have an **administrative problem just relating to this course**: contact *Student Connect* or your *course convenor*

If you have **non-academic problems that are affecting your study**: contact your *course convenor* or *program director*

For issues relating to your **status as a student**: contact *Student Connect*

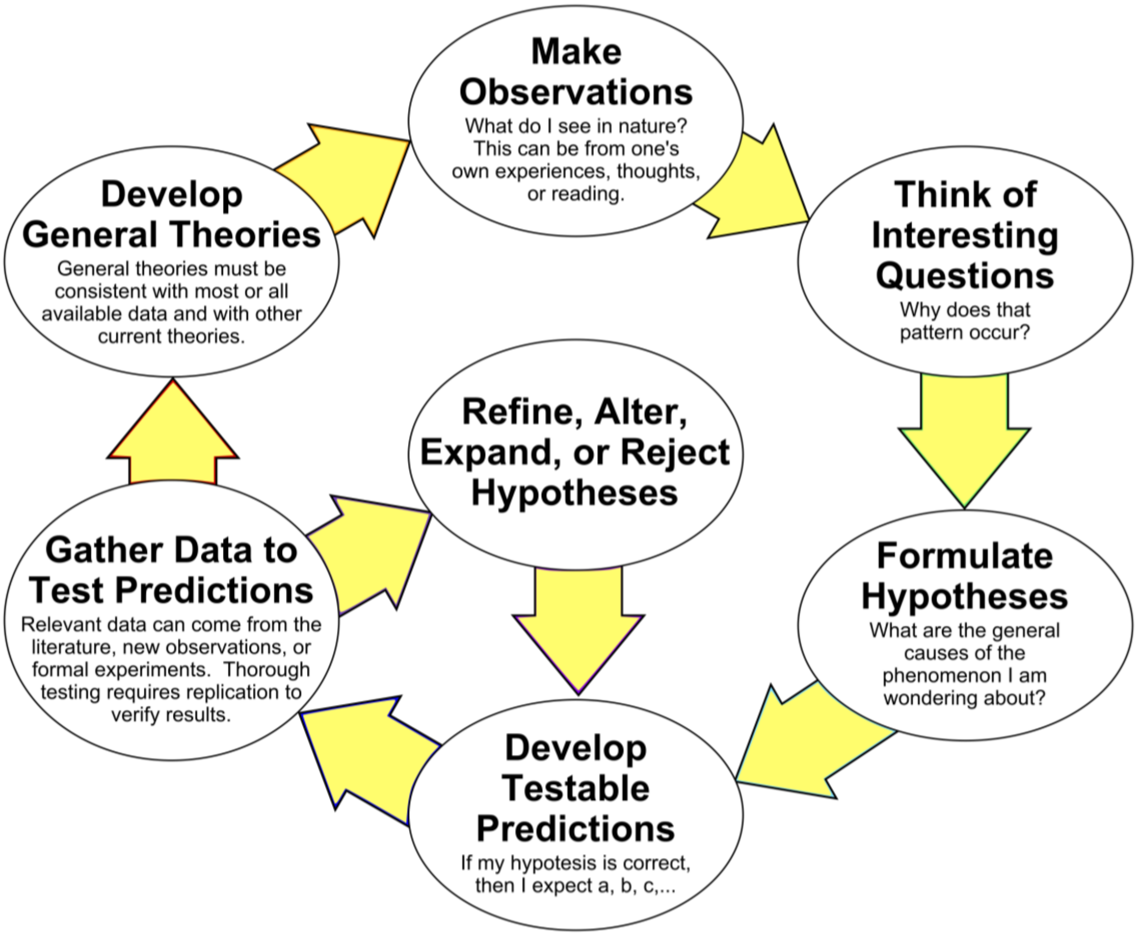
If you have a **broader administrative problem regarding your degree**: email your *program director* or *program support officer*

What is science?

Science is not a simple thing to describe. In class, we will consider some of the key attributes of science

Attributes of science (and what lies beyond it)?

The Scientific Method



How did Ignaz Semmelweis apply the Scientific Method?

In class and in the videos, we will consider one or two other specific questions, and how the scientific method might be applied to answer them

Question:

How can we apply the scientific method to answer this question?

- What data could we gather?
- How could we use it to confirm/refute our hypothesis?

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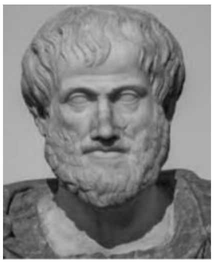
Some more advanced comments on the Scientific Method

We can think of the Scientific Method as comprising three core elements

- Observation
    - We must take care to distinguish facts and assumptions;
    - Be wary of unconsciously favouring what we expect (confirmation bias)
    - Make use of other available data beyond what we find ourselves
    - Extraordinary claims require extraordinary evidence
- Explanation
    - We must distinguish correlation from causation (more in a few weeks)
    - There are different forms of explanation:
        - Cause: explanation in terms of an antecedent
        - Causal mechanisms: explanation in terms of a chain of causes
        - Laws: explanation in terms of a general principle
        - Underlying processes: explanation in terms of component parts
        - function/role: explanation in terms of purpose
    - We usually prefer explanations that introduced the fewest new questions (Occam's Razor)
- Experimentation
    - We should design tests to minimize
        - false confirmation (i.e. could our experiment succeed even if our hypothesis is not true?); and
        - false rejection (i.e. could our experiment fail even if our hypothesis is true?)

Negative results can be an important part of the Scientific Method!

Science History Sidebar!



Aristotle is widely credited as the father of the scientific method. In his life (384–322 BC) he applied his methods to almost everything, poetry, politics, astronomy, and natural history. While Aristotle may have popularised this approach, evidence shows the Edwin Smith Papyrus (dated c. 1600 BC) presents a rational and scientific approach to medicine in ancient Egypt over a thousand years earlier!

The Scientific Method isn't always linear

- e.g. making a range of (hopefully educated) guesses rather than hypothesising

Some examples of explanations and false confirmation/rejection

Where do quantities fit in?

We use mathematics to evaluate quantities and provide data, e.g.

- calculating mortality rate of coronavirus vs other similar disease
- estimating CO_2 released from bushfires

We use statistical approaches to establish

- how correlated are two quantities?
- how likely is an outcome, given an underlying theory?

We use mathematical models to establish causation

- Can we explain/predict results using a mathematical model of underlying processes?