Queen Mary
University of London

'Beyond the Formula': Embedding ethics and sustainability in mathematics through co-creation

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The Classic Oil Pipe Problem

An oil company wants to build a pipeline connecting an oil platform to a refinery (on land).

The coastline is straight; the oil platform is a distance D_1 from the coast and the refinery is D_2 from the coast.

The distance along the coastline between the platform and the refinery is H. Building the pipeline has a cost per unit length c_1 at sea, and c_2 on land.

How should the pipeline be built?

Ethics/Sustainability in Mathematics: An Overview

- Why do we need it?
- What is its current state?
- How should we embed it?
- How did we integrate it?
- Student feedback and impact highlights

Need for Ethics in Mathematics (EiM)

- Mathematics (**both pure and applied)** can lead to ethical consequences and is an extremely sharp **double-edged sword**

- Many examples of this such as **financial mathematics, data science, AI, statistics, mass surveillance, social networks, industrial mathematical modelling, cryptography, communication metadata, etc.**

- STEM disciplinary practitioners are **uniquely** responsible for the immediate **moral, ethical and legal consequences** of their work

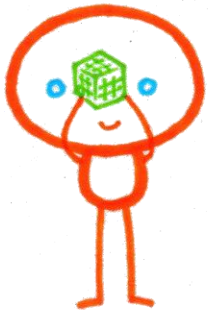
- As STEM educators, we train future graduates, but are we really giving them an **inclusive professional training** covering the ethical aspects they will need to confront?

Need for Sustainability in Mathematics (SiM)

- Mathematics usually taught through **memorisation** and repetitive application of **formulae**.
- Often **limited emphasis on** the role of mathematics in addressing **sustainability challenges**.
- Existing curricula rarely highlight how mathematical tools contribute to **solving global issues**.
- Students struggle to recognise the connection between **mathematics and sustainability**.
- This reinforces the perception that mathematics is **theoretical** and **disconnected** from real-world issues.

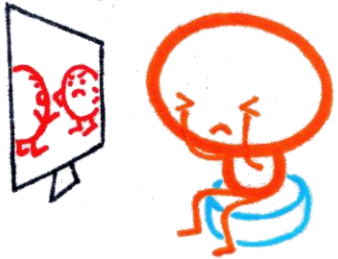
Current state of EiM/SiM: Not my problem!

This is M.



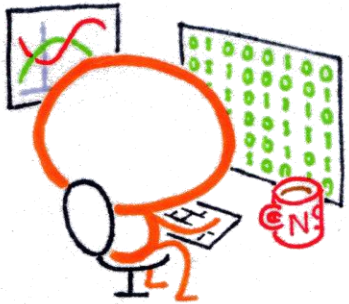
M is very clever and likes solving fun puzzles and maths problems.

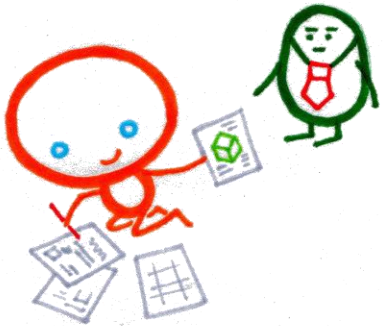
M doesn't like thinking about politics or society.



The outside world is scary.

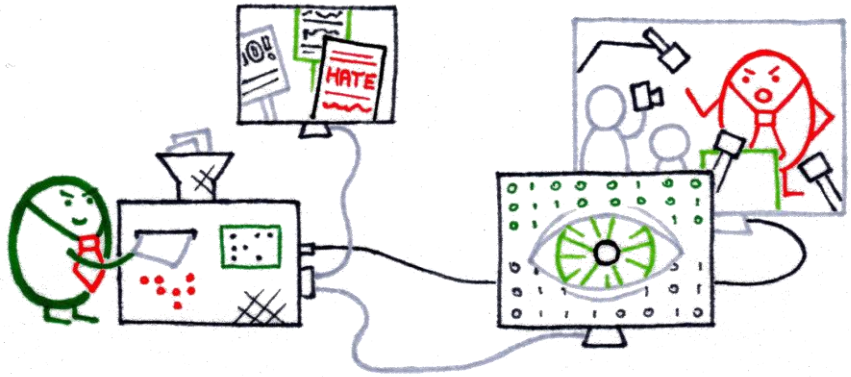
At work, M is given shiny new problems to work out every day.





M is well looked after, and doesn't have to confront the outside world at all.

Current state of EiM/SiM: Not my problem!



And who would want to anyway?

The news seemed to be getting worse every day, which made M feel worried and scared.

Better far to ignore it all, and get back to that interesting problem…

Made by Phoebe Young
www.ethics.maths.cam.ac.uk

Previously…..

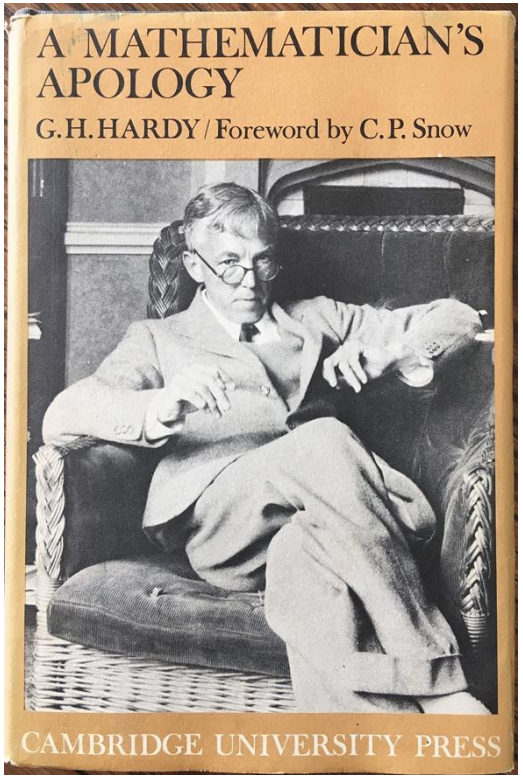
- Mathematical community often still believes that while mathematics might be applied to various situations with social consequences, it is itself *free of ethical considerations*.

"No discovery of mine has made, or is likely to make, directly or indirectly, for good or ill, the least difference to the amenity of the world."

- ***G.H. Hardy,*** *A Mathematician's Apology* (1940)

Note: How ironic!!

(Hardy is most known for the Hardy-Weinberg principle in mathematical biology, which is in fact widely used today for testing population structures in genetics)



But today…..

- **Policy requirements:**

QAA Subject Benchmark Statement: Mathematics, Statistics and Operational Research (March 2023)

The UK Standard for Professional Engineering Competence (UK-SPEC) Fourth Edition (August 2020)

Sustainability

1.44 MSOR has a vital role to play in achieving the UN's Sustainable Development Goals, underpinning many technological, scientific and digital developments which have potential to improve health, drive economic growth, transform societies and enhance our environment. For example, mathematical models inform forecasts of climate change, analysis of health data informs public health provision and algorithms help users optimally navigate transport networks. Policies which encourage sustainable development and reduce inequalities can be developed and analysed based on mathematical models and data analysis. MSOR degrees are themselves a driver of social mobility with many graduates from a range of socio-economic backgrounds earning high incomes.

Chartered Engineer (CEng)

E. Personal and professional commitment

Chartered Engineers shall demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment.

The applicant shall demonstrate that they:

1. Understand and comply with relevant codes of conduct
2. Understand the safety implications of their role and manage, apply and improve safe systems of work
3. Understand the principles of sustainable development and apply them in their work
4. Carry out and record the Continuing Professional Development (CPD) necessary to maintain and enhance competence in their own area of practice
5. Understand the ethical issues that may arise in their role and carry out their responsibilities in an ethical manner.

How should we embed EiM/SiM?

Basic principles:

- **Seamless and organic, not artificial and contrived**

- Focus on how students engage with sustainability, **do not treat as an add-on component**
- Ensure that concepts emerge naturally from the technical problem by aligning to a realistic scenario

- **Subjective and reflective aspects**

- answers will involve **open-ended discussions** unlike the usual objective 'right or wrong' answers

- **Link with** UN Sustainable Development Goals

- **map problems to the 17 SDGs** for a more holistic view of sustainability within the context of the discipline

How did I implement it in my modules?

- **Co-creation** of teaching toolkit with **2 current undergraduate students**
- Toolkit includes **visually appealing posters** showcasing the **importance of sustainability and ethics** in mathematics, examples of **real-world mathematical problems** linked to these issues and **formative practice quizzes** to assess conceptual understanding
- Implemented across **two large undergraduate applied mathematics modules** for 800 engineering students (Year 1 – sustainability, Year 2 – ethics)
- Embedded as **asynchronous, formative resources** on QMUL virtual learning platform for students to use alongside course content

Module Implementation

Motivation

The mathematical exercises provided below are designed to raise sustainability and ethical awareness and imbibe transferable skills among undergraduate students in STEM disciplines as part of an ongoing scholarship research initiative undertaken by **Dr. Rehan Shah (School of Engineering and Materials Science)** from QMUL with current undergraduate student co-creators **Ms. Malmi Mahagamage** and **Ms. Meherun Soud**. Some of the mathematical content in these exercises was inspired by actual tutorial sheet questions from the Mathematical Tripos course taught at the University of Cambridge.

Sustainability Exercise Questions

1. **Pipeline Construction (SDGs: 7, 9, 14 and 15)**
2. **Environmental Disasters (SDGs: 6 and 12)**
3. **Simpson's Paradox (SDGs: 5 and 10)**

Ethics Exercise Questions

1. **Confronting Your Boss with Logic**
2. **Ethics of Crime Scene Investigation**
3. **Mathematics of Military Engagement**
4. **Mathematical Communication**

Tasks (will count towards formative engagement)

- **Engage and go through the resources** provided below
- **Complete the feedback survey below by end of SKEMP week Fri 7 Nov 2025 (17:00)** based on your engagement with these resources (responses will be monitored, checked and count towards formative engagement) **(note: feedback responses left blank, or with only punctuation or binary yes/no text responses will be discounted and will you have to the survey again)**
- **Complete the practice quiz below (released after the lecture in SKEMP week) by end of SKEMP week Fri 7 Nov 2025 (17:00)** (responses will be monitored, checked and count towards formative engagement)

Before…..(pilot run)

Handout: Why do we need Ethics in Mathematics?

Have you ever thought about the ethical issues that mathematicians and people using mathematics might encounter? Have you ever thought about all those issues that are specific and peculiar to mathematics?

Since primitive humans first began to use language and organise themselves socially, they have also counted and used simple arithmetic. It is a way of talking about and knowing about the world that is as much a part of what it is to be human as anything else that we might characterise as being an essential part of being human. Elementary mathematics – arithmetic, simple geometry, and the logic of problem solving have always been part of human activities and forms of knowledge of almost all human societies. But in the 21st century things are a bit different. High-end mathematics done by highly trained professional mathematicians is ubiquitous, and is unavoidable in a digital world. Most of the technology around us does not just use elementary arithmetic, algebra, and geometry – it often uses the most cutting-edge mathematics, the products of recent research and of the most technically sophisticated and abstract mathematics that humanity has produced. Mathematicians seem to be taking over the world, except that nobody has noticed. For example:

- The global financial markets are run by computer programmes that use mathematical models and mathematical analysis of financial products and markets. Modern financial mathematics is cutting-edge, highly developed, sometimes Nobel Prize winning and seriously hard. When the models fail, the economic consequences can be disastrous. A lot of mathematicians go and work for financial institutions, developing tools that come straight from research mathematics.

Sustainability in Mathematics Exercise Questions

Exercise 1: Pipeline Construction

SDG Mapping: 7 (Affordable and Clean Energy), 9 (Industry, Innovation and Infrastructure), 14 (Life Below Water), 15 (Life on Land)

An oil company wants to build a pipeline connecting an oil platform to a refinery (on land). The coastline is straight. The oil platform is at a distance of D_1 from the coast. The refinery is on the coastline, a distance D_2 from the point on the coast closest to the platform. Building the pipeline will lead to a cost per unit length c_1 at sea and c_2 on land.

Calculate the optimal length for building the pipeline. What are the factors that need to be considered when providing a response to this question?

Exercise 2: Environmental Disasters

SDG Mapping: 6 (Clean Water and Sanitation), 12 (Responsible Consumption and Production)

A chemical accident took place near a small village in Peru. The region's local water reservoir has a volume V. The inflow and outflow of the reservoir is given by the flow rate r. Let $x(t)$ be the amount of mercury in the reservoir at time t. Assume that the reservoir was clean at the beginning i.e., $x(0)=0$. Let $C(x)$ be the concentration of mercury flowing into the reservoir.

a) Set up and solve a differential equation describing the concentration of the reservoir.
b) What are some relevant questions you can ask about the concentration of mercury in the reservoir? How much does it matter?

After…..(through co-creation!)

Queen Mary University of London

Why do we need sustainability in mathematics ?

"Since the introduction of the UN Sustainable Development Goals (SDGs) in 2015, universities have struggled to integrate sustainability into mathematics education. "

Why is this a challenge for universities?
Universities struggle to incorporate sustainability in mathematics since it is frequently viewed as 'abstract', 'theory-driven subject with few direct connections to real-world issues.

So, this needs to change!
According to a report from the American Mathematical Society, sustainability should permeate mathematics curricula at high school and university levels. We have been applying sustainability in mathematics unconsciously e.g., when tackling energy optimisation. It is crucial, that students increase their awareness to enhance their mathematical and sustainability understanding.

Why should STEM programmes help students understand environmental, social, economic issues related to sustainability development?
These fields play a crucial role in sustainability-related issues. By integrating sustainability, STEM education can provide students with the skills necessary to create innovative solutions that will enable a sustainable future to be achieved..

What are UN sustainability development goals?

The Sustainability development Goals (SDGs) represent a global initiative to eradicate poverty, safeguard the environment, and enhance the well-being and future-prospects of people worldwide. Adopted by all United Nations Member States in September 2015, the SDGs area key component of the 2030 Agenda for Sustainable Development, which outlines a 15-year framework for achieving these goals and their associated targets (United Nations, 2022).

References: United Nations (2018). Sustainable Development Goals (SDGs) and Disability | Division for Inclusive Social Development (DISD). [online] social.desa.un.org. Available at: https://social.desa.un.org/issues/disability/sustainable-development-goals-sdgs-and-disability.

SCHOOL OF ENGINEERING AND MATERIALS SCIENCE

Queen Mary University of London

Why do we need ethics in mathematics ?

"Have you ever thought about the ethical issues that mathematicians and people using mathematics might encounter? Have you ever thought about all those issues that are specific and peculiar to mathematics?"

Why is it important for universities to integrate ethics in mathematics?

Since ancient times, mathematics has been a vital part of daily life from basic arithmetic to advanced mathematics models. In the 21st century, advanced mathematics is embedded in technology and digital life, making it an essential component in shaping our world.

How is ethics and mathematics integrated in the real-world?

- **Finance:**
The global financial markets are run by computer programs that use mathematical models and mathematical analysis of financial products and markets. Ethical concerns could arise when financial models prioritise profits instead of customer satisfaction.

- **Aviation:**
Airplanes rely on complex mathematical algorithms to keep them flying. Airlines also use these complex mathematical algorithms to optimise fuel consumption, supply and demand of seats, and the logistics of moving aircraft as well as a thousand other things using computer-run optimisation software. Ethical questions arise when airlines need to decide between the fair pricing or safety protocols.

Scan QR code for QMUL Ethics in Mathematics Resources

Embedding SiM – Example Problem (Year 1)

Problem 3 – Simpson's Paradox
Mathematical topic : Probability
Contribution to SDGs : Gender Equality (SDG 5), Reduced Inequalities (SDG 10)

Context of the problem: In a particular admissions cycle, a mathematics department observes a higher success rate for male applicants than for female applicants. To investigate whether this is the same across the two sub-departments of Pure and Applied Mathematics, the following year the department asks each applicant to give their preference for pure or applied mathematics (they are not allowed to be ambivalent) and records the resulting statistics as shown:

Total:

	Applications	Successful
Female	300	30
Male	1000	210

Prefer applied:

	Applications	Successful
Female	270	18
Male	350	15

Prefer pure:

	Applications	Successful
Female	30	12
Male	650	195

- Compare the success rates for male and female applicants that prefer applied mathematics, prefer pure mathematics and their success rates overall.
- What do you notice? Why is this possible? This is known as **Simpson's paradox**.

Explore the *'Making Diversity Count'* research project
The research project highlights the importance of representation in STEM, linking to our discussion of gender equality (SDG 5) and equity (SDG 10).

Discover biographical posters of STEM Champions
Learn about diverse mathematician and scientists who challenged stereotypes and inspire the next generation!

Mathematical approach: This problem focuses on applying **probability** and **data analysis** to demonstrate Simpson's paradox, a statistical phenomena in which a trend appears in several groups of data but disappears or reverses when the groups are combined. The question involves calculating and comparing the success rates for male and female applicants within each of the subgroups, which are Pure Mathematics and Applied mathematics, as well as for the whole group. By examining how group sizes and success rates contribute to combined data, the analysis provide a deeper understanding of the mechanics of the paradox.

Key sustainability insight: This question combines mathematics with real-world issues related to gender equality (SDG 5) in education and professional environments.

- **Gender disparities in STEM**: This question draws attention to gender disparities in mathematics and other STEM fields worldwide.
- **Broader inequalities**: It highlights how misinterpreting data can reinforce existing inequalities and shows the importance of transparency and accountability in data analysis, aligning with SDG 10.

This issue demonstrates the crucial role of mathematics in undercovering hidden disparities and supporting informed decision-making to promote fairness and equity.

Embedding SiM – Example Solution (Year 1)

Problem 3 – Simpson's paradox
Mathematical topic : Probability
Contribution to SDGs : Gender Equality (SDG 5), Reduced Inequalities (SDG 10)

Calculations:
The success rates for male and female applicants based on preference (Applied or Pure Mathematics) and overall are calculates as follows:

	Prefer applied	Prefer pure	Total
Female	$\frac{18}{270} = \frac{14}{210}$	$\frac{12}{30} = \frac{4}{10}$	$\frac{30}{300} = \frac{10}{100}$
Male	$\frac{15}{350} = \frac{9}{210}$	$\frac{195}{650} = \frac{3}{10}$	$\frac{210}{1000} = \frac{21}{100}$

Observations:
Simpson's paradox is observed here: Females have higher success rates within each sub departments, yet their overall acceptance rate is lower than males; **0.21 (male)** vs **0.1 (female)**.

Explanation:
- The largest male cohort (those who prefer pure mathematics – 650 applicants) has a high success rate of 0.3, raising the overall male success rate.
- However, the largest female cohort (those who prefer applied mathematics – 270 applicants) has a much lower success rate of 0.067, which drags down the overall female success rate.

Key questions to think about:
1. Analysing fairness in data aggregation:
   - How do different cohort sizes influence the outcomes?
   - What is the impact of Simpson's paradox on policy making in education?
2. Understanding sustainable systems
   - How can mathematics be used to promote equity and fairness in admission policies?
   - What steps can institutions take to ensure diversity and inclusivity in male dominant fields?
3. Sustainability in decision making
   - How does this analysis connect with broader sustainability goals, such as reducing gender equality **(SDG 5)** and ensuring quality education **(SDG 4)**.

Why these questions matter:
- Mathematical analysis supports sustainable problem solving by revealing hidden trends like Simpson's Paradox.
- In this way, it is possible to avoid misleading conclusions and promote the development of more inclusive, fair outcomes.
- These insights enable educators, policymakers, and researches to incorporate equity and sustainability into their decisions, supporting diversity and sustainable development.

Y1 SiM Student Feedback Responses (n = 140)

(1) Were you aware of "sustainability in mathematics" before coming across these problem exercises?

*"I was **familiar with sustainability in engineering but not in mathematics**. Every time I hear about sustainability, I **tend to focus on the design aspects**."*

*"**No**, I was **not aware** because this was **never taught in our schools**, and how mathematics can be related or used as a tool to tackle the goal of sustainability was never explored before."*

*"I am **surprised there is such term as "sustainability in mathematics",** I never thought it could exist."*

(2) What did you find most enjoyable or interesting about these exercises?

*"I found it **interesting how seamlessly sustainability is incorporated into the maths curriculum**, making it seem natural and relevant. I also liked **how the reflective aspect encourages students to consider the broader implications of their work**."*

*"I found it interesting the **mathematical techniques that can be used in real life** to measure issues faced and **provided quantitative data** that can then be used to **make changes.**"*

*"I found that this would be **good to push for more critical thinking** and closer attention to detail."*

Y1 SiM Student Feedback Responses (n = 140)

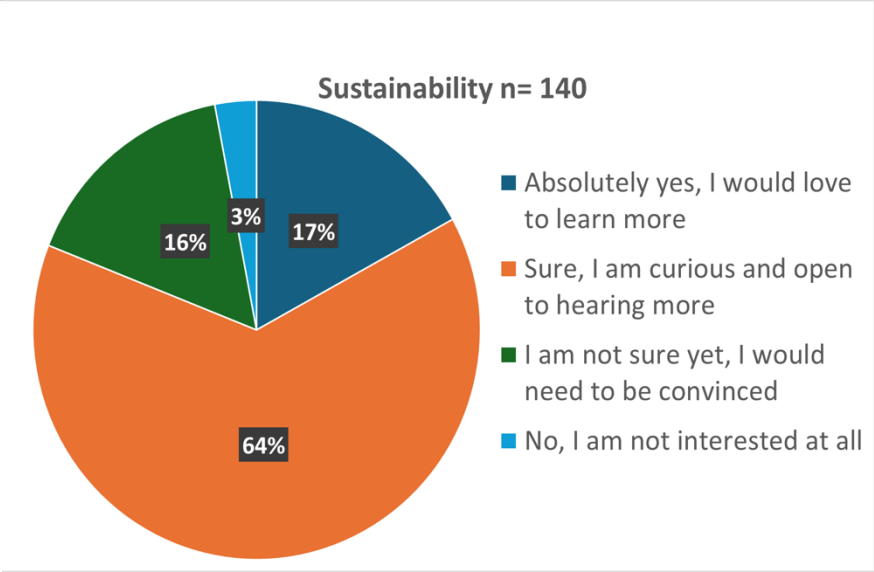
(3) What suggestions, if any, do you have for improving these exercises?
*"I would add **an accompanied diagram** with the solutions to make it easier to understand it would be a **visual aid** as well as **links to similar questions** I can do to check my understanding."*
*"It would be nice to have an **optional in-person session** for those interested in more, maybe **even a society** that runs sustainability related events."*
*"To improve these exercises, create questions that will **use A-level content** that the majority of **first year students will know** from learning in prior years."*

(4) Would you like such exercise problems to be introduced in a classroom setting e.g. in lectures or tutorials?
***"Yes**, I think it would be good to introduce such exercise problems in **problem-solving sessions** and **worksheets provided for the week** so that we are able to get a better understanding on the topic covered."*
***"Yes**, as they **make the learning more real** and potentially **easier to understand** as they are linked to a real-life context."*
***"I wouldn't be fond** of such material to be presented in-class as it is **not examinable content and might not be of high interest** to all students. It should be recommended **for online reading** at **one's own pace and spare time**."*

Y1 SiM Student Feedback Responses (n = 140)

(6) Did these resources makes you want to learn more about sustainability in mathematics and its impact in real-world?

*Majority (80%) open to learning more, with only 20% not very sure, **highlighting strong engagement and uptake overall**.*



Formative Practice Quiz

- Introduced in 2025-26 implementation in **response to student feedback** from previous years
- Designed to **capture students' understanding** of sustainability and ethics in mathematics.

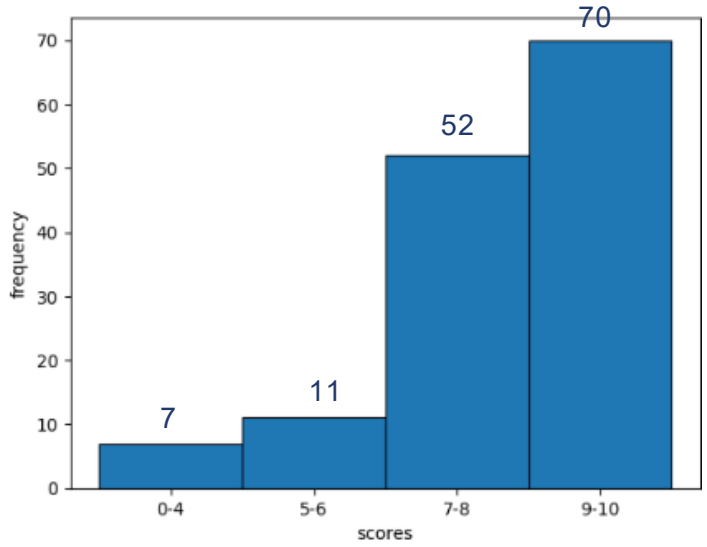
Which SDGs are linked to the **'Simpson's Paradox'** problem?

- a. Affordable and Clean Energy (SDG 7) and Industry, Innovation and Infrastructure (SDG 9)
- b. Reduced Inequalities (SDG 10) and Gender Equality (SDG 5)
- c. Decent Work and Economic Growth (SDG 8) and No Poverty (SDG 1)
- d. Clean Water and Sanitation (SDG 6) and Life on Land (SDG 15)

Which of these mathematical topics is most relevant to modelling the spread of a pollutant over time?

- a. Probability
- b. Differential equations
- c. Trigonometry
- d. Number theory

Quiz Performance (n = 140)



Score	0	1	2	3	4	5	6	7	8	9	10
Frequency	0	0	3	2	2	4	7	18	34	68	2
Relative Frequency	0%	0%	2%	1%	1%	3%	5%	13%	24%	49%	1%

- Quiz results **indicated a strong overall understanding** of the poster material.
- Out of 140 students, approximately **74%** achieved a score of 8 out of 10 and more.
- High scores **suggest students read the posters thoroughly** and engaged meaningfully.
- Overall, the practice quiz successfully **increased engagement** and **reduced superficial interaction.**

Embedding EiM – Example Problem (Year 2)

Problem 1 - Confronting Your Boss with Logic

Topic: Propositional logic

Context of the problem: Your boss has given you a task. The task is well within your technical capability, but you are not sure whether it would be legal or ethical. You feel uneasy, but your boss tells you: '*If you don't do it, then someone else will.*'

Do you think that the boss' argument is cogent? Does that depend on who you are or what the project is? How would you answer your boss?

Mathematical approach : This problem can be mathematically examined by investigating the **reasoning** and **logic** behind the boss's statement.

- The statement *'If you don't do it, then someone else will,'* shows that someone else could replace you to do the task.
- Therefore, by using the tools of **propositional logic**, you can work out the likelihood for someone else to do the task instead of you.

Key ethical insight: Ethical decision making considers both logical reasoning and personal values.
Interpersonal integrity: It is essential to act morally as unethical behaviour could lead to unreliability.
Responsibility: Promoting ethical decision-making in the workplace can result in a positive environment to work.

Embedding EiM – Example Solution (Year 2)

Problem 1 – Confronting Your Boss with Logic
Topic: Propositional logic

Sock Analogy – to understand the problem

- Imagine a bag containing **1 red** sock and **9 blue** socks. There are **10 people** who pick a sock from the bag. The statement ***'If you don't pick the red sock, someone else will'*** is only **true if all 10 people pick a sock**.
- If **not all 10 people participate**, there is a chance that the **red sock may never be picked**. What is true instead is ***'If you don't pick the red sock, someone else might.'***

This shows that just because an action can happen it does not mean it will happen. The probability of an event happening depends on how many people are actually willing to do it.

This is a **flawed assumption**:

- The phrase assumes at least one person will carry out the task.
- This is not true as if no one else is available or willing to do it, the task may not happen at all.

Therefore, going back to the problem:

- The correct phrasing should be ***'If you don't do it, someone else might.'*** So now we are accounting for the probabilities of the event's occurrence.

Ethical Considerations:

- Ethical decision making depends on evaluating its consequences not just its probability of occurrence.
- Justifying actions based on the belief that something will happen can lead to unethical decisions since it ignores the chance that it may not occur.

Embedding EiM – Example Problem 2 (Year 2)

Problem 4 – Mathematical Communication

Topic: Numerical methods

Context of the problem:

(a) A smooth function $F : [a, b] \to \mathbb{R}$ satisfies $F(a) < 0 < F(b)$ and $F'(x) > 0$, ensuring a unique solution c to $F(x) = 0$. Numerical approximations to c can be obtained using the Newton-Raphson iteration method, which converges quadratically. **State the Newton-Raphson formula and explain it graphically for a none technical audience.**

Mathematical approach: This problem involves using two mathematical techniques:

1. **Newton-Raphson iteration**: This method numerically approximates the root c of a function $F(x) = 0$. By iteratively drawing tangents to the curve $F(x)$ and finding where they intersect the x-axis, we create successively better approximations of c. This method converges quadratically, making it efficient for practical applications.

Key ethical insight: This problem demonstrates the importance of effective mathematical communication in real-world contexts, particularly to non-technical audiences. Key ethical insights include:

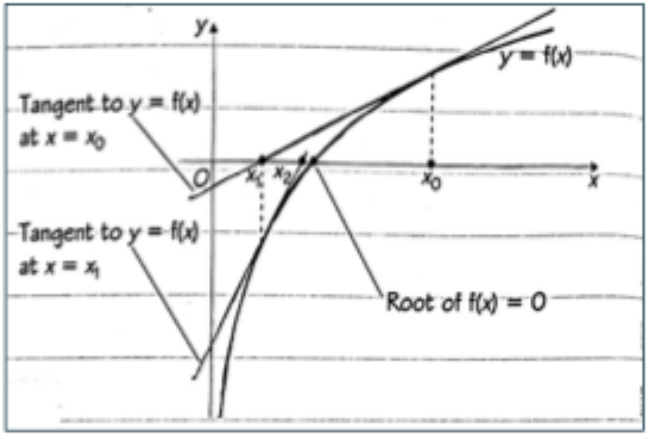
- **Accessibility and inclusivity:** Simplifying mathematical concepts ensures broader understanding, empowering non experts to engage in informed discussions.
- **Transparency and responsibility:** Clear and accurate explanations build trust, ensuring stakeholders understand the limitations and implications of mathematical models without risking misinterpretation.

Therefore, mathematical communication should prioritise clarity and inclusivity to promote ethical understanding and responsible decision making across diverse audiences.

Embedding EiM – Example Solution (Year 2)

Problem 4 – Mathematical Communication

Topic: Numerical methods (Newton Raphson Iteration)



(a) Newton Raphson Iteration:

Newton-Raphson iteration is a method used to find approximations of roots of a function $F(x)$ when an exact solution is difficult to determine. It follows the iterative formula:

$$x_{n+1} = x_n - \frac{F(x_n)}{F'(x_n)}$$

Simplified Explanation for Non-Mathematicians.

- Think of a smooth curve that starts below the x-axis and ends above it. In between, it must cross the x-axis and that is its actual root.
- To approximate the root, we start with a reasonable guess and improve it using refined adjustments based on the tangent line (slope of curve) to get a better estimate.
- This process can enable us to get closer to the actual root within a certain degree of accuracy.

Ethical Considerations

- **Simplifying mathematical terminology:** Avoid using advanced terms like 'derivative' or 'convergence'. Instead use familiar language such as 'rate of change' for 'derivative' and 'getting closer to the answer' for 'convergence'. This ensures a lay audience can understand the explanation.
- **Respect for educational background:** Many people may not have studied beyond high school mathematics. Therefore, avoid discussing complex mathematical properties like 'smooth functions' or 'uniqueness of solutions' without providing clear, intuitive explanation. Visuals and analogies are key to making the content reliable.

Y2 EiM Student Feedback Responses (n = 188)

(1) Were you aware of "ethics in mathematics" before coming across these problem exercises?

*I was **aware of law in mathematics** however this was the **first time coming across the ethics** side of the subject."*

*This was the **first time I had come across the ethics in maths**. After looking at the questions, it became clear that the nature of the **ethics is much more abstract than the laws of mathematics**."*

*I have always explored the world of ethics from a broader point of view than specific to mathematics. **Ethics for me has always been a moral philosophy** to know how to differentiate right from wrong in life."*

(2) What did you find most enjoyable or interesting about these exercises?

***'I really enjoyed these exercises because they went beyond just maths**—they made me think about real-world ethics. The '**Confronting Your Boss with Logic' problem** showed how people justify unethical actions, which was **eye-opening**. The **Crime Scene Investigation problem felt like a detective**"*

*'I found it **interesting how mathematics can be used in real-world decision-making** and the ethical dilemmas that arise from these applications. The '**Newton's Law of Cooling'** example in crime scene investigation was **particularly engaging**, as it demonstrated how mathematical models can influence forensic conclusions."*

*The nice thing about these exercises is that they are **based on current topics**, e.g. **ethics applied to the world of natural disasters** which for me is a very fundamental topic **linked to my degree (sustainable engineering)**."*

Y2 EiM Student Feedback Responses (n = 188)

(3) What did you find most challenging or difficult about these exercises?

*"The **abstract nature of the questions was something that I had never come across before**, especially given the fact that, **as engineers we focus of applied mathematics and not open-ended questions**."*

***"I wouldn't be able to solve them without the solutions. However, I don't think that that's a bad thing,** as these questions provided a different type of challenge which was a nice change."*

(4) What suggestions, if any, do you have for improving these exercises?

***"Less mathematical questions** and more **questions like the 'Confronting Your Boss with Logic'** would be preferred."*

*"More **videos and maybe add quizzes**, to make it more interactive."*

(5) Would you like such exercise problems to be introduced in a classroom setting e.g. in lectures or tutorials?

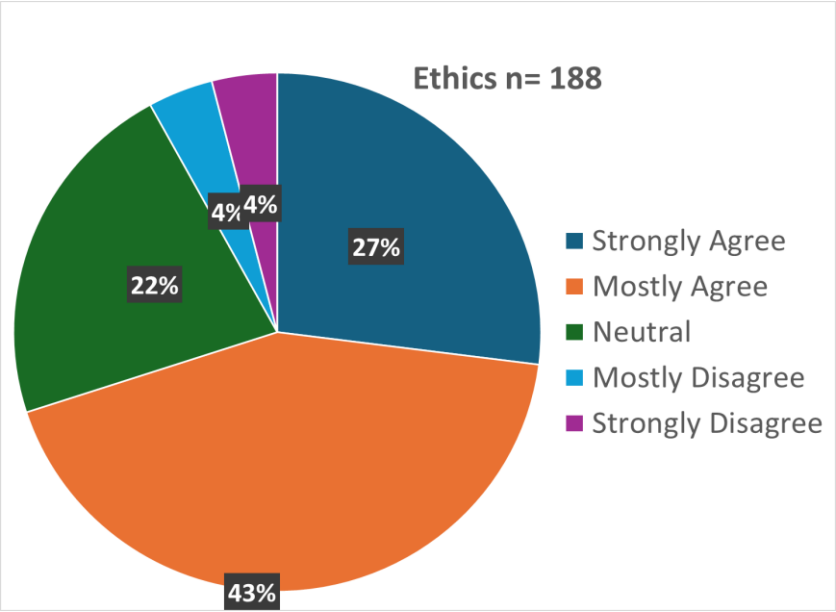
*"Maybe **during skills and employability week**, but **not during regular classes** unless it was actually relevant to the topic."*

*"Yes, in our **problem-solving exercises**, by adding an **ethical question at the end of each problem**."*

Y2 SiM Student Feedback Responses (n = 188)

(6) These resources made me want to learn more about ethics in mathematics or its impact in the real world.

Majority (70%) agreed, with only 8% disagreeing and 22% remaining neutral, ***highlighting strong engagement overall****.*



Analysis of Student Feedback (EiM and SiM)

- Most students **unaware of both ethics and sustainability in mathematics** (only aware of them in design/engineering/law contexts)
- Students **enjoyed** integration of ethics/sustainability and mathematics, through real-world scenario-based problems
- Students **appreciated the clear layout, simple explanations, and step by step solutions,** which made the material easier to understand.
- Several students suggested adding more **videos, quizzes, visuals and discussion-based activities** to improve engagement and learning.
- Many students supported introducing content **in lectures or tutorials** (**only if done in a relevant manner),** others preferred keeping them **optional**.

Concluding Remarks

- **Faculty support is critical** for integrating ethics/sustainability in technical modules, but this can be hard. (responses such as "*I teach mathematics/mechanics/computing; how can I incorporate ethics/sustainability into my course?"*).

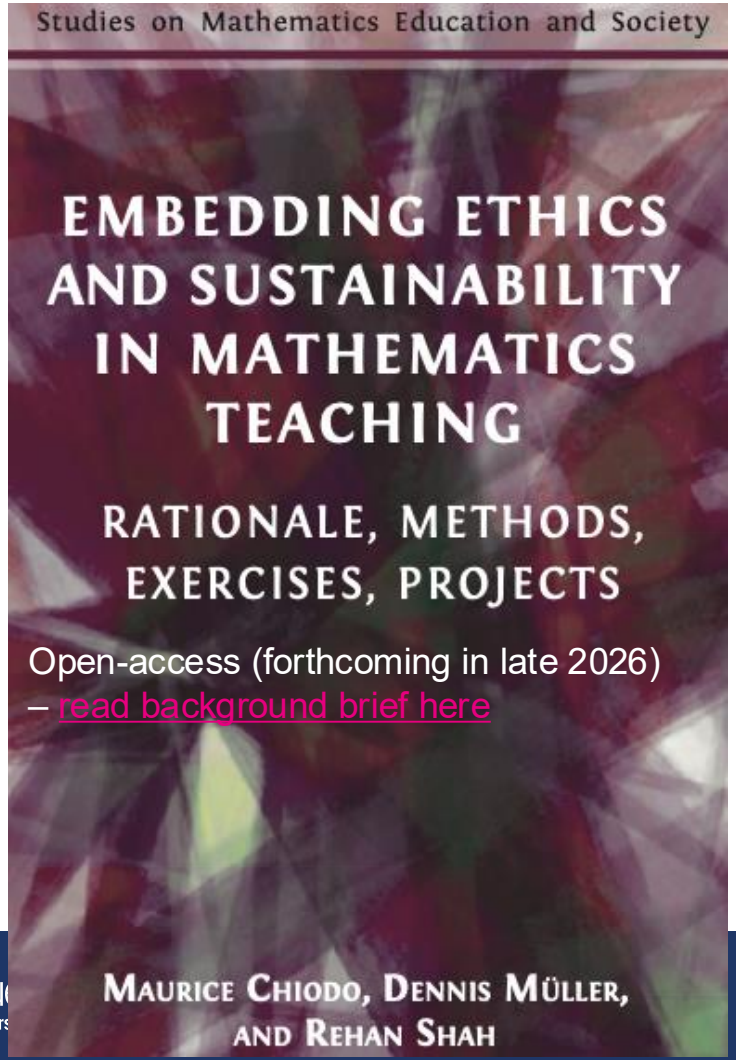
- As educators, we have a **responsible to equip students with the tools to address global challenges** by embedding sustainability, societal and environmental issues into the mathematical curriculum.

- Ethics *is* a matter of opinion, and it *is* subjective, **does not mean it cannot (and should not) be addressed?**

- When other disciplines face ethical/sustainabillity issues and train professionals to deal with them, **how can we exclude ourselves from them?**

Impact Highlights of Project

- **Increase in module student satisfaction results** over 3 years (from 67% to 82%)
- Students presented findings at **QMUL Festival of Education** and represented QMUL to showcase work at **London Student Sustainability Conference** in 2025 and 2026
- Work incorporated in featured in new university-wide sustainability awareness module 'Foundations of Sustainability' and as part of an inclusive sustainability toolkit course with UCL
- Dr. Shah **invited to deliver workshop sessions** at University of Kent, UCL, University of Cambridge (now Bath!) and served as **expert reviewer** for sustainability in **QAA subject benchmark statement**
- Both student **co-creators awarded QMUL Student Enhanced Engagement and Development (SEED) Award** for contributions to project
- Dr. Shah's work **nominated for QMUL Education Excellence Awards** for 2025-26 and **among top 3 finalists for QMSU Education Award** for '*Sustainability Champion of the* Year' for 2024-25



Open-access (forthcoming in late 2026) – read background brief here

Supplementary Resources

Ethics in mathematics:

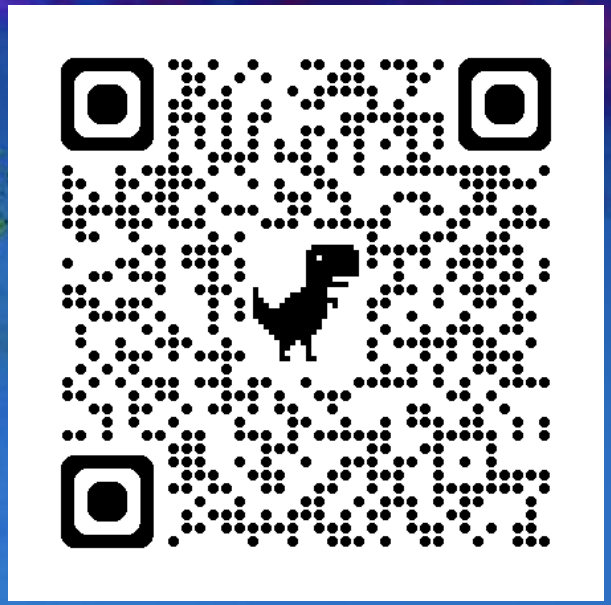
- Ethics in Mathematics Teaching Toolkit, M. Chiodo, D. Muller, **R. Shah**, arXiv, 2025.
- The role of ethics in a mathematical education, M. Chiodo, R. Vyas, Ethics in Mathematics Discussion Papers, 2019.
- Teaching Ethics in Mathematics, M. Chiodo, P. Bursill-Hall, LMS Newsletter **485**, 22-26, November 2019. Republished in the EMS Newsletter **114**, 38-41, December 2019
- Cambridge Ethics in Mathematics project, M. Chiodo, D. Mueller

Sustainability in mathematics:

- EPC Sustainability Toolkit Guidance Article, **R. Shah** (Mar 2024)
- IMA Mathematics Today Feature Article, **R. Shah** (Feb 2025)
- QMUL non-credit bearing Foundations in Sustainability module

Thank you for listening!

Scan to access our toolkit resources (Project 2)



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