Queen Mary
University of London

Teaching Ethics in Mathematics?

You Must be Joking!

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Ethics in Mathematics: An Overview

- Why do we need it?
- What is its current state?
- How can we embed it in our teaching?
- Feedback and concluding remarks

Need for Ethics in Mathematics (EiM)

- **Both** pure and applied mathematics can lead to ethical consequences, mathematics today is an extremely sharp **double-edged sword**

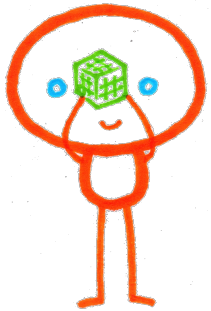
- Many examples of this such as **financial mathematics, data science, AI, statistics, mass surveillance, social networks, industrial mathematical modelling, cryptography, communication metadata, etc.**

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

- As educators, we train professional mathematicians, but are we really giving them a **professional training?**

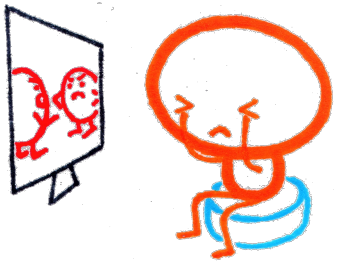
Current state of EiM: Not my problem!

This is M.



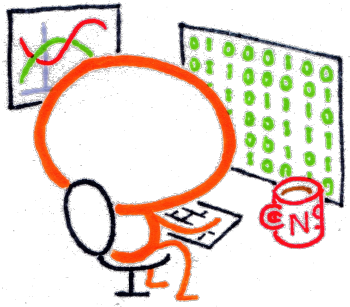
M is very clever and likes solving fun puzzles and maths problems.

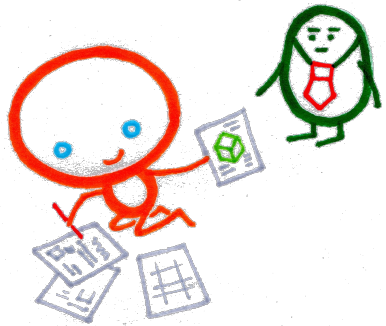
M doesn't like thinking about politics or society.



The outside world is scary.

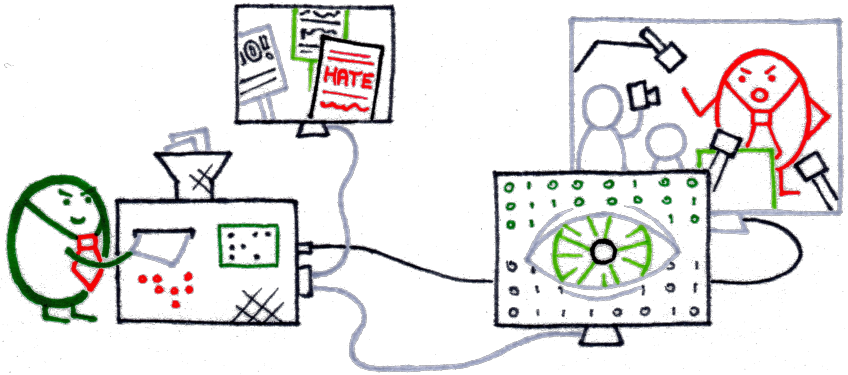
At work, M is given shiny new problems to work out every day.





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

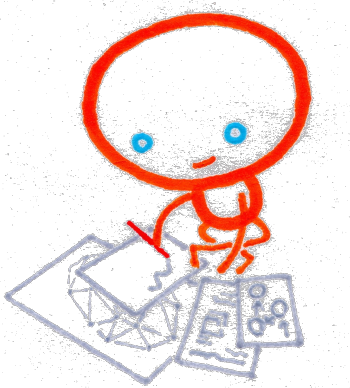
Current state of EiM: Not my problem!



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

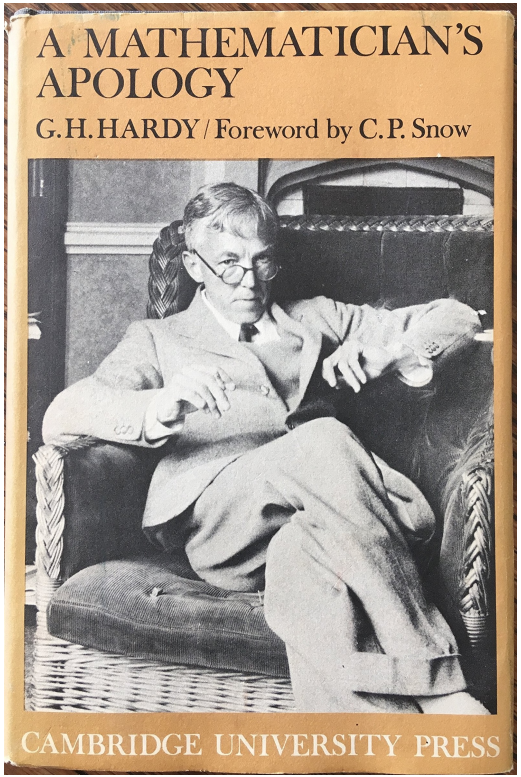
Professional Views of EiM

- 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)

- The *London Mathematical Society's* (LMS) ethical policy is largely **concerned only with academic ethical issues** (publishing, reviewing, discrimination)



How can we teach EiM?

- **Interweave ethics into existing mathematics-based courses**

- involves **inserting ethical perspectives into standard mathematics courses**

(e.g. like EPC's engineering ethics toolkit)

- usually done through **careful design of 'tutorial' questions** on weekly problem sheets

(will require training academic staff, not been done before)

- first pilot run implemented in two large (300-400 students each) **first and second-year** undergraduate **applied mathematics modules** (through asynchronous learning)

How do we integrate EiM?

Basic principles:

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

- Focus on how students engage with ethics, **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

'Thought-Provoking' Ethics in Mathematics Questions (RS)

Motivation

The mathematical exercises provided below are designed to raise ethical awareness and imbibe transferable skills a
STEM disciplines as part of an ongoing scholarship research initiative undertaken by Dr. Rehan Shah from QMUL wit
of Cambridge. Some of the mathematical content in these exercises was inspired by actual tutorial sheet questions
course taught at the University of Cambridge.

In addition to traditional mathematical content, each of the exercise questions below also contain some ethical con
order to solve the problem fully, you will need to take into account this ethical aspect and consider it as part of your

"Solutions" to as many of these exercises as possible have been provided. These include both a full exposition of th
question, as well as a discussion and incorporation of the societal and ethical issues that are embedded in the quest
points for further discussion with Dr. Shah and your peers.

If you are more interested in this area and would like to engage in it further, please get in touch with Dr. Shah.

Exercise Questions

1. Confronting Your Boss with Logic
2. Ethics of Crime Scene Investigation
3. Mathematics of Military Engagment
4. Ethics of Environmental Disasters
5. Optimisation of Pipeline Construction
6. Mathematical Communication
7. Simpson's Paradox

Task

Please engage and have a look through these materials and then provide your feedback by comple
29 March 2024).

Introductory Handout: Why do we need ethics in mathematics? 172.2 KB

Ethics in Mathematics Exercise Questions 891.5 KB

Ethics in Mathematics Exercise Solutions

Available from **12 February 2024, 9:00 AM**

Feedback Survey

Embedding EiM: Example Problem 1

Problem 1: Pipeline Construction

Topic: Optimisation

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 13km from the coast. The refinery is on the coastline, a distance 10km from the point on the coast closest to the platform. Building the pipeline will lead to a cost of £90,000 per km at sea and £60,000 per km 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?

Embedding EiM – Example Problem 1 Commentary

Solution comments*: The cost-minimising path is given by Snell's law and is an exercise in trigonometry and calculus. But who said we were optimising over cost? This is an assumption often engrained into mathematicians, engineers, scientists and economists, while they are students, but it need not always be the right way to optimise. How many decisions made by government agencies (often based on advice offered by mathematical consultants) use economics as the sole criterion for optimization?*

Economic actions almost always have externalities, such as possible damage to the environment (the pipe may go through a coral reef or protected habitat) or to existing infrastructure (it may go through a school or a site of archaeological significance). How could we mathematically model the environmental and human impact of laying this pipe? There are numerous factors to consider and students, much like policymakers would, should take a holistic view of these effects and at least be aware of, and question the implications of basing decisions solely on economic factors.

Embedding EiM: Example Problem 2

Problem 2: Simpson's Paradox

Topic: Probability

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 he two sub-departments of Pure Mathematics 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

a) Compare the success rates for male and female applicants that prefer applied mathematics, prefer pure mathematics and their success rates overall.
b) What do you notice? Why is this possible? This is known as Simpson's Paradox.
c) If possible, find the admission statistics by gender and mathematics preference (pure/applied) from your university's mathematics department and see if the same phenomenon occurs.

Embedding EiM – Example Problem 2 Commentary

Solution comments: *The purpose of this question is to demonstrate Simpson's paradox in which a trend appears in several different groups of data, but disappears or reverses when these groups are combined. It also attempts to highlight the immense gender disparity in many mathematics departments around the world.*

(a) We calculate the success rates:

	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	$\frac{15}{350} = \frac{9}{210}$	$\frac{195}{650} = \frac{3}{10}$	$\frac{210}{1000} = \frac{21}{100}$

(b) We note that females with a given preference have a higher success rate than males with the same preference, but lower overall. This is Simpson's Paradox.
The heuristic reason for why this is possible is that the largest male cohort (prefer pure) has a much higher acceptance rate (0.3) than the largest female cohort (prefer applied) which is about 0.067. So what dominates the overall acceptance of men is for those who prefer pure (0.3), while what dominates overall acceptance for women is those who prefer applied (0.067).
This is a great lesson in why it is usually a terrible idea to "take averages of averages".

Student Feedback Survey Responses

(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**. I had assumed that the concept, upon first sight, would surround mathematical laws. After looking at the questions, it became clear that the nature of the ethics is much more abstract that 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 found the **challenging and thought-provoking** which was a **nice change to the examined maths** that we have been doing in this semester so far.*

Learning about the different issues and problems that also occur in Maths.

*I found it very **interesting how ethics is applied in mathematical problems** and how the mind is used to be able to carry out these exercises requires a lot of reasoning and reflection. The nice thing about these exercises is that they are **based on current topics**, specifically the most interesting exercise was number 4 where we have **ethics applied to the world of natural disasters** which for me is a very fundamental topic linked to my degree (sustainable engineering) and helped me understand the management of pollutants.*

Student Feedback Survey Responses

(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 didn't solve the questions by myself, I **used the solutions to read through the questions**. Therefore, the exercises made sense when doing so.*

*The **difficult part of these exercises is the reasoning** required for each of them. The most challenging exercises were 6 and 7 where a more advanced level of mathematics was applied compared to the first exercises.*

***I wouldn't be able to solve them without the solutions. However, I don't think that that's a bad thing.** I was used to being challenged academically but on practical questions, therefore these questions provided a different type of challenge which was a nice change.*

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

*I believe that **examined material and additional knowledge should stay strictly separate**. However, this topic could be **integrated within the skills and employability week** curriculum.*

*If there was a **link to the classroom materia**l, then it would be interesting for e.g. **industrial applications** which could be useful for engineers to have knowledge of.*

***Maybe one question per week**, so there is time to do course material and some ethics*

Concluding Remarks

- **Faculty support is therefore critical** for integrating EiM into courses, but this can be hard (responses such as "*we're a mathematics/engineering department* or *this is a technical mechanics module, why are we teaching ethics here?"*)

- Ethics *is* a matter of opinion, but that **does not mean it cannot be addressed**

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

- As educators, we have a **duty to teach our students** how to use the mathematics they learn responsibly

References

Ethics in mathematics resources: Cambridge EiM project website

- Ethics in Mathematics Teaching Toolkit (V1), M. Chiodo, D. Muller, R. Shah

- 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


Thank you for your time!
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