THE ROLE OF ETHICS IN A MATHEMATICAL EDUCATION: A WHITEPAPER

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1. Introduction

Ethical considerations become evident and essential in a discipline the moment it (that is to say, its practitioners) begin to have a measurable impact on the world and the way it is shaped. Mathematics, in the manner in which it is taught and practised, has traditionally maintained a distance from real world considerations due to the sheer abstraction of its subject matter. However, the majority of students who study mathematics as undergraduates do not continue in academia, but instead move into other industries. In the early 21^{st} century it is surely a commonplace that mathematics and mathematicians play a fundamental role in the economy and in society, impacting sectors ranging from engineering and biotechnology to finance, information technology, data science, and public policy.

2. Ethics in science and technology

Most mathematics students do not have formal exposure to the legal, ethical, and social implications that can arise as a byproduct of their work; the contrast is particularly stark when compared with the ethical training individuals working in other technical subjects, such as engineering, or the biological, physical, or digital sciences, receive. Medics, biologists, physicists, engineers, chemists, psychologists, social scientists, and even lawyers(!) are taught ethics because their professional work has an important effect on the lives of others. There is a general understanding among practitioners in various scientific and engineering disciplines that their work can have broader ethical implications for society.[1] The Association of Computing Machinery explicitly states that it "... affirms an obligation of computing professionals, both individually and collectively, to use their skills for the benefit of society, its members, and the environment surrounding them" in its Code of Ethics and Professional Conduct.[2] The American Chemical Society claims to "supports high standards of ethical conduct and integrity in the community of chemistry and related disciplines for the benefit of science and society."[3] The American Physical Society regularly issues statements covering a comprehensive range of ethical issues.[4] The Royal Statistical Society state in their Code of Conduct[5] that "Fellows should always be aware of their overriding responsibility to the public good; A Fellow's obligations to employers, clients and the profession can never override this."

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[1] P. Rogaway, *The moral character of cryptographic work*, http://web.cs.ucdavis.edu/~rogaway/papers/moral.html

[2] https://www.acm.org/code-of-ethics

[3] https://www.acs.org/content/acs/en/about/governance/committees/ethics.html

[4] https://www.aps.org/policy/statements/

[5] http://www.rss.org.uk/Images/PDF/join-us/RSS-Code-of-Conduct-2014.pdf

Similar statements emanate from bodies representing a wide spectrum of scientific and engineering communities; these are reflective of a broad consensus amongst members of these communities that their scientific work can have and does have social consequences. Moreover, a recent issue[6] of the Philosophical Transactions of the Royal Society A was dedicated to the impact of algorithms on society.

3. Ethics in mathematics

It is instructive to contrast this with ethical perspectives held by groups of mathematicians around the world. The American Mathematical Society offers a policy statement on ethical guidelines, but this document is essentially concerned with the ethical issues that arise from mathematics as a branch of academia: aspects related to performing, publishing, and reviewing research, and those related to discrimination within the mathematical community.[7] A similar perspective is offered by the European Mathematical Society.[8]

While the Society for Industrial and Applied Mathematics does provide a "Statement of Inclusiveness" covering discrimination,[9] it does not appear to provide a broad ethical policy statement. The subtext here seems to be that while there are ethical issues in applied mathematics, these are imported from the disciplines that the mathematics in question is being applied to, and thus do not require a separate mention. However, their monthly publication *SIAM News* has, over the last decade, been publishing articles relating to ethics in mathematics which have had a gradually increasing level of depth and seriousness.

This lack of policy statements is broadly reflective of a long-standing consensus within the mathematical community: that while mathematics might be *applied* to various situations with social consequences, mathematics itself is free of ethical connotations.[10] Mathematics is always done by people, and they always live, work and think in a complex social environment.

4. The need for this today

The majority of mathematics students, both pure and applied, end up working in roles where they *are* using their mathematical skills in a manner that can and does have ethical consequences. There are many examples of this, in sectors ranging from finance (the construction of very sophisticated, complex, and potentially toxic financial products) to government surveillance, to data science and information technology (the growing influence and impact of large-scale, complex, automated networks, and the algorithms that operate on them) to classical engineering disciplines (the mathematical modelling behind many industries in the hydrocarbon extraction and processing sectors). This, in turn, results in capable and trained individuals entering industry, government, and policy sectors without any training or taught sensitivity to the ethical tools that enable them to effectively appreciate and grasp the moral consequences of their actions. Indeed, the very nature of a pure mathematics education can exacerbate this imbalance: abstract

[6] Sofia Olhede and Patrick Wolfe (eds), *Discussion meeting issue: "The growing ubiquity of algorithms in society: implications, impacts and innovations"*, Phil. Trans. Royal Soc. A, **376**, no. 2128 (2018).

[7] http://www.ams.org/about-us/governance/policy-statements/sec-ethics

[8] http://euro-math-soc.eu/committee/ethics

[9] https://www.siam.org/About-SIAM/Policies-Guidelines/Detail/statement-on-inclusiveness

[10] "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*.

pure mathematics courses are often taught by individuals with little or no experience working or engaging with structures outside academia, thus preventing broader context from manifesting even by osmosis. The effect of this can be dramatic: well-meaning individuals can end up engaging in technical work without being fully aware of the broader impact of their actions; beyond moral and ethical considerations, these actions can often have legal consequences. We train professional mathematicians; are we giving them a *professional training*?

Some may argue that mathematicians working in industry or policy will inevitably develop the skills required to ethically orient themselves in whatever space they are operating in. While those working in any given industry may indeed gain some insight into the legal and regulatory mechanisms that oversee it, we do not believe that this necessarily leads to broader ethical overview of the manner in which harm may emanate from it. Every organisation develops an internal culture, and this internal culture determines how those working there behave, what they become aware of, and how they react to what they become aware of; it is very easy for young people who have no prior ethical training to simply imbibe the ethical perspectives (or lack thereof) of their first few employers. The frantic pace of work in modern industry often does not allow those working in it the time to even consider issues that are outside their immediate purview. It is therefore important that individuals who will engage in technical work gain some exposure to the manner in which harm can arise as a byproduct of their work during their education, as this may permit them to develop the skills required to instinctively detect ethical issues in their later life; this is especially important for those whose technical training has been at a very abstract level in subjects such as mathematics.

5. **So what do we do?**

We argue that universities and faculties should develop formal processes to expose students studying mathematics to the broader ethical space in which they operate.

5.1. **Interweaving ethics in other lecture courses.**

One option is to insert ethical perspectives into standard university mathematics courses, either in content or through the framing of certain questions on an example sheet. This is difficult and delicate to do effectively; to discuss ethical aspects in a substantial manner without compromising on mathematical content, and to do so in a manner that does not seem overly contrived. There are certain mathematical subjects that may naturally lend themselves to this project, such as financial mathematics, mathematical biology, or certain aspects of mathematical physics; however, mathematicians lecturing across the pure mathematics spectrum might be encouraged to consider such an exercise. It would be important for that resources are available for those colleagues who wish to do this, because nobody trained *them* in it.

5.2. **Ethics courses.**

Historically, exposure to ethics in some form has been the norm for individuals working in the natural sciences. Recently, there has been a burgeoning interest in providing ethics lecture courses for individuals learning and working in technical disciplines such as computer science.[11] [12] An example of such a course given at Cambridge is Professor

[11]A list of over 200 such courses can be found here: https://docs.google.com/spreadsheets/d/1jWIrA8jHz5fYAW4h9CkUD8gKS5V98PDJDymRf8d9vKI

[12]It should be noted that ethics courses have historically been common in the computer science community: for example, the Association of Computing Machinery requires the presence of some ethical

Ross Anderson's examinable course on Economics, Law and Ethics at the Computer Laboratory.[13] Other examples are courses at Harvard - MIT[14] and Stanford,[15] with budgets in the millions of dollars. Additionally, the 2018 SIAM Conference on Applied Mathematics Education[16] hosted a parallel session on ethics in mathematics.

Awareness of this is, in some sense, reaching top-level mathematics faculties, as evidenced by a recent comment[17] by the Head of Applied Mathematics at Oxford, Prof. Michael Giles:

> *Cambridge Analytica is interesting from one point of view in that, if you'd asked me 20 years ago whether mathematicians at the DPhil level needed to be exposed to ideas of ethics, I would have said 'Clearly, that is irrelevant to mathematicians'. Now I really think that this is something we have to think about, in the same way that engineers have courses looking at 'What it means to be a professional engineer', and 'Ethics, and your responsibilities as an engineer'. I think that is something that we have to think about as mathematicians now.*

In comparison with computer science, there are far fewer instances of university courses about ethics aimed at mathematics students. The first attempt at such a course seems to be one given annually from 1998 to 2004 at the University of New South Wales by Professor James Franklin;[18] more recently, since 2016, the student-run Cambridge University Ethics in Mathematics Society[19] has hosted a series of lectures, given by Dr Maurice Chiodo.

What would a course in ethics in mathematics contain? Very roughly, it would cover the following topics: the ubiquity of ethical issues and the ambiguity that is inherently present in ethical issues; the fundamental, critical, and relatively unique roles that individuals with mathematical skills play in the economy and human society; the various ways harm can arise as a byproduct of the work of mathematicians. These would be illustrated through the use of real case studies drawn from classical engineering and technical examples, from finance, from government policy, and from the 'new' economy that is currently arising out of data science and algorithmic design.

Today, the majority of ethics courses available to (but not necessarily targeted at) mathematicians and computer scientists are at universities based in the United States, where the flexibility inherent in the American higher education system makes it easier to manage the logistics around proposing and organising such courses. Developing courses that might fit into the British university context, where university programs are more structured and focused, will be an interesting and more delicate task.

6. **Should mathematicians be teaching ethics?**

Should mathematicians concern themselves with, and try to formally teach content that is not strictly mathematics? We argue that we should, and indeed already do. Mathematicians across the board tend to show an extensive but informal interest in the

training before they certify a course. The courses alluded to here are those which have a major focus on the manner in which technology intersects with governance and policy.

[13] https://www.cl.cam.ac.uk/teaching/1617/EconLaw/

[14] https://www.media.mit.edu/courses/the-ethics-and-governance-of-artificial-intelligence/

[15] https://stanfordcs181.github.io/

[16] https://www.siam.org/Conferences/CM/Main/ed18

[17] https://twitter.com/OxUniMaths/status/1044863537405923328, 26 September 2018.

[18] http://www.austms.org.au/Publ/Gazette/2005/May05/franklin.pdf

[19] https://cueims.soc.srcf.net/

sociology of mathematics – the manner in which mathematicians interact with each other and form groups and cliques, and in the nature of academic rank, power, and privilege. We display a great deal of interest in the historicity of our subject, both with the purpose of staking claim and clarifying who proved what first, and also better understanding the growth and development of mathematics as a discipline over the ages. Often this interest in the history of mathematics extends into a formal context: Cambridge, for many years now, has offered undergraduate students a non-examinable course on this.

The interests described in the previous paragraph are *cultural* ones, albeit with a focus towards facets that are internal to the mathematics community. Of course, these aspects are not unique to mathematicians; practitioners in every academic discipline take an interest in the dynamics and development of their subject area. What is distinctive amongst the mathematical community is the sheer degree to which our cultural interests are *only* focused inwards; we claim that this is reflective of the consensus that mathematics, in its abstract and pure form, maintains a certain distance from 'real world' considerations.

In this document, we have argued that irrespective of the ethical implications of pure mathematics as an academic discipline, mathematicians have a large, fundamental, and growing impact on the world and the way it is changing. We believe that this should have an effect on the manner in which mathematicians – not just as individuals, but as a community - view and teach their subject, particularly with respect to the ways it can influence the world, and the harm that can arise from that influence.

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`https://www.ethics.maths.cam.ac.uk`

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