Integrated Ethics in Mathematics: Strengthening the STEM Curriculum with Ethical Reasoning

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We propose that the future of STEM education, and especially quantitative fields involving or featuring mathematics, should feature the explicit integration of ethical aspects of mathematical work as a normative curricular element. Ethical reasoning should be a critical component across the STEM curriculum, and mathematics courses are powerful opportunities to introduce, refine, and continue to develop these skills. Ethical and mathematical reasoning are each systemic approaches to problem solving, and naturally and mutually reinforce one another.

Why ethical reasoning and why mathematics?

Ethical reasoning is a concrete sequence of steps leading to a justifiable, evaluable decision. It is a learnable, improvable, set of knowledge, skills, and abilities. It can therefore be integrated into quantitative courses as observable learning outcomes and can strengthen mathematics and other quantitative reasoning courses, while also promoting ethical practice of, and with, mathematics.

We advocate a curriculum-spanning and culturally-ubiquitous engagement with the ethical aspects of mathematical work by contributors to, and users of, its techniques and outputs. When "ethics training" is limited to a single course, it teaches and reinforces that ethics is only important in that class. Instead, we propose that ethical decision-making should be a core, normative, feature in mathematical and other quantitative work.

Integrated, cross-curricular engagement with ethical reasoning-- by the mathematician and the user of mathematically-derived tools and methods -- should be normalized. Time and institutional support and resources should be committed to support the development of a library of materials for incorporating ethical reasoning into *all* mathematics courses, at the undergraduate and the graduate levels, for students within and adjacent to the discipline itself. Curriculum-spanning initiatives like this require engagement by faculty, students, and the wider community. Students and faculty will need practice and guidance in identifying and navigating ethical dilemmas, identifying and weighing options, considering the harms and benefits of their actions (or inactions), and recognizing the social consequences of their work. Normalization of ethical reasoning through curriculum-spanning integration should promote the recognition of, and responsibility to consider and address, ethical challenges inherent in mathematical work. A coherent plan is needed that fosters a commitment to *both* teaching and learning about ethical considerations in mathematical practice.

What it might look like

The presentation in the future of mathematics education is three-fold through resources, cultural shift, and education. A materials library, including valid assessments with scoring rubrics must be accompanied by robust professional development to support the effective use of the materials in the quantitative classroom. This initiative will only succeed with a cultural shift among mathematicians who teach in higher education. Incentives to attend to, and integrate, ethical considerations into all math courses, and the removal of professional or institutional *disincentives* to do so, may require, as well as foster, a necessary and fundamental shift in mathematicians' sense of identity towards a normative view that ethical mathematics is a valuable, and learnable, perspective.

This cultural shift will not be easy, as mathematics can be perceived as neutral, and without ethical, legal, or social implications. Normalizing ethical reasoning as a core component of innovation in, and application of, mathematical work will require both grass-roots and top-down commitment and engagement.

Transforming the world of STEM through ethical and mathematical reasoning

There are evident pathways to discuss ethics in data and algorithms which have become ubiquitous in twenty-first century life. We have seen scandals surrounding data privacy, such as the Cambridge Analytica scandal and have algorithms dictating everything from who has access to credit to the neighborhoods where policing is concentrated. Professionals designing or using these computational tools have an ethical obligation to consider the social ramification of their work. Perhaps of equal importance, those who utilize, and base decisions on, their outputs also have a responsibility to consider the harms and benefits of reliance on these algorithms in decision making and resource allocation. However, what are the ethical expectations for those computational fields? Ultimately, the ethical contract for creators of STEM and users of STEM must go far beyond those building algorithms into the fabric of algebra, quantitative reasoning, and calculus to graduate study. We must prepare students for the questions of 2040 and beyond.

The need for ethics in mathematics extends beyond scholarship, government, and industry; teaching must also be ethical. STEM and mathematics majors historically have higher drop-out rates than other majors. This is attributed to the instructional culture of STEM, and mathematics in particular, characterized by instruction that tends to replicate historical methods without consideration of modern understanding of teaching and learning in higher education. The reliance on outdated instructional approaches by the "gatekeepers of STEM" all but discourage the engagement of students from diverse backgrounds and opportunities. The results are high drop-out rates and perceived or actual limitations on participation based on gender, race, and socioeconomic stratum. Thus, it is an ethical obligation of institutions, departments, and instructors to seek to teach as effectively as possible – utilizing evidence-based practices informed by the learning sciences rather than historical precedents.

Normalizing ethical reasoning, and revisiting it throughout a mathematics curriculum, communicates the importance and value for ethical practice to all students. If they learn these values, and learn to sustainably apply those values to those decision making, we can empower our STEM graduates to challenge power structures and demonstrate the relevance in multiple contexts, particularly where they may least expect it. Using, consuming, or creating mathematics has consequences, and learning to think about those consequences through ethical reasoning can improve how STEM impacts the world around us.