Empowering Mathematics: Access for All, Not Just the Elite

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Teaching and learning Mathematics have tremendous potentials for promoting equity, diversity and inclusivity (EDI). I hold this belief primarily because the process of mathematical thinking involves identifying common characteristics amongst seemingly different structures, making connections, and generalizing and unifying previously known facts to derive new results. Such a process values flexibility as well as the ability to change frameworks, which aligns with my understanding of EDI. While the nature of knowledge construction in mathematics inherently encourages inclusive teaching and learning practices, it is essential to acknowledge that there are serious gaps in our current approaches toward math education when it comes to promoting EDI. These gaps can hinder the provision of equal opportunities for all learners to flourish and reach their full potential.

In this note, I begin with some examples that illustrate why I believe mathematical concept and knowledge development align with the EDI principles. I also discuss certain factors demonstrating that teaching and learning in mathematics may not be as inclusive as it should be, and they can, at times, be detrimental to the learner's confidence in their thinking capabilities. Finally, I will address a specific area of focus that requires attention to enhance the teaching and learning environment with respect to EDI.

First, let us examine four examples within the realm of mathematical concepts, which highlight the benefits of making connections and embracing the inclusion of diverse ideas.

1. Euler Formula

The Euler formula is widely regarded as one of the most beautiful equations in mathematics. One may wonder what exactly makes it so captivating? Let us try to explore some of the reasons behind its beauty.

The Euler formula elegantly combines five significant numbers, namely, 0, 1, e, i, and π, through the basic arithmetic operation of addition and the concept of equality. This seemingly simple formula manages to encapsulate our entire understanding of the number system through a concise representation. It denotes a harmonious relationship between different mathematical concepts, capturing the essence of the interconnectedness that mathematics is built upon.

2. Spacetime Framework

In the Minkowski framework, space and time are intricately connected through a four-dimensional manifold. This model assigns three dimensions to represent spatial location and one to represent time. Remarkably, such a four-dimensional manifold of space-time has demonstrated significant predictive capabilities of illuminating workings of the natural world. The fusion of space and time exemplifies the extraordinary flexibility of our thinking process. By combining these two seemingly distinct concepts, we gain a more profound understanding of our universe. This integration allows for perceiving the interplay between spatial dimensions and the progression of time, enabling us to explore phenomena in a more comprehensive and holistic manner. It is through such a versatile and interconnected perspective that we can unravel the mysteries of our world, and make meaningful predictions about its behavior.

3. Non-Euclidean Geometries

The conventional Euclidean geometry taught in the high-school is based on a set of five axioms that are universally accepted to be intuitively true. These axioms form the foundation upon which logical reasoning and previously proven facts are applied to derive the results of geometry. There is a certain fascination with the unquestionable nature of such axioms—facts that cannot be disputed. However, what happens if we dare change one of these axioms? Surprisingly, by altering a single axiom, we create new geometries with distinct sets of results, essentially constructing new frameworks. These new geometric structures can lead to novel applications. For instance, hyperbolic geometry emerged when the usual parallel axiom was modified. In hyperbolic geometry, given a point outside a line, there exist infinitely many possible parallel lines passing through the point, in contrast to a single parallel line in Euclidean geometry. Consequently, the conventional results of Euclidean geometry no longer hold on a hyperbolic plane. Notably, for example, the sum of the angles in a triangle on a hyperbolic plane is always less than 180 degrees. By exploring alternative geometries beyond Euclidean geometry, we gain a deeper understanding of the possibilities inherent in different frameworks. These discoveries broaden our perspective, and enable us to make valuable insights in various fields, from practical applications in navigation to profound implications in our understanding of the fundamental nature of space and the universe.

4. The Unified Land of Mathematics

Mathematics encompasses a wide range of subfields, each dedicated to solving specific problems using unique approaches and methods that may not be commonly employed in other areas. However, there are instances where the solutions to certain problems require the integration of methods from two or more seemingly unrelated subfields. It is through discovering certain relations between diverse subfields that we may be able to uncover the unified mathematical landscape, defined by the inherent symmetry of nature, rather than a patchwork of isolated fragments. Maryam Mirzakhani, a renowned mathematician, exemplifies the ability to establish such connections. In her work, she successfully bridges the gap between disciplines such as hyperbolic geometry, complex analysis, topology, string theory, and dynamical systems. By drawing on the tools and concepts from these disparate areas, she was able to make significant advancements and contributions to mathematics.

Mirzakhani's achievements highlight the power and potential of interdisciplinary exploration within mathematics. By actively seeking out connections and integrating methodologies from different subfields, we can enhance our understanding of the subject as a whole. These interconnected discoveries not only deepen our appreciation of the underlying unity of mathematics, but also pave the way for groundbreaking insights and solutions to complex problems.

My point in providing the above four examples is to highlight the processes and methodologies of mathematics knowledge production, rather than focusing on the individuals who produced the knowledge. It is crucial to recognize that, at least for the first three examples, the mathematicians involved were predominantly European males, leading to a lack of diversity in the body of knowledge producers. Indeed, one of the significant weaknesses in the field of mathematics is the tendency to concentrate knowledge among certain individuals, and discourage the contribution of others, perpetuating a culture of elitism. This exclusivity can stifle creativity and innovation by limiting diverse perspectives and fresh ideas from emerging within the mathematical community. Allow me to share with you a relevant personal anecdote here, highlighting some of the struggles that a learner might face in the field. During the first year of pursuing my Ph.D., I eagerly attended office hours of my course instructors to ask questions about the content and seek their guidance on challenging problems. However, one of my course professors seemed to be unable to understand my genuine passion for learning, and regarded me inattentively, possibly due to my visible minority status. During one of the sessions, he went so far as to tell me that "*mathematics is for the elites only*." As a learner whose mother tongue was not English, I was prompted after the session to contemplate on what exactly he meant and the meaning of the word "*elites*." Discovering the implications of his statement left me shocked, but it also fueled my determination to prove the professor wrong, and showcase my true talent and capabilities in the subject.

There are certain factors indicating that the current approach to teaching and learning mathematics is still far from being genuinely equitable, diverse and inclusive.

First, there is often a lack of student engagement in the formal mathematics education, majorly due to the failure in creating an interactive learning environment that values diverse perspectives and encourages active participation from all students.

Secondly, there is a promotion of an elitist culture, which implies that only a select group of learners possess exceptional thinking skills, while others are considered as unfit to advance their knowledge in and contribute to mathematics. Such a culture perpetuates inequality. It is crucial for educators to foster a growth mindset, and create opportunities for all students to develop their mathematical thinking skills.

Thirdly, educators need to actively work towards understanding the gaps in students' knowledge, and providing adequate support for helping them enhance their learning. This requires a commitment to customizing instruction, differentiating learning strategies, and addressing the unique needs of each student, through the implementation of the principles of Universal Design for Learning.[1]

Lastly, assessment methods that do not align well with the taught materials can hinder students' performance. Penalizing students for poor results without critically examining the assessment tools and their coherence with the intended learning outcomes can further marginalize certain groups of students. In a recent study that I conducted about the assessment methods in mathematics learning, I employed the notion of Community of Inquiry [2] as a theoretical framework for analyzing the experience of students and instructors with assessment practices. One noteworthy finding of the study was the students' mention of the irrelevance of the test contents to the lecture materials. Such a disconnect between the test contents and lectures can lead to an emotional turmoil, as one student described:

> *"… there are some issues with the questions in the tests…I feel like 'Oh, wait, that's totally not what was talked about in the lecture.' It's heartbreaking. It's so disconnected from the lecture. After taking it, I totally had no idea what I was supposed to do in the rest of the course."*

In my view, the pervasive opinion that "*I am not good at math*," commonly expressed by the public, may be a result of the persistent discouragement received by learners through the conventional feedback system. Mathematics education is often conducted within such damaging environment, where learners develop discouraging feelings that reinforce negative perceptions about their math abilities. It is essential to encourage learners to gain the belief that we are all capable of excelling in mathematics, because we are all thinkers at different levels. By fostering this view, we can inspire them to see the values of learning mathematical concepts as a means of further developing their thinking skills. Mathematics offers a powerful platform for honing critical thinking, problem-solving, and analytical capabilities, which extend beyond the subject itself, enriching learner's overall cognitive abilities.

By embracing EDI practices in mathematics education, we can dismantle barriers, empower learners, and foster a sense of agency and confidence in all individuals, regardless of their background or perceived mathematical abilities. Such an inclusive approach enables us to cultivate a society where individuals have a better opportunity to thrive and contribute their unique perspectives to the decision-making processes that shape our collective future.

References

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[1] Universal Design for Learning is a comprehensive framework rooted in scientific insights into human learning, aiming to enhance and optimize teaching and learning experiences for all individuals.

[2] Central to the Community of Inquiry theory is the underlying belief that higher education embodies a blend of collaborative and individually constructivist learning (Vaughan et al., 2013, p. 10). Therefore, a nurturing community of inquiry should adeptly fuse cognitive autonomy with social engagement within the learning journey (Garrison, 2016; Vaughan et al., 2013). As stipulated by the CoI theory, the attainment of profound and substantial learning hinges upon the cultivation of three essential presences: cognitive, social, and teaching.