

Addressing STEM in the context of teacher education

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Fuchang Liu

School of Education, Wichita State University, Wichita, Kansas, USA

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Abstract

Purpose – This article discusses several issues concerning STEM in the context of teacher education.

Design/methodology/approach – Using a review of the literature of the past two decades, this article approached the topic of addressing STEM in the context of teacher education through six issues.

Findings – 1. Integration is key. 2. Disciplinary knowledge needs emphasizing. 3. Equitability of discipline representations is a nonfactor. 4. Still, mathematics deserves a heavier dose. 5. Collaboration is a desired component. 6. Inequality issues deserve more attention.

Originality/value – This article is original. It informs researchers, practitioners and policymakers of what issues to focus on concerning STEM in the context of teacher education.

Keywords Inequality, Interdisciplinary, STEM education, Integrated STEM

Paper type Viewpoint

Received 3 February 2020
Revised 2 March 2020
Accepted 16 March 2020

During the years leading to the turn of the new millennium, it was becoming increasingly apparent that we were at a time when many economic, environmental and social factors were impacting all countries across the world in a way that jeopardizes global security, public health and economic stability. The global urgency to improve STEM education, namely, education involving the disciplines of science, technology, engineering and mathematics, was deemed as a timely as well as effective way to address such far-reaching and wide-impacting issues. Researchers have since been advocating for explorations of teaching and learning methods that seek to develop what became known as 21st-century skills and strengthen the relation among the STEM disciplines (Kertel and Gurel, 2016).

Although education involving the individual disciplines of STEM is nothing new and has actually been the foundation for discovery and technological innovations throughout modern human history, the importance of the nature of STEM education and the manner of its instruction as a whole have only been recognized for the last two decades or so. What lies in the core of STEM education is its integrated and interdisciplinary nature – the instruction of these disciplines is conducted as a holistic whole rather than as separate, isolated subjects. It has thus been argued that STEM education should transcend disciplinary boundaries in order to develop students' 21st-century skills and address STEM-related global issues (Bybee, 2013).

For this reason, researchers have argued for a new approach to the handling of STEM education in the new era. It has been recommended that STEM education should even include elements not readily found in traditional textbooks for each individual subject. The [National Science and Technology Council \(2018\)](#), for example, listed three critical features of this new approach: the teaching of academic concepts through real-world applications, the



combination of formal and informal instruction and emphasis of both hard skills such as critical thinking and problem-solving skills and soft ones such as cooperation and adaptability.

Central to this new approach is that students learn the basic STEM concepts early, preferably at the elementary school level. The rationale for this early start is that students' interest in new concepts is the easiest to pique when they are young. It should not come as a surprise that children's foundational understandings of STEM disciplines and their interests and career ambitions in them are formed while in elementary school and shaped by their teachers' beliefs and attitudes (Bybee and Fuchs, 2006). Nevertheless, recent trends suggest that fewer students are taking on STEM subjects than before (Hom, 2014).

This is where teacher education comes into play. New perceptions of and approaches to existing concepts by school-age children are dependent upon well-informed and well-trained teachers, and without such teachers, quality STEM education is unlikely to be successful. MacFarlane (2016) observed that the availability of a quality STEM program would facilitate students' talent development in STEM areas. During the learning and practice required to develop STEM talent, teachers and STEM programs are essential in providing the opportunities, support and experiences needed for students to reach their potential. Bell (2016) reported that teachers' perception of STEM, their individualized knowledge base and their understanding involving that knowledge base are intrinsically linked to the effectiveness of STEM delivery in their own classroom practice. Where a teacher's own knowledge and understanding is deficient, the potential for student learning is naturally limited.

Teacher education, thus, plays a crucial role in shaping how STEM is perceived, taught, learned and practiced, and how the next-generation workforce is provided bona fide 21st-century skills to meet the needs driven by mechanisms functioning in today's society. With this in mind, some issues concerning STEM in the context of teacher education warrant a little discussion here.

Integration is key

First and foremost, the integrated and interdisciplinary nature in STEM is what truly makes STEM education STEM education. Devoid of this defining feature, what is left is nothing more than the individual and separate areas of study the teacher education programs have been dealing with for decades. It is particularly for this reason that researchers have been arguing for an increased attention on STEM integration (English, 2016). Using this as a starting point, the integrated and interdisciplinary feature of STEM education should be adequately reflected in curriculum development in teacher education programs. Future teachers should be trained not only in individual STEM courses *per se* but also in the general, interdisciplinary area of all STEM subjects.

This brings up the questions of what teacher education programs should comprise and, more specifically, what courses to offer for teacher candidates undergoing the relevant training for their future career. In the USA, even though some colleges of education classify their enrollees as STEM majors as opposed to non-STEM majors, such "STEM majors" are actually those preservice teachers who declare one of the STEM areas of study as their academic specialty but not necessarily majors concentrating on content across all STEM disciplines.

In view of this reality, teacher education programs may need to, as a starter, design and implement a general STEM course for all education majors. Such a course should emphasize on integration strategies and approaches by which preservice teachers learn how to solve problems by associating content and practices of multiple STEM subjects. Obviously, it is conceivable that there will be challenges in this endeavor. Ryu *et al.*

(2019), for example, listed three challenges in their study of integrating STEM in their teacher education program: existing school structure, curriculum and instructional approaches deemed as a salient impediment to STEM integration, preservice teachers' being limited in content knowledge and practices in disciplines other than the one they have chosen as well as relations among STEM disciplines, and an absence of role models in teachers, students and instructional resources that they could follow. Such challenges should be taken into serious consideration when designing integrated STEM courses.

Disciplinary knowledge needs emphasizing

Needless to say, the foundation for an integrated STEM education is the conceptual understanding and procedural knowledge necessary in satisfactorily handling the content of the individual disciplines at the beginning stage. This can be examined in two perspectives. On the part of students, a strong potential for a successful STEM career pathway starts with a high level of content understanding of individual STEM disciplines. As noted by [National Academy of Engineering and National Research Council \(2009\)](#), integrating ideas across all STEM disciplines is challenging when students have little understanding of the relevant ideas in the individual disciplines. This is hardly surprising in that an integrated STEM education is built on individual disciplines as its very foundation. Furthermore, students do not always or naturally use their disciplinary knowledge in an integrated context.

On the part of teachers, strong content preparation in individual disciplines is indispensable for leading to a successful integrated STEM education. For mathematics, for example, elementary teachers tend to make certain common mistakes, and this may have to do with their generalized training as a reflection of the non-departmentalized setup of elementary schools ([Liu, 2011, 2017](#)). All this indicates that STEM integration will go nowhere without the disciplinary knowledge for either the student or the teacher.

Equitability of discipline representations a nonfactor

There has been a concern that discipline representations in STEM research and learning outcomes are not equitable ([English and Kirshner, 2016](#)). But the goal of reaching equitability in all STEM disciplines is probably unrealistic to attain. In general, the evolution of individual STEM disciplines is not at the same rate or in the same direction all the time. Specifically, while the evolution of the basic content materials in mathematics is very slow, new concepts, designs and implementations in science, technology and engineering are coming out constantly. After all, we are in a technology- and innovation-driven era. This distinction is very much like that of the courses of human anatomy as opposed to biological science. The treatment of human anatomy as an academic course may not be very different from that of 20 years ago, but the contemporary treatment of biology may be virtually unrecognizable to a student who took the course two decades ago. In the same manner, it is conceivable that while the content materials in mathematics will not be drastically different in the coming years, what the curriculum and instruction of technology and engineering will encompass several years from now will have to adjust to new advances in these fields. Such unbalanced developments in STEM disciplines have certainly resulted in unbalanced representations in them, and they are perhaps part of STEM education itself. Therefore, equitable representations of STEM disciplines are not a necessary goal to strive for. Reflected in teacher education, this contemplation has the implication that adjusting to and updating on the new developments in technology and engineering are crucial components in STEM education for teacher training programs.

Still, mathematics deserves a heavier dose

Of the four STEM disciplines, mathematics plays a unique role in that it is needed in the componential fabric of the other disciplines – it is indisputable that it provides some type of service to their teaching and learning.

However, contrary to what needs to be done with regard to the omnipresence of mathematics in all other STEM disciplines, mathematics is actually shunned by students who need it most, for the perceived difficulty in its learning. This is what has become known as “mathematics anxiety”. This is peculiar in that there are no comparable phenomena such as “physics anxiety” and “language arts anxiety”. The effect is that one discipline is singled out to feed into the perception that it is more difficult than others and that it is not a subject that every student can learn. This phenomenon has a grave implication for teacher education in that elementary students with high-mathematics-anxiety teachers learn less mathematics than those with a low level and that female teachers’ mathematics anxiety affects girls’ performance in mathematics (Beilock *et al.*, 2010). As most elementary school teachers are female, some of the girls who get mathematics anxiety from their female teachers, when later becoming teachers themselves, will likely take this anxiety to their own classrooms, forming a stubborn, vicious cycle.

Collaboration is a desired component

With the intrinsically unbalanced nature of STEM disciplines and the natural inertia between any new discovery and this new discovery making its way into classroom discussions, teacher education programs ought to seek close collaboration with technology and engineering companies to ensure that teacher education candidates are kept abreast with what is new in these fields. This collaboration should entail building a proper channel for reflecting new developments in technology and engineering in teacher education programs. Such collaboration will be beneficial to both teacher education programs and technology and engineering companies. For the former, teacher candidates will get a chance to be informed of what is occurring in the actual fields they will be teaching about. For the latter, as the demand for STEM professionals is on the rise worldwide, addressing current and future shortages in the STEM workforce and a widening STEM skills gap in the workforce in general has top priority. In this perspective, children to be taught by teachers trained in a collaboration-based program will be more likely to become a desired pool feeding into the workforce pipeline of these fields.

Inequality issues deserve more attention

Rather than trying to address the lack of equitability and representations of STEM disciplines, the attention for future STEM in the context of teacher education, for researchers and practitioners alike, should instead be given to a number of inequality issues with regard to gender, ethnicity, immigration status and so on.

The underrepresentation of girls and women in STEM careers has been a continual concern for social scientists and policymakers. Even with this frequently noted inequality, much needs to be done, as our understanding of the issue is still limited. For example, [Stoet and Geary \(2018\)](#) found that in countries that empower women, they are still less likely to choose STEM-related professions.

An equally important but less studied issue is racial inequality in students’ choice of STEM areas of study and further on of their future careers. It has been noted that in the USA, African American and Latino youths who begin college in STEM fields are more likely to depart than their White peers, and there is evidence of persistent racial or ethnic inequality in STEM degree attainment not found in other fields ([Riegle-Crumb *et al.*, 2018](#)).

An even less discussed inequality in STEM education is, particularly in the USA, students' immigration status. On average, immigrant students have significantly higher rates entering and persisting in STEM fields than their native counterparts (Jia, 2019). Such STEM advantage for immigrant students is largely due to the better academic preparation in mathematics and science at high school level in their home countries. This indicates that improvement in students' college STEM attainment may depend crucially on a country's policy efforts devoted to strengthening the quality of high school mathematics and science education.

All these issues deserve a close examination in the development and implementation of curriculum and instruction in teacher education so that STEM education becomes a viable tool for training students into desired workforce of the 21st century.

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Corresponding author

Fuchang Liu can be contacted at: fuchang.liu@wichita.edu