

Special Editorial Team Introduction: The Foundation of STEM is Mathematics Education

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Assembling a special issue concerning science, technology, engineering, and mathematics (STEM) for the *Journal of Mathematics Education* required the team to consider several important factors; however, none were more paramount than keeping mathematics as a central theme for the issue. All too often, the term STEM is used as code for “fun activities” that mitigate the true learning of real content in mathematics and science. In addition, STEM educators rarely consider a clear or precise definition aside from the long-form translation of the acronym itself. For this special issue, the following definition of STEM clearly situates the included articles in terms of how we, the guest editorial team, believe they contribute meaningfully to the literature in mathematics education. Moreover, the definition clearly situates the works, in which mathematics is the linchpin, within a broader and more applied context.

To engage in STEM education, one must not mitigate or subjugate any of the subjects. Each subject has to be integrated into a unifying whole where specific content knowledge is taught and then integrated to build new more powerful knowledge affording students the ability to do something they could not do before in ways they never before imagined. A classroom should be student centric, where learning happens within individuals, dyads, small groups and interactive discussion moderated by the teacher within a safe and challenging work world experience. (Capraro, 2018, p. 107)

To foreground the relevant research context for the reader, it is essential to interpret some of the research surrounding STEM to date and identify what appear to be patterns or what might be on the surface interpreted as contradictory information. There are several published studies in which authors examined the impact of STEM school designation (Franco & Patel, 2017). Although the research base can be contradictory on a superficial level, researchers examined distinct key variables and controlled for differing background variables. These distinctions are a pathway to defining theoretical constructs that at some point can be tested through a robust study. However, even with these various studies in which different results were reported, the

field is still not ready for meta-analytic studies. It is difficult to predict when that time may come; however, it may be sooner than anyone might anticipate. In fact, there has only been one comprehensive meta-analytic study dealing with the STEM teaching and learning process, and even this one was relegated to comparing differing combinations of the core subjects often not situated in a general STEM school context (i.e., Nite, Capraro, Capraro, & Bicer, 2017).

In addition, there have been several studies in which researchers reviewed the elusive STEM curriculum. Although there are many teacher materials and texts classified as STEM, few meet the rigor of the definition to which we subscribe for this special issue, and most of those materials are under-researched and perilously supported by research conducted or supported by the publisher. Even when that research is “at-arms-length”, the findings are mixed, in some cases for sound methodological reasons. For example, consider the research on just one adopted curriculum, *Project Lead the Way* (PLTW). There is research that has shown that using PLTW delivers major content learning outcomes (cf. Bicer, Boedeker, Kopparla, Capraro, & Capraro, 2015; Bicer, Capraro, & Capraro, 2017; Stohlmann, Moore, & Roehrig, 2012). This is balanced by other reports that indicated that PLTW delivers social and affective benefits (cf. Bicer et al., 2017; Lee et al., 2018). Then there are studies in which the findings disentangled the effects by showing either no difference in achieving major content learning or that the affordances are highly contextualized to particular groups of students. The primary concern underlying the vast majority of STEM curriculum studies through 2018 seems to be that of providing an estimate of fidelity of implementation. That is, in most studies researchers have not accounted for differences in teacher enactment, or fidelity of implementation, given that the students, in many cases, are fully nested within the teacher for nearly all of their STEM experiences. However, in one study researchers did disentangle fidelity of implementation of STEM teaching to show that higher levels of teacher fidelity were associated with higher levels of student content learning, and perhaps more importantly, that poor fidelity tended to result in lower levels of learning as compared to student learning before the STEM curriculum implementation (Capraro et al., 2016). Therefore, studies reporting positive or negative results must include some indication of the level of fidelity of implementation for which the data are being reported. When research is based on whole-school (Kasza & Slater, 2017), district (Stohlmann, 2019), or state implementations (Glennie, Mason, & Dalton, 2016; Peterson, Bornemann, Lydon, & West, 2015), the research condition may not afford a means for reporting fidelity; however, these reports still provide very important and aggregable information.

The research reported in this special issue unpacks the mathematics in STEM pertaining to several very timely areas. We arranged the articles by levels: middle school, high school, post-secondary, and finally one dealing with the impact of STEM standards for inservice teachers pursuing a master’s degree.

In the first study, by Basu and Panorkou, the intervention was a project dealing with greenhouse gases and the greenhouse effect in sixth-grade classrooms using treatment and control groups to estimate the impacts. These researchers employed both quantitative and qualitative data analysis and disentangled a difference in student learning and student development of more complex reasoning skills because of their experiences with the greenhouse effect simulation.

There are many variations in what constitutes a STEM project. That said, game-based experiences have been under-researched and likely underfunded by both the Institute for Education Sciences and the National Science Foundation. In the second study, Stohlmann unpacked her experiences with integrating games into instruction. She found that students who engaged in game-based instructional experiences developed persistence and a high degree of tolerance and acceptance of productive struggle. The development of productive struggle is possibly the most important finding because of the strong relationship between student engagement in productive struggle and their success in problem solving and problem posing.

These qualitative findings lead very nicely into the work of Young, Young, and Witherspoon who used a nationally representative data sample, the *High School Longitudinal Study* (HSLs), to draw conclusions about the informal learning experiences of African American students that led to a more productive mathematical identity. An additional contribution to the literature is a carefully designed analytic method in which propensity score matching was used to draw a high-quality comparison group. It has been suggested that propensity score matching provides estimates of effects that approach the robustness of those obtained through true experiments.

In the exploratory study by Bicer and Lee, they examined the nuanced differences in students' affect and their changes in perceptions toward pursuing a STEM degree and career during an informal STEM summer camp experience. They found that students' interest in STEM majors and careers increased after experiencing STEM project-based learning.

Bringing the special issue into the postsecondary level, researchers in three of the articles addressed undergraduate STEM education. In the Kwon, Vela, Williams, and Barroso study, STEM efficacy and careers were unpacked using a path analysis. Their work showed that there was an important relationship between STEM career interest and science self-efficacy. What may bare out as an important finding was that mathematical self-efficacy was only related to technology, engineering, and mathematical career interests. Further research may provide insights into why mathematical self-efficacy was not related to interest in science careers. A secondary innovative contribution of this study was that the authors provided a nearly textbook description and implementation of path analysis to account for the interrelated ideas.

In the Burton study, she examined three teacher candidates working with 3rd through 5th grade students to explore their perceptions of teaching

mathematics during a STEM experience focusing on robotics, structures, and forces and motion. Her interpretive phenomenological analysis provides a highly contextualized and fine-grained examination of the experiences the teacher candidates lived for the three weeks of primary teaching responsibility. She found that the teacher candidates transformed across a gamut of stages during their experiences. Additionally, she detailed those principle transition points to help build a framework for how a primary teaching responsibility can assist a novice teacher in building critical skills in a highly dynamic and contextualized learning environment.

We concluded the post-secondary section of the special issue with a meta-analysis. The findings expressed in the study by Kopparla represented a synthesis of results from articles published dealing with post-secondary retention. The primary factors of this meta-analysis were SAT scores, first college mathematics course, and first college mathematics grade. Across the 19 studies, the most important predictor of post-secondary mathematics success was earning a high grade in one's first college mathematics class.

A STEM special issue would not be complete without an article dealing with the importance of standards within the educational system. In the final article, Rosengrant, Hensberry, Vernon-Jackson, and Gibson-Dee delved into the complex standards that educators and stakeholders within all the STEM content areas are rushing to build. They discussed salient standards from each of the STEM content areas. The authors used the lens of practicing teachers enrolled in a STEM master's degree. They reported program evaluation results, culminating with a reduced set of proposed STEM standards. These proposed standards provide a theoretical framework by which to test the standards as a theoretical model. Moreover, the theoretical framework may be used to determine the extent to which using these standards might influence teacher success in helping students learn STEM content more efficiently.

We gratefully acknowledge the JME teams' hard work, the tenacity of the authors, and all those authors who dutifully submitted their work for consideration. We received a total of 12 manuscripts. Of those, eight made it through the review process. Each article was peer reviewed, and authors worked diligently to address reviewer comments. We are especially grateful to Ms. Mykala Madson, our chief Copy Editor, who ensured that each article met exacting standards. Regretfully, Ms. Madson applied to and was accepted into an occupational therapy program and will begin her college program in the upcoming Fall 2019 semester. We dedicate this special issue to her and all her efforts to make all of us grammatically smarter, more efficient, and better writers. We wish you well in your new studies and career.

References

- Bicer, A., Boedeker, P., Kopparla, M., Capraro, R. M., & Capraro, M. M. (2015, October). Comparing students' mathematics achievement by their school

- types: Inclusive STEM schools that implemented PLTW curriculum with inclusive STEM schools that did not implement PLTW. In 2015 *IEEE Frontiers in Education Conference (FIE)* (pp. 1-5). IEEE.
- Bicer, A., Capraro, R. M., & Capraro, M. M. (2017). Integrated STEM assessment model. *International Journal of Education in Mathematics, Science, and Technology*, *13*(7), 3959-3968.
- Capraro, R. M. (2018). Catalyzing fundamental STEM paradigms in the accountability millennium. In M. Shelly & S. A. Kiray (Eds.), *Research highlights in STEM education*, (103-115). Istanbul, TR: International Society for Research in Education and Science.
- Capraro, R. M., Capraro, M. M., Morgan, J., Scheurich, J., Jones, M., Huggins, K., ... & Younes, R. (2016). The impact of sustained professional development in STEM in a diverse urban district. *Journal of Educational Research*, *109*(2), 181-196.
- Franco, M. S., & Patel, N. H. (2017). Exploring student engagement in STEM education: An examination of STEM schools, STEM programs, and traditional schools. *Research in the Schools*, *24*(1), 10-30.
- Glennie, E., Mason, M., & Dalton, B. (2016). The role of STEM high schools in reducing gaps in science and mathematics coursetaking: Evidence from North Carolina. *Research Report*. RTI Press Publication RR-0025-1603. RTI International.
- Kasza, P., & Slater, T. F. (2017). A survey of best practices and key learning objectives for successful secondary school STEM academy settings. *Contemporary Issues in Education Research*, *10*(1), 53-66.
- Lee, Y., Bicer, A., Capraro, R. M., Capraro, M. M., Barroso, L., Kwon, H., & Rugh, M. (2018, October). Comparing mathematics and science achievement of students from schools with PLTW versus schools without PLTW. In 2018 *IEEE Frontiers in Education Conference (FIE)* (pp. 1-5). IEEE.
- Nite, S. B., Capraro, M. M., Capraro, R. M., & Bicer, A. (2017). Explicating the characteristics of STEM teaching and learning: A meta-synthesis. *Journal of STEM Teacher Education*, *52*(1), 31-53.
- Peterson, B., Bornemann, G., Lydon, C., & West, K. (2015). Rural students in Washington state: STEM as a strategy for building rigor, postsecondary aspirations, and relevant career opportunities. *Peabody Journal of Education*, *90*(2), 280-293.
- Stohlmann, M. (2019). Three modes of STEM integration for middle school mathematics teachers. *School Science and Mathematics*, *119*(5), 287-296.
- Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *2*(1), Retrieved from <http://docs.lib.purdue.edu/jpeer>