STEM Integration in Field Experience for Mathematics and Science Teachers

Danielle Dani, Courtney Koestler, & Lizhen Chen, Ohio University

STEM educators emphasize the need for an integrated approach to STEM education, whereby mathematics and science (content and practices) are presented through the lens of technology and engineering; the content is anchored in the design process; and learning is situated within the present needs of students (Bybee, 2010; Claymier, 2014; DeJarnette, 2012). Conversely, mathematics and science teacher candidates learn content as distinct disciplines where the interconnections between the STEM fields take a back seat, and limited opportunities for engaging in authentic mathematical practices (Weber, 2004) or engaging in science and engineering practices are available (Feder, 2017). Moreover, teacher candidates' lack of content knowledge in technology and engineering makes STEM integration more challenging (Honey et al., 2014). While mathematics and science pedagogy courses often model inquiry-based and student-centered mathematics and science teaching that may integrate STEM approaches, teacher candidates do not always have opportunities to observe or experience these methods as they complete their clinical experiences (e.g., Capps et al., 2016; Cunningham & Carlsen, 2014). Given the limited and isolated opportunities that teacher candidates have for learning STEM content, it is not surprising that they have repeatedly reported insecurities and low self-efficacy about their STEM content knowledge and knowledge of strategies for teaching STEM (Ryu et al., 2019). Though new STEM courses that integrate science, technology, engineering, and mathematics have begun to appear in teacher preparation, there is a surprising lack of information about how STEM is integrated, what content is left behind because of the integration, what and how STEM practices are included, and how teacher candidates identify natural connections between content areas (Seen et al., 2016). The purpose of this article is to describe lessons learned from STEM Camp, a non-traditional clinical experience intended to address the above-described challenges in a master's with licensure program for individuals who have an undergraduate degree in a STEM field, hereafter called fellows.

STEM Camp

Our graduate program started with an introductory course that focused on STEM content and practices and engaged fellows as learners in STEM-focused tasks and activities. STEM camp, a one-week STEM summer camp for students aged 11 to 14 years constituted a key component of the course. The camp was the fellows' first field experience and was co-hosted with a local school district partner. We designed STEM Camp to model STEM content, practices, and teaching strategies and provide fellows opportunities to enact and reflect on their developing ideas about STEM teaching and learning. Three principles guided our work: A place-based curriculum that integrates STEM content and practices (Nichols et al., 2016), co-teaching that engages fellows in teaching and reflection cycles (Dani et al., 2019), and a clinical experience context that allows fellows to work with diverse students (Dani & Harrison, 2021; Dani & Stigall, 2021; Dani et al., 2016, 2018).

Place-Based Curriculum

We worked in teams composed of STEM faculty (geology, physics, and computer science) and STEM education faculty (mathematics and science) to develop an integrated, responsive STEM curriculum. STEM scholars propose four ways to conceptualize the integrated nature of STEM teaching: transdisciplinary, interdisciplinary, multidisciplinary, and content and context (Herro et al., 2016; Moore et al., 2014). In the transdisciplinary method, the collective expertise of all the STEM disciplines is used to present and solve a problem. The interdisciplinary method emphasizes the similarities between two or more selected STEM disciplines. In multidisciplinary approaches to STEM integration, a common theme is investigated from the perspective of multiple disciplines. Finally, content from one STEM discipline is emphasized in the context and content approach, with a second discipline providing context to enhance relevance and promote design or problem-solving (Moore et al., 2014).

We adopted a place-based approach (Nichols et al., 2016) to curriculum development to be responsive to students' needs. In our rural context, a focus on agriculture and mining meant that our students were connected to local land and geography. We created learning experiences in which students explored landslides, phenomena common to our region, through a model-based science inquiry that led students to make hypotheses about which conditions caused landslides and which angle of elevation was needed for different types of debris to fall down a slope (Dani & Stigall, 2021). Mathematically, students used technology to explore different slopes, develop a formula for measuring slope, and compare angles of elevation. Students had to justify their scientific claims using data from their experiments and mathematically justify their reasoning by computing and testing formulas. We consistently structured camp activities around cross-cutting STEM practices such as constructing arguments and modeling to unify our place-based topics.

Teaching and Reflection Cycles

Fellows, STEM faculty, and STEM education faculty co-taught the camp. To give fellows multiple opportunities to teach the same lesson to different students, we engaged them in teaching and reflection cycles whereby they taught lessons, analyzed and reflected on student learning, and then modified and tested instructional decisions with the support of faculty mentors (Dani et al., 2019). We divided the STEM camp students into two groups, structured the days into two sessions, and assigned fellows to one of two rooms (one mathematics and one science). On the first day, faculty led an opening session for all students. For the rest of the camp, groups rotated between the two rooms. In the second session of each day, fellows co-taught a new integrated STEM lesson to one of the student groups, typically with faculty taking the lead role. During the afternoon debrief, they critically analyzed the lesson with faculty and peers, hypothesized how to modify the lesson based on what they learned about STEM camp students, and discussed changes for the next day's session. The next day, student groups switched rooms and during the first session, fellows retaught the previous day's lesson to the new group, taking on the instructional lead from faculty. This design allowed for an opportunity to learn from experience and immediately apply feedback in re-teaching.

Diverse Contexts and Students

The Council for the Accreditation of Educator Preparation (CAEP, 2020) advocates that high-quality clinical practice should provide teacher candidates opportunities to interact with diverse students and their proximate communities in various settings. To vary the clinical experience context, we created this initial field experience outside a formal school structure. In prior work, we report how informal and community-based STEM events provide effective clinical contexts to promote teacher candidates learning and cultural competence (Dani & Harrison, 2021; Dani & Stigall, 2021; Dani et al., 2016, 2018). STEM camp did not take place in a typical classroom setting where particular standards had to be addressed for high-stakes tests. Fellows were afforded the flexibility to experiment with different modes of instruction, including facilitating small and large group conversations. During these discussions, we asked fellows to focus on students' STEM ideas and prior experiences in sense-making, and consider examples of activities and contexts of interest to the students that could best serve to illustrate or apply target concepts. Students who struggled with the traditional school structures were involved, providing fellows the opportunity to think about how to motivate learners. To support fellows' ability to get to know students during this short clinical experience, we asked them to conduct small group interviews with students to ask about their in-school and out-of-school experiences and interests, characteristics of their favorite mathematics and science teachers, and perceptions of a safe and inclusive learning environment.

Lessons Learned

We learned a number of lessons through the process of implementing the STEM camp we used to facilitate an early field experience for the mathematics and science fellows that were beginning our teacher preparation program. Reflecting on our experience, we identified benefits and challenges related to the integration of STEM disciplines, use of teaching cycles, and inclusion of the teaching experience with diverse contexts and students. From a curricular perspective, we recognize that the phenomena we selected lend themselves to transdisciplinary STEM exploration, where all STEM disciplines are used to present and solve a problem. Our enactments, however, were more consistent with the context and content approach at best. Maintaining integration as a central focus was challenging. In the mathematics fellows' classroom, the mathematics content tended to be lifted away from the science context to focus on numbers, formulas, and technology applications. In a lesson on density, mathematics fellows attended to concepts of ratio and proportional reasoning, but they did not address why density was important from a scientific perspective. Although science fellows facilitated students' application of mathematical knowledge in data collection, their focus was on performing experiments with insufficient attention given to integrating mathematical analysis with the scientific decision-making or reasoning in experiments.

Faculty tended to emphasize content areas in which they held expertise. Education faculty used their pedagogical expertise to mediate conversations between novice fellows, who could not always articulate their struggles, and our STEM faculty content experts, who struggled to unpack their pedagogical knowledge.

To implement teaching cycles, the camp students were divided into groups that cycled from activity to activity. This meant that faculty and fellows taught activities twice. Fellows could see activities implemented once, carefully debrief the activities, hypothesize improvements with expert guidance, and immediately test their improvements the next day. Many fellows reported on aspects of the activities that they hoped would be part of their future classrooms, and appreciated having the camp as a good model of inquiry science and of problem-solving mathematics. They described ways in which the camp employed various pedagogical techniques, such as small group and whole group discussions, simulations, and primary experiences.

Though the structure of our camp provided opportunities to observe and re-teach, it did not allow science fellows the opportunities to observe how mathematics teachers talked about mathematics and vice versa. Fellows of each content area needed to hear how their counterparts with different content expertise talked about their discipline. While we went into the camp planning centered on STEM concepts, because of structure and our own faculty expertise the opportunities to learn for our fellows still tended to be bifurcated. Debriefing together using a framework for STEM practices that looked at ideas, methods, and values related to STEM teaching (Lowrie et al., 2018**)** was helpful for guiding our conversations.

For many fellows, the camp represented their first STEM teaching experiences with middle school students. Both mathematics and science fellows tended to use questions that had only one right answer. This served to remind our faculty that prospective teachers with stronger than typical content knowledge also need specialized support in challenging their long-held conceptions of their disciplines (e.g., single versus various solutions). Some of them struggled with identity as a teacher, as they shared the tension in supporting and motivating learners when compared to doing mathematics or science for themselves.

Finally, STEM camp as a diverse field experience context prompted fellows to think about how formal or informal to be with students and how to engage “off-task” students. Many fellows noticed that the nature of the learning task matters to student engagement and on-task behavior. Camp tasks and activities were hands-on, used multi-modal materials and resources, and allowed students to participate in different ways. Fellows commented that the camp’s content was interesting to students and fellows could connect the characteristics of camp activities to how often students were engaged and on-task. That is, the more active the learning, the more engaged the students were. This served as a reminder to them that all students are learners, deserve an enriched curriculum, and that they need to be careful of deficit perspectives. Fellows recognized that while these children represented “typical” middle schoolers, they held individual strengths and backgrounds. Fellows noticed individual student differences and their implications for learning and teaching. For example, students might have difficulty explaining their thinking on a written assessment, but they still deeply understand the content and can describe their thinking verbally, using tools, and even hand gestures. We believe this noticing was the first step to building their own philosophy of STEM teaching.

Conclusion

STEM camp provided fellows with opportunities to experience and analyze integrated STEM curricular tasks and advance diverse students' mathematics and science learning. It also provided fellows with robust models for integrating STEM practices using responsive and place-based approaches. STEM camp allowed us to recognize the factors that challenged *our* ability to maintain STEM integration in curriculum enactment. We recommend incorporating the integrated STEM conceptualization model (transdisciplinary, interdisciplinary, multidisciplinary, and content and context) as an element of the teaching cycle process to ensure that more fidelity is achieved. We also recommend intentionally creating spaces for mathematics and science teacher candidates to observe and reflect on how the other engages students in disciplinary talk. This practice will enhance teacher candidates' ability to recognize and amplify connections between content areas. In short, our STEM Camp model can serve as an effective field experience to promote the development of mathematics and science teachers' knowledge of integrated STEM content, practices, and teaching.

References

Burgan, M. (2006). In defense of lecturing. *Change, 6*, 31-34.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and engineering teacher*, *70*(1), 30.

Capps, D. K., Shemwell, J. T., & Young, A. M. (2016). Over reported and misunderstood? A study of teachers' reported enactment and knowledge of inquiry-based science teaching. *International Journal of Science Education, 38*(6), 934-959.

Claymier, B. (2014). Integrating STEM into the elementary curriculum. *Children's Technology & Engineering, 18*(3), 5.

Council for the Accreditation of Educator Preparation (2020). *Standard 2: Clinical practice*. Council for the Accreditation of Educator Preparation Standards. https://caepnet.org/standards/2022-itp/standard-2

Cunningham, C. M., & Carlsen, W. S. (2014). Teaching engineering practices. *Journal of science teacher education, 25*(2), 197-210.

Dani, D. E., Hallman-Thrasher, A., Harrison, L., Diki, K., Felton-Koestler, M., Kopish, M., Dunham, J, & Harvey, L. (2019). Affordances of a cyclical and content specific model of collaborative mentoring. In T. E. Hodges, & A. C. Baum (Eds.). *Handbook of research on field-based teacher education* (pp. 117-141). Hershey, PA: IGI Global.

Dani, D. E., & Harrison, L. M. (2021). Family science nights: Venues for developing cultural competence. *Teaching and Teacher Education, 103,* 103370. https://doi.org/10.1016/j.tate.2021.103370

Dani, D. E., Hartman, S., & Helfrich, S. (2018). Learning to teach science: Elementary teacher candidates facilitate informal STEM events. *The New Educator, 14*(4), 363-380.

Dani, D. E., Helfrich, S., Hartman, S., Kennedy, C., Payne, S., Mullins, H., West, L., & Hoisington, L. (2016). Science nights: PDS partnership create informal learning opportunities. *PDS Partners, 12*(1), 17-18.

Dani, D. E., & Stigall, A. L. (2021). Landslides: Using model-based inquiry to investigate local mass wasting events. *Science Scope, 44*(4), 46-55.

DeJarnette, N. (2012). America's children: Providing early exposure to STEM (science, technology, engineering and math) initiatives. *Education*, *133*(1), 77-84.

Feder, T. (2017). Undergraduate labs lag in science and technology. *Physics Today, 70*(4). Retrieved on Nov 12, 2017 From http://physicstoday.scitation.org/doi/10.1063/PT.3.3520

Herro, D., Quigley, C., & Dsouza, N. (2016). STEAM enacted: A case study exploring middle school teachers implementing STEAM instructional practices. *Journal of Computers in Mathematics and Science Teaching, 35*, 319-342. doi: 10.1080/19415257.2016.1205507

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Committee on Integrated STEM Education; National Academy of Engineering; National Research Council. Washington, DC: The National Academies Press.

Lowrie, T., Leonard, S. & Fitzgerald, R. (2018). STEM Practices: A translational framework for large-scale STEM education design. *Educational Design Research, 2*(1), 1-20. http://dx.doi.org/10.15460/eder.2.1.1243

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In Ş., Purzer, J., Strobel, & M. E. Cardella (Eds.), *Engineering in pre-college settings: Synthesizing research, policy, and practices* (pp. 35-60). Purdue University Press.

Nichols, J. B., Howson, P. H., Mulrey, B. C., Ackerman, A., & Gately S. E. (2016). The promise of place: Using place-based education principles to enhance learning. *The International Journal of Pedagogy and Curriculum, 23*(2), 27–41.

Ryu, M., Mentzer, N., & Knobloch, N. (2019). Preservice teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation. *International Journal of Technology and Design Education*, *29*(3), 493-512.

Seen, A., Fraser, S. P., Beswick, K., Penson, M., & Whannell, R. (2016). Marketing an alternate model for science and mathematics initial teacher education. *Australian Journal of Teacher Education, 41*(11), 77–89. https://search.informit.org/doi/10.3316/aeipt.214089

Weber, K. (2004). Traditional instruction in advanced mathematics courses: A case study of one professor's lectures and proofs in an introductory real analysis course. *The Journal of Mathematical Behavior, 23*(2), 115-133.

Acknowledgment

The research reported here was supported in part by National Science Foundation Award #1758484. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We also express gratitude to our project team, school colleagues, and students with whom we work.