Documenting STEM Teaching Interns' Development of Science and Engineering Practices

R. Charles Dershimer, Teacher Education, School of Education, University of Michigan
Victoria Bigelow, Evaluation Coordinator, Center for Educational Design, Evaluation, and Research, University of Michigan

Abstract

The Next Generation Science Standards (NGSS Lead States, 2013) ask science teachers to address both science and engineering content and processes in school curricula and assessments. STEM teacher education programs in the United States do not traditionally include any formal or informal classroom experiences to support pre-service teachers with the development of disciplinary knowledge in engineering (Katehi, Pearson, & Feder, 2009). In addition, clinical programs in which pre-service teachers engage for student teaching often take place in classrooms that do not provide examples of how to implement engineering experiences in the science classroom.

This is a preliminary evaluation of the impacts of a pre-service teacher engineering education program that integrates engineering and science into a secondary science education methods class. These engineering education learning experiences (EELE) included a variety of activities (speaker panels, engineering laboratory tours, 'maker space' workshops, and model STEM or science, technology, engineering, and math lessons) for developing knowledge and practices for integrating engineering into science instruction. The goal of the EELE program was to engage the participants in experiences that represent how engineering is a field of study for all students who are interested in creatively solving problems to meet human needs.

Methods

Our hypothesis was that involving teacher education students in different engineering education learning experiences would support these students with identifying how they could make use of engineering activities to help their students learn science.

The design of the different EELE activities were guided by Social Cognitive Theory (Bandura, 1977) to develop pre-service students' capabilities by integrating engineering practices into science teaching. Social Cognitive Theory relates self-efficacy, or the level of belief in oneself to take action, with social experiences that can impact one's emotional response to being able to participate in or complete the action (Clark, Byrnes & Sudweeks, 2015). The EELE activities allowed pre-service students and their mentors to participate collaboratively in "social experiences" that included structured pedagogical discussions about teaching and reflections on the integration of the science and engineering modeled in each EELE experience.

Collected data included written reflection statements produced by the pre-service students (n= 18) for each of the five model STEM lessons that occurred in a three hour seminar. Each two-page reflection was guided by the same prompts that asked students to "synthesize one or two important ideas (descriptive reflection), "provide insightful (analytical) reflections about what you learned" and "be explicit about what you will and will not (evaluative reflection) apply to your future teaching." Analysis followed a grounded theory approach (Lincoln & Guba, 1985), characteristic of a naturalistic inquiry seeking themes in qualitative data.

References:

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84, 191-215.
Clark, S. K., Byrnes, D., & Sudweeks, R. R. (2015). A Comparative Examination of Student Teacher and Intern Perceptions of Teaching Ability at the Preservice and Inservice Stages. Journal of Teacher Education, 66(2), 170-183.
Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). Engineering in K-12 education: Understanding the status and improving the prospects. Committee on K-12 Engineering Education, National Academy of Engineering and National Research Council. Washington, DC: National Academies Press.
Lincoln, Y. S. and Guba, E. G. (1985). Naturalistic inquiry. Beverly Hills, CA: Sage.
NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Engineering Education Learning Experiences

1. **STEM Professional Panel Discussion: "What workplace skills are important in today's STEM industries?"**
   Focus: Connecting classroom instruction to STEM workforce skills; Encouraging student interest in STEM fields.
2. **Tour of University Engineering Laboratories: "How are STEM practices represented in different contexts?"**
   Focus: Review engaging engineering spaces for inspiration and learning about engineering practices.
3. **Model Lesson: "How can we provide clean water in a community?" (Earth Science**)
   Focus Scientific Practice: Evaluating & Analyzing Collected Data; Proposing Reasonable Explanations or Solutions
   Focus Teaching Practice: Promoting and Managing Scientific Discourse; Scientific Concept Formation
4. **Model Lesson: "Why did the letters on the sign change in the rain?" (Forensics/ Chemistry)**
   Focus Scientific Practice: Using Models to Support Predictions or Hypotheses
   Focus teaching Practice(s): Promoting and Managing Scientific Discourse; Scientific Concept Formation
5. **Model Lesson: Plants in Space Project – "How can we support plant growth as we travel to Mars?" (Biology)**
   Focus Scientific Practice: Investigating Answerable Questions
   Focus Teaching Practice: Setting Norms for Scientific Work
6. **Model Lesson: "How can we use technology to describe changes in matter?" (Physical Science)**
   Focus Scientific Practice: Evaluating & Analyzing Collected Data; Using Models to Support Predictions or Hypotheses
   Focus Teaching Practice: Promoting and Managing Scientific Discourse; Scientific Concept Formation
7. **Model Lesson: "What Factors Impact Vehicle Motion?" (Physics)**
   Focus Scientific Practice: Investigating Answerable Questions; Using Models to Support Predictions or Hypotheses; Computational Thinking
   Focus Teaching Practice: Promoting and Managing Scientific Discourse

Acknowledgements

This Program Evaluation is
Coordinated by the Center for Educational Design, Evaluation, and Research (CEDER)

The U-M Noyce Program's Primary Investigator is
Dr. Elizabeth Moje

SCHOOL OF EDUCATION
UNIVERSITY OF MICHIGAN

Results/Discussion

Preliminary findings represent several emergent themes related to the use of engineering activities for teaching science:

Theme "Problematizing the Science Content with an Answerable Question."

Pre-service teachers noted that they *"…intend to integrate answerable questions as the frame of labs"* and they felt that *"…each group was focused on solving a common issue—how would we survive in space…?"*

Theme "Addressing Real World Needs to Make Science Content Accessible, Engaging, and Useful."

Reflection comments include how the engineering activities *"…allow students to identify problems in society or their local communities that they are personally interested in...This is science in action, and science with a purpose."* And *"In this 3 day teach, I realized this connection, that if students cannot see the phenomena, the concrete, it will be harder to move towards the abstract, more higher order thinking."*

Theme "Using the Collaborative Social Aspects of Engineering to Support All Students with Learning Science"

Reflection comments noted that model STEM lessons *"supports effective collaboration"* through *"- the designation of roles and responsibilities… everyone must actively participate"*

The pre-service teachers commented on how the engineering activities supported all students with learning science, noting *"this type of activity, I imagine, would develop the confidence of young scientists, particularly with underrepresented students as they would enjoy small and numerous successes: assembling the light box, using tools, generating data, and applying their data to accept or reject their stated hypothesis. "*

Implications

Pre-service student teacher reflections include statements that indicate that they recognize how engineering can be used to support student learning of science content and practices, and the reflections identify strategies that are representative of positive beliefs for using engineering tasks in their own classroom teaching.

The EELE program was designed to support the pre-service students with associating positive emotional experiences with the integration of science and engineering. For example, the panel, tour, and modeled lessons were designed as "vicarious experiences," allowing participants to observe how engineers and master science teachers support the integration of engineering and science content. The maker space workshops were designed to provide pre-service students and mentors a space to participate collaboratively in "social modeling" by engaging in pedagogical discussions about the use of effective teaching practices in the modeled engineering lessons. Debrief protocols allowed pre-service students to receive positive feedback on their ideas, their concerns, and their use of teaching practices when reflecting on their learning about using engineering in the science classroom. Exploring pedagogies that help pre-service teachers learn and apply engineering design knowledge and skills in the science classroom, while also impacting their beliefs about the importance of these practices, is important for teacher education and professional development.