In Practice

Collaborators in Elementary STEM: Engineering and Teacher Education

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Abstract

This article describes a collaboration between engineering and teacher education departments from two universities in Virginia in the 2015-2016 semesters on how engineering students and teacher education students enhanced the skill sets of elementary students in science, technology, engineering, and math (STEM) in their classrooms. Engineering students observed and participated as student teachers taught STEM units. Teacher education students observed and participated as engineering students conducted short STEM hands-on sessions. The outcome was mutually beneficial as engineering students learned teaching techniques and skills, while teacher education students learned STEM knowledge and engineering practices. Future ideas include co-designing engineering challenges and cooperation in summer STEM camps.

The Growth of STEM Education

Newly graduated K-12 teachers in the United States are scrutinized with more intensity than ever before. They are expected to demonstrate content mastery in literacy and math, and are further expected to be able to apply the latest technology skills (Carroll & Resta, 2010; Yildiz & Palak, 2016; Zhao, 2010). Of the movements resulting from expectations for improvements in K-12 education over the last two decades, science, technology, engineering, and math (STEM) have risen the fastest. (Bybee, 2013; Ritz & Fan; 2015). In teacher education, the response to the need for STEM expertise lags, but has improved in recent years (Goldhaber, Krieg, Theobald, & Brown, 2014; Nadelson, Callahan, Pyke, Hay, Dance, & Pfiester, 2013). The STEM Education Act of 2015 is the latest cause of a spike in activity, and serves as a significant indicator of long term government support.

Prior government efforts in STEM education were detailed in Kuenzi's (2008) report, a survey of 13 federal agencies. It listed 207 federal education programs aimed at increasing the number of students in STEM-related fields or of improving the quality of STEM education, but these were largely directed toward bringing college students into STEM careers. As for lower grade levels, the story was different. "Improving K-12 teacher education in STEM areas was the least frequent of the major goals, improving infrastructure was the least frequent of the main types of assistance, and elementary and secondary students were the least frequent group targeted by federal STEM education programs" (Kuenzi, 2008, p. 19).

There is an acknowledged and documented need for STEM in elementary schools (Bybee, 2013; Epstein & Miller, 2011; National Research Council, 2013). The shortage of STEM in elementary schools across the nation led to the President's Council of Advisers on Science and Technology to recommend 800 STEM-focused elementary and middle school initiatives (Best Practices, 2012). Additionally, the National Science and Technology Council Committee (2013) released a report underscoring STEM needs, objectives, and provides roadmaps to implementation. The momentum is increasing for STEM education, not only in middle and high schools, but also in elementary schools. This need has led schools of teacher education to begin integrating STEM programs with elementary education. Examples include The National Center for STEM Elementary Education at St. Catherine's University, Central Michigan University's Center for Excellence in STEM Education, Johns Hopkins School of Education, the University of Cincinnati, the College of Education at Georgia State, and others. Although not the norm, the list continues to grow.

Based on these national trends, observations of interest, and activity in Virginia schools, a move toward a pilot program in STEM with student teachers at Radford University was born. As an assistant professor and cohort leader, I believed that benefits would be felt immediately by the student teachers, and the resulting data could inform future discussions of STEM in teacher education at Radford University.

Early STEM Planning

As an assistant professor in teacher education at Radford University, my role was guiding student teachers (interns) through a two-semester field experience. Teacher education interns are placed in local elementary classrooms with experienced cooperating teachers, and they emerge at the end of the year, ready to graduate as licensed teachers in the state of Virginia. While this methodology worked well to address regular academic areas, it did not address STEM. So, after deciding to implement a pilot, the next step was how exactly to make this happen. The logical path was to springboard off my own science background - my other university responsibilities included teaching a science methods course. In addition to using the Virginia Standards of Learning, I had introduced the Next Generation Science Standards (NGSS) in my science course. The NGSS are built on four core ideas: life science, engineering and technology, earth and space sciences, and physical sciences (Concord Consortium, 2013). These standards provided a practice-based approach which defined student experiences in STEM (Houseal & Ellsworth, 2014).

An Accidental Collaboration

STEM on Wheels Trailer

Looking around in my region for STEM opportunities led me to the director of the Virginia Tech Center for the Enhancement of Engineering Diversity (CEED). I learned of a Virginia Tech program called *STEM on Wheels* and wondered if it could be brought to visit my cohort. It turned out that the program had been discontinued, so this seemed at first to be a dead end. The actual trailer, which held all sorts of STEM materials, was sitting unused in a Virginia Tech parking lot. I learned that there was an effort underway to revive the *STEM on Wheels* program *and* that volunteers were needed – perfect for my needs. But when I met with the CEED director to discuss possibilities, a different situation presented itself, something beyond STEM material in a trailer. The CEED director and I discussed our respective plans and goals, and uncovered a commonality. While I had needs for more technical information on STEM for my interns, the CEED director needed assistance on teaching practices and tips for engineering students, who were planning to conduct STEM demonstrations in elementary classrooms. This was clearly an "aha moment" for both of us.

Symbiosis: Education and Engineering

CEED is an organization for undergraduate students pursuing different kinds of engineering majors including chemical, ocean, civil, mechanical, electrical, etc. In CEED, the engineering students are required to be part of various outreach volunteer programs. One of the available choices was interacting with elementary classrooms, to help teachers enhance science and math instruction while at the same time introducing engineering education into the classroom. These classroom teaching visits were meant to provide engineering students with service learning opportunities, while helping young learners develop an understanding of what it means to be an engineer.

Prior to the agreement to work together, the engineering students had conducted school visits with mixed results. The engineering students were short of teaching experience and techniques, so their STEM lessons were often perceived as events in which entertainment and engagement were high, but not necessarily that science and engineering content had been learned and remembered. Any classroom teacher knows that just having the knowledge of content does not translate to student learning. The use of organization, language, wait time, classroom management, transitions, clear directions, developmentally appropriate vocabulary, checking for understanding, involving all students, and the meaningful use of technology all contribute to a successful lesson (Evertson & Weinstein, 2013; Lewis, 2015). These are the mainstays of elementary learning experiences – the structures, knowledge, and techniques that teacher education programs provide and that veteran teachers know by heart. Next steps? How would we begin the mutual sharing of the engineering students' technical knowledge and the interns' classroom teaching skills so that each might benefit from the knowledge of the other?

Student Teacher Reflection: The STEM Assignment

At the end of our early field experience, our teacher education supervisors explained that we would be the first cohort to integrate STEM into our work sample unit in the fall of 2015. Our cohort completed two semesters of classroom experiences: an early field experience in the spring and student teaching in the fall. Over the summer, our cohort prepared for this challenge by researching STEM and how it could be incorporated within the science curriculum. To do this, we were encouraged to become student members of the National Science Teachers Association (NSTA) so we would receive a science journal which focused specifically on STEM in the elementary classroom, something that none of us were familiar with. Going along with STEM, we were asked also to become familiar with the Next Generation Science Standards which focus on specific practices and cross cutting concepts (Concord Consortium, 2013).

Upon returning in the fall for student teaching, we were given supplementary information in regards to our STEM work sample unit. Our instructors said we would be challenged to plan and implement a five-hour STEM unit correlating with a science Standard of Learning. As student teachers, we were to incorporate three of the four components of STEM within all of our lessons. Additionally, we were required to plan and introduce an engineering problem or challenge requiring our students to use all four STEM components as guided by the engineering design process to create solutions.

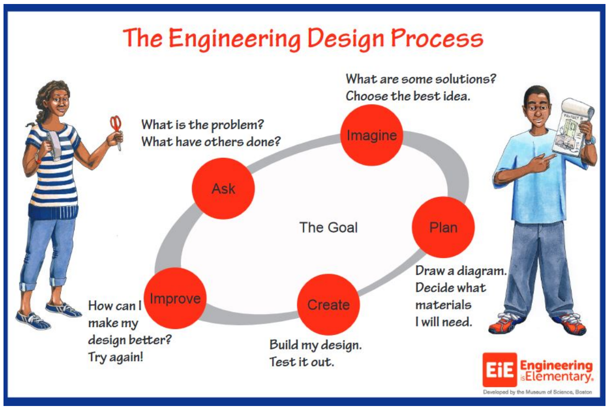
Radford University Teacher Cohort

In the fall of 2015, twelve interns began their final semester of the teacher education program. The first part of the semester was early field experience, a time for observing, assisting, with minimal responsibilities, a period of getting to know the school setting, working with a cooperating teacher, and to experience the social dynamics of children. The final placement would engage these interns in something entirely different from our usual student teaching process.

Instead of the usual summer off, this group of interns completed readings and assignments on STEM. They signed up with National Science Teachers Association (NSTA) as student members, and in doing so, they received *Science and Children*, a journal dedicated to teaching science to young learners K-5. Based on the Next Generation Science Standards, the journal provided background on science and engineering, core idea themes, engineering projects, connections for English language learners, lesson plans using trade books for K-2 and 3-5 classrooms, and lab safety instructions. Student memberships included access to the science teacher web site including archived journals, and downloads for materials and handouts needed for the lessons. In the fall 2015 semester, interns entered their K-5 elementary placement classrooms, again working with cooperating teachers, but this time they were expected to take on much more responsibility. A major required assignment in student teaching was the science *work sample unit* - this assignment structure provided an excellent vehicle for exercising STEM capabilities and experiences.

Beginning the STEM Unit – What is Engineering?

Interns were asked to teach their science units with STEM, a significant departure from the usual unit assignment. For example, in addition to defining and demonstrating a science concept, interns were asked to think and act with a cross-curricular, problem solving approach. This is where the engineering would become clear – when science concepts were applied to a need or a problem in the world. From their summer studies, interns had learned that generally science seeks to explain and understand phenomena, while engineering is the practice of designing solutions to solve problems or meet human needs (Guelph Engineering, 2016). STEM planning and lessons were basically guided by the engineering design process as shown below.



Engineering is Elementary® Engineering Design Process (Museum of Science, Boston, used with permission)

When student teachers observed typical elementary science lessons taught by cooperating teachers, the approach was usually a guided step-by-step. The scientific method was sometimes introduced, and elementary students often engaged in observations, took measurements, made hypotheses, read science literature, and observed demonstrations of science concepts (Talbot-Smith, Abell, Appleton, & Hanuscin, 2013). For example, in studying forms of matter, using water to show solid, liquid, and gas, an expected outcome would be elementary students learn these properties by following the steps of the lesson. Students would observe phenomena and record data, all steps that could be reproduced by other young scientists, and therefore illustrating some aspects of the nature of science. This method can result in learning, however, no application by the students occur in this process.

For this same process to be viewed from a STEM perspective, the students would need to use scientific principles to solve a real-world problem or to construct a device that solves a real-world problem connected to the states of water. Possibilities might include situations caused by water erosion, freezing and melting effects of water, keeping water out of homes, preventing flooding, protecting wildlife from polluted water, etc. In this case, the students would need to understand the properties of water and then devise solutions to counteract or leverage the properties to help meet the needs of humans or other organisms in the environment.

Compared to the science classroom example on the properties of water, in the STEM example, the students would need to go beyond showing understanding. In finding an engineering solution, they would engage in cross-curricular aspects using language, science, technology, engineering, and math. They would be required to create a plan or build a device to meet these needs. Following the engineering design process, they would test their ideas, tinker with variables, then refine until arriving at an acceptable solution (Daugherty, 2013).

Engineering Students Observe the Interns

Using the Virginia Standards of Learning, resources from NSTA and the instructor's preservice teacher web, the interns designed engineering challenges for their units. They were asked to distinguish between science and engineering, and to make sure that students knew what it meant to learn in a blended situation of science, technology, engineering, and math. First-graders designed devices to prevent pumpkins from rolling downhill. Second graders engineered clay models of flooding rivers and oil spills. In fourth grade, students created catapults to launch weights over a wall from a specified distance. Fifth-graders worked on a water erosion problem for a real dam in northern Virginia which was in danger of collapsing. Selected examples are shown below.

Projects planned by preservice teachers

During each of these STEM challenges, an engineering student from Virginia Tech was present in the classroom observing, asking and answering questions, and generally looking for ways to interact with the elementary students. Interns were directing classroom activities, managing behavior, asking higher order questions, and transitioning groups between learning situations. As newcomers, the engineering students were reserved at first, and mainly watched, but once the challenges began, they took more initiative. In the catapult lesson, several devices were malfunctioning. One engineering student was heard to ask elementary students what could be changed or improved to make the device work – addressing the variables of engineering design. In another case, elementary students were designing inventions to strain large and small particles of trash and plastic from the ocean, a real-world problem requiring science and engineering. An engineering student explained how the circular motion of ocean currents "trapped" garbage into huge floating clumps.

Short conversations with the engineering students following their observations revealed some common themes. Each remarked that it seemed difficult to keep the attention of all of the elementary students for more than a few moments. They noted that some students were not listening and following instructions, while others were highly engaged. All of the engineering students described the classroom as a more complicated environment than they had thought would be. Most of the engineering students said they had expected that the elementary students would listen and follow directions.

Student Teacher Reflection: Mutual Observations: Education and Engineering

While teaching a 5th grade STEM unit on the rock cycle and weathering, erosion, and deposition, I had the pleasure of working with a Virginia Tech engineering student in my class. This helped my students understand the engineering model we were using was the same one that real engineers followed when creating solutions. The engineering student was able to answer my students' specific questions about engineering, things I was not qualified to answer. This provided our lesson with a real-world application because the kids could see an engineer demonstrating her role in problem solving.

Additionally, I was given the opportunity to work with an engineering student in a 5th grade classroom at a different school where we implemented a

STEM challenge dealing with cleaning up garbage in the ocean. I observed how the challenge was set up and how the students created wonderfully individualized solutions even though they were all given access to the same criteria and engineering materials.

As a result of both experiences, I realized, from the teacher education side, I noticed that the teacher has the strength of knowing the students. More specifically, the teacher knows who works well with one another so that appropriate groups can be designed for cooperation. Additionally, the teacher has knowledge of classroom management techniques, which I used in this instance to get the classroom in order, while the engineering student was introducing the challenge. Individuals who are not education majors do not usually realize the professional skills needed in order to conduct an orderly STEM challenge with a group of 20 students, as well as staying within the constraints of classroom time. Comparing, I noticed that the engineer could provide students with more accurate information than I could as the classroom teacher, since they were talking about content from their field, and were very comfortable with that content. This collaboration resulted in the success of the STEM experience because multiple individuals were able to contribute their knowledge (Best Practices, 2012).

VCEC Logo © Used with permission

Student Teacher Reflection: Presenting at a Conference – February 2016

The Virginia Children's Engineering Council Conference was the first time I presented at a conference. I was honored to be a part of the experience. However, although I am comfortable speaking in front of a group of children, speaking in front of a group of teachers, and possibly principals, made me nervous. During the conference, I became less nervous because we had already experienced the STEM challenge previously in our 5th grade classroom practice session. Having done that preparation was a valuable lesson. It helped us all become more aware of the components of our presentation so that we were prepared for the conference. I interacted with the audience members of the conference comfortably as if they were my co-workers. Based on background information and instructions from our presentation, audience members came up to the materials table and began working on the engineering challenge. I felt as if we created an energetic atmosphere that lent itself to every participant feeling as if they were taken back to their elementary school days.

Collaboration at the STEM Conference

The Virginia Children's Engineering Council Conference is a major regional gathering of STEM and engineering-based teachers. Our presentation was a four-part event showcasing the collaboration between Virginia Tech and Radford University: two college students, and two university professors. Neither the engineering student nor the teaching intern had ever presented at a conference before, and there was a heightened sense of excitement. Together, they took charge of an elaborate, hands-on STEM experience in which audience members were challenged to use an array of materials to create a floating device of specific dimensions, and to place the device into a water tank to complete the task of removing plastic particles. As we have seen in many STEM challenges, every device was different, and participants were quick to try, rebuild, try again, and again as necessary--demonstrating the engineering loop design process. Some of their examples are below.

Devices created by audience members

Student Teacher Reflection: How This Relates to My Future

These experiences helped provide a foundation for my future career in education. In the schools where I have worked as a substitute teacher, STEM is common; its implementation takes place on a daily basis. One school had set up its own STEM lab where elementary students worked together on many different STEM challenges. Accessible were a wide range of construction materials such as empty egg cartons, old newspaper, straws, craft sticks, duct tape, wire, rubber bands, electric motors, and hot glue guns. As STEM has become increasingly popular within the elementary curriculum, I am encountering more opportunities for learning how to integrate STEM into a tight curriculum. From the perspective of teaching and learning, STEM experiences provide wonderful opportunities for critical thinking and hands-on activities that students need. Giving students the freedom to work with STEM shows how capable they can be when they are not limited by one answer, but instead presented with an open-ended, engaging problem that matters to them (Bybee, 2013).

Concluding Discussion

This pilot program involved the collaboration between professors from two universities, in departments of engineering and teacher education, and students from both academic areas. In the process, the professors shared goals and techniques from their respective programs, and found areas of commonality for reaching elementary students from pedagogical and STEM content perspectives. Professors observed their respective students interacting in classroom situations as well as in presenting their knowledge together at the VCEC conference. From the view of teacher education, this pilot program suggests that collaborations between student teachers and students from other disciplines can produce positive results not typically attainable in either the education or the engineering environment alone.

Future, discussions are in place for more collaboration between Virginia Tech engineering students and Radford University student teachers. Ideas for next steps include the co-design of STEM topics and lessons for the work sample unit, and enlisting teacher education interns to teach in the Virginia Tech summer STEM camp. Experiences described in this article involved a small pilot group of preservice teachers and engineering students, but its overall context for learning is important. Teachers know that content-rich, active learning experiences are the most engaging and the most effective. STEM can offer the context of working and learning with real world challenges that require multiple modes in a blend of content areas. Such experiences provide students the opportunities to truly construct their own knowledge.

STEM Organizations Cited

National Science Teachers Association – http://www.nsta.org

Center for the Enhancement of Engineering Diversity - https://www.eng.vt.edu/ceed

Virginia Children's Engineering Council – http://www.childrensengineering.org/

International Technology and Engineering Educators Association – http://iteaa.org

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