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Advancing Science Learning: Increasing Elementary Teacher's Ability to Teach Science Using Engineering Problems

SESSION I: Leadership Role for Technology and Engineering

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Note: This paper summarizes the results of year 3 of a three-year project. It contains some materials that were presented in papers summarizing previous year's finding.

INTRODUCTION

Elementary teachers in Northwestern Wisconsin are learning how to use engineering problems to advance science learning. Year 3 of The Advancing Science Learning (ASL) project partnered 11 rural and high poverty school districts in Northwestern Wisconsin with staff from the Wisconsin Cooperative Education Service Agency (CESA) 11 and faculty members in science, engineering, and education from the University of Wisconsin-Stout. This three year professional development project was supported by a Wisconsin Improving Teacher Quality Grant (WITQ), which is funded by the federal Elementary and Secondary Education Act (ESEA). The goals of the project were to: (1) increase teachers' content knowledge for teaching science, (2) establish a relationship among participants and partners, (3) increase teacher application of content-specific pedagogy in science, and (4) improve student achievement in science. The focus for the third year of the ASL project was on utilizing engineering problems to teach earth science concepts and engaging participants in the science and engineering practices, as described in the Next Generation Science Standards (NGSS) (NAP, 2013).

NEEDS ASSESSMENT

According to the U.S. Department of Education, “not enough of our youth have access to quality STEM learning opportunities.” (2015). This is especially true at the elementary level in science. Some argue that many pre-service elementary teachers demonstrate a naïve understanding of the nature of science (Abd-el-Khalick, 2001). According to Weiss, Banilower, McMahon, and Smith, only 24% of elementary teachers in the United States reported feeling well qualified to teach science (2001). The number of teachers who felt well qualified to teach the life sciences (29%) was slightly higher than the number of teachers who felt well qualified to teach the physical sciences (18%). By comparison, the same study found that 76% of elementary teachers felt well qualified to teach reading and 60% felt well qualified to teach math.

In some cases, this lack of self-efficacy in science content and pedagogy has led elementary teachers to avoid teaching science and spend more time on other, more familiar subjects (Appleton & Kindt, 2002). When combined with an increased emphasis on math and reading, it is not surprising that the amount of time devoted to science in elementary schools has decreased over the past twenty years. From 1993-1994 to 2007-2008, the amount of time devoted to science in elementary schools in United States has decreased from 3.0 hours per week to 2.3 hours per week (NCES, 2008). For the 2007-2008 school year, the number of hours devoted to math was more than twice (5.6 hours per week) the number of hours devoted to science and the number of hours devoted to English was more than five times (11.7 hours per week) the number of hours devoted to science.

In addition to these national trends, a local needs assessment of Wisconsin elementary teachers in the CESA 11 region revealed a need for professional development in science. In the spring of 2012, the CESA 11 Science, Math, and Technology consortium sponsored a Next Generation Science Standards (NGSS) workshop series. A survey showed that 90% of the teachers who attended were generalists with elementary licenses, with little to no additional background or training in science content and pedagogy. These teachers were assigned to teach and often provide leadership in science within their grade level or school based on "team need" or "comfort" with science. These assignments were often based on teacher attitude toward science, rather than expertise or specialization.

The survey also showed that 77% of the teachers were "not confident" in applying inquiry within their science lessons and even less confident in applying literacy practices in science, such as science notebooking. The participants who signed up for the ASL project also expressed their desire to receive training with "interactive notebooks." They needed a formal system to facilitate inquiry-based learning, formative assessment, and reflective practices in their science teaching. The survey also showed that the schools needed the leadership required to move forward with a common vision of standards-based and research-based practices in science education.

Furthermore, 100% of the teachers surveyed had a "strong" interest in professional development to further develop their content and pedagogical knowledge and skills for teaching science at the elementary level. When asked about their need for further study in various science content areas, the elementary teachers indicated that they had "some" need for life science and a "great" need in physical science, earth and space science, and engineering and technology. Overall, our survey demonstrated a local need for a high-quality professional development in all of the Disciplinary Core Ideas of the Next Generation Science Standards (NAP, 2013). This data helped to inform our design of the professional development experiences.

The need for high quality professional development for teachers in the area of science is clear. According to Blank, Alas, and Smith, the current standards reforms "requires teachers to have deep knowledge of their subject and the pedagogy that is most effective for teaching the subject" (2007, p. 3). In particular, elementary teachers locally and nationally need more instruction and support to teach the disciplinary core ideas, cross-cutting concepts, and science and engineering practices described in the Next Generation Science Standards (NAP, 2013). The ASL project was intended to meet this need.

ESTABLISHING PARTNERSHIPS

The Advancing Science Learning (ASL) project is a collaborative partnership between Cooperative Education Service Agency (CESA) 11, the University of Wisconsin-Stout, and local schools in Northwestern Wisconsin. Faculty members from the University of Wisconsin-Stout included Kevin Mason (Associate Professor of Science Education), Adam Kramschuster (Associate Professor of Plastics Engineering), Mathew Kuchta, Assistant Professor of Geology). Brian McAlister, (Professor of Technology

Education) was the Principal Investigator for the grant. Denise Michaelson, a certified Science teacher from CESA 11 served as an instructor and the project manager.

The participants for the ASL project in year 3 included 40 participants from 11 different schools districts: Amery, Chetek-Weyerhaeuser, Ellsworth, Hudson, Osceola, Pepin, Spring Valley, St. Croix Central, St. Croix Falls, Turtle Lake, and Unity. These schools recognized the need to improve elementary teachers' content and pedagogical knowledge in order to improve student performance in science.

The ASL project included 12 teachers in grades K-1, 10 teachers in grades 2-3, 16 teachers in grades 4-6, 1 Library Media Specialist and 1 Special Education teacher. There were 34 female (85%) and 6 male (15%) participants, which is typical of elementary teachers locally and nationally. By race, there were 39 Caucasian (97.5%) and 1 Native American (2.5%) participants, which is typical of elementary teachers locally. The professional development experiences were designed specifically to meet the needs of these participants, as determined by a needs assessment.

PROFESSIONAL DEVELOPMENT

Professional development for teachers is a proven methodology for improving instruction and student performance in science. Desimone, Smith, and Phillips identified four essential characteristics of effective professional development in math and science (2007). First, it must focus on the subject matter and how students learn the subject matter. In science, teachers must be engaged in doing inquiry-based science, which is reflected in the science and engineering practices of the Next Generation Science Standards (NAP, 2013). Second, effective professional development must be sustained over an extended period of time. Similarly, Harwell described professional development as a process, rather than a single event (2003). Third, it must be consistent with other activities in the school and professional community. Fourth, it must allow teachers the time to interact, communicate, and support one another as they learn, grow, and apply their new knowledge of content and pedagogy.

The ASL project was designed with these evidence-based practices in mind. The professional development experiences included a Professional Learning Community (PLC) Vision Conference, Summer Academy, classroom observations by instructors, local collegial networking within schools, collaborative exchanges between schools, and ongoing electronic communication among all partners. The professional development experiences engaged the participants in learning science content and pedagogy related to the Next Generation Science Standards during a one-week Summer Academy, but also provided opportunities for interactions and supports as teachers attempted to implement their new knowledge and skills throughout the school year.

The first activity of the ASL project was a Professional Learning Community Vision Conference in the spring of 2013. At this event, the participants were introduced to the partners and given a pre-test on the nature of science and engineering. Participants were also given another pre-assessment on the content knowledge they were going to experience prior to each summer academy. The 2015 participants were given a pre-assessment of their earth science content knowledge using the Diagnostic Science Assessment for Middle School Teachers (DTAMST) from The University of Louisville Center for Research in Mathematics and Science Teacher Development. The corresponding post-assessments of their earth science content knowledge and their understanding of the nature of science and engineering were given on the final day of the Summer Academy.

THE SUMMER ACADEMY

The Summer Academy utilized engineering problems to increase the teachers' knowledge of each science discipline, deepen their understanding of the nature of science and engineering, and engage them in the science and engineering practices of the Next Generation Science Standards (NAP, 2013). Engineering is Elementary (EiE) was selected as the curriculum for the project, because of its proven effectiveness in engaging elementary students in rich, authentic, and meaningful engineering problems (Cunningham, Lachapelle, & Hertel, 2012). The EiE curriculum begins each unit by introducing the students to an engineering problem, which is set in an authentic, real-world context. The students learn to utilize the design process to propose, create, and test a solution, and, in the process, the students are engaged in many different science and engineering practices. The EiE curriculum resources were also made available to the participants throughout the academic school year, so they could replicate the professional development activities to engage their students in the science and engineering practices using the EiE kits.

To support the science and engineering learning activities, the teachers in the ASL project were taught to use interactive notebooks, as a pedagogical strategy for promoting inquiry-based learning, scientific literacy, language literacy, reflective writing, and formative assessment. The use of interactive notebooks was both taught through a series of short lecture and discussions each day and modeled during the EiE activities. According to Klentschy, "Science notebooks have the potential to move students beyond completing the task to making sense of the task" as well as "support the development of students' scientific reasoning" (2010, p.8).

An interactive notebook also allows the student to reflect on and write about their prior knowledge and current understanding of scientific concepts. In her book, *Teaching Science with Interactive Notebooks*, Marcarelli explained that "students record their observations, ideas, and thinking, and they reflect on their learning in a variety of interactive ways" (2010, p. xii). In an interactive notebook, the students' thoughts and reflections are recorded on the left-hand page, while the more traditional, teacher-directed activities such as lectures and labs are recorded on the right-side page. After practicing and discussing this strategy during the Summer Academy, teachers were able to implement the use of interactive notebooks in their classrooms during the following school year with support from colleagues and instructors in the project.

THE 2015 SUMMER ACADEMY

The focus of the 2015 Summer Academy ficussed on utilizing engineering problems to teach earth science concepts and engaging the participants in the science and engineering practices described in the Next Generation Science Standards (NGSS) (NAP, 2013). The instructors selected three Engineering is Elementary (EiE) units to be used as instructional activities during the 2013 Summer Academy:

- *A Sticky Situation: Designing Walls*
- *A Stick in the Mud: Evaluating a Landscape*
- *Water, Water Everywhere: Designing Water Filters*

These kits were selected based on their alignment with the earth science core ideas and science and engineering practices of the Next Generation Science Standards (NAP, 2013), as illustrated in the table below. The EiE activities were also supplemented with instructional activities in the earth sciences, provided by Mathew Kuchta, a faculty member in Geology Physics at the University of Wisconsin-Stout.

EiE Kits	NGSS Earth and Space Science	
A Sticky Situation: Designing Walls	**2-PS1-1.**	Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.
	2-PS1-2.	Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
	4-ESS3-2.	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
A Stick in the Mud: Evaluating a Landscape	**2-ESS1-1.**	Use information from several sources to provide evidence that Earth events can occur quickly or slowly.
	2-ESS2-1.	Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.
	2-ESS2-2.	Develop a model to represent the shapes and kinds of land and bodies of water in an area.
	3-ESS3-1.	Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
	4-ESS2-1.	Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.
	4-ESS3-2.	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
	5-ESS2-1.	Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
Water, Water Everywhere: Designing	**K-ESS3-3.**	Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.
	2-ESS2-3.	Obtain information to identify where water is found on Earth and that it can be solid or liquid.

Water Filters	**5-ESS2-2.**	Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.
	5-ESS3-1.	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

In addition to addressing earth science concepts and standards, the EiE learning activities utilized during the Summer Academy also addressed the engineering, technology, and applications of science standards by engaging the teachers in the engineering design process: asking questions, defining problems, making observations, gathering information, comparing solutions, developing models, analyzing data from tests, and making improvements (Next Generation Science Standards K-2-ETS1.1-3, 3-5-ETS1-1-3). The use of engineering problems and the engineering design process provided an authentic context for engaging teachers in the science and engineering practices of the Next Generation Science Standards (NAP, 2013), which parallel the engineering design process.

The eight science and engineering practices of the Next Generation Science Standards are: asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics, constructing explanations and solutions, engaging in arguments from evidence, and obtaining, evaluating, and communicating information (NAP, 2013). These are very similar to the engineering design process described in the engineering, technology, and application of science standards (NAP, 2013). Through these engineering problems and additional learning experiences in the life sciences, the participants were able to improve their understanding of the nature of science and engineering, which is profoundly needed for improving science education in elementary classrooms (Abd-el-Khalick, 2001).

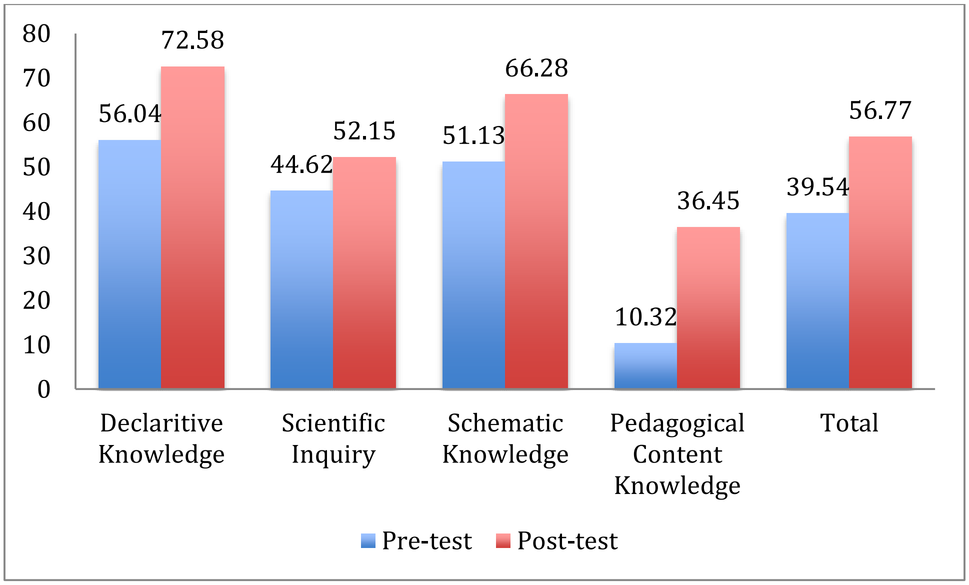
FINDINGS

The pre and post-assessments provided evidence that the teachers' gained valuable earth science content knowledge and a deeper understanding of the nature of science and engineering through the professional development activities. The teachers' content knowledge in earth science was assessed by the Diagnostic Science Assessment for Middle School Teachers (DTAMST) from The University of Louisville Center for Research in Mathematics and Science Teacher Development. Although there were 40 participants in year three of the ASL project, not all were present on the both days when the pre and post-assessments were administered. Therefore the sample included 31 participants that participated on both days.

The DTAMST pre and post-assessment scores can be disaggregated into four types of knowledge: Declarative Knowledge (e.g. definitions and facts), Scientific Inquiry (e.g. scientific practices), Schematic Knowledge (e.g. laws and theories), and Pedagogical Content Knowledge (e.g. teaching strategies in earth science).

The pre and post-assessment results shown in Figure 1 reveal the strengths and weaknesses of the teachers' knowledge in earth science before and after the professional development experience. The highest average score on the pre-assessment occurred in Declaritive Knowledge (56.04%) and the lowest in Pedagogical Content Knowledge (10.32%)

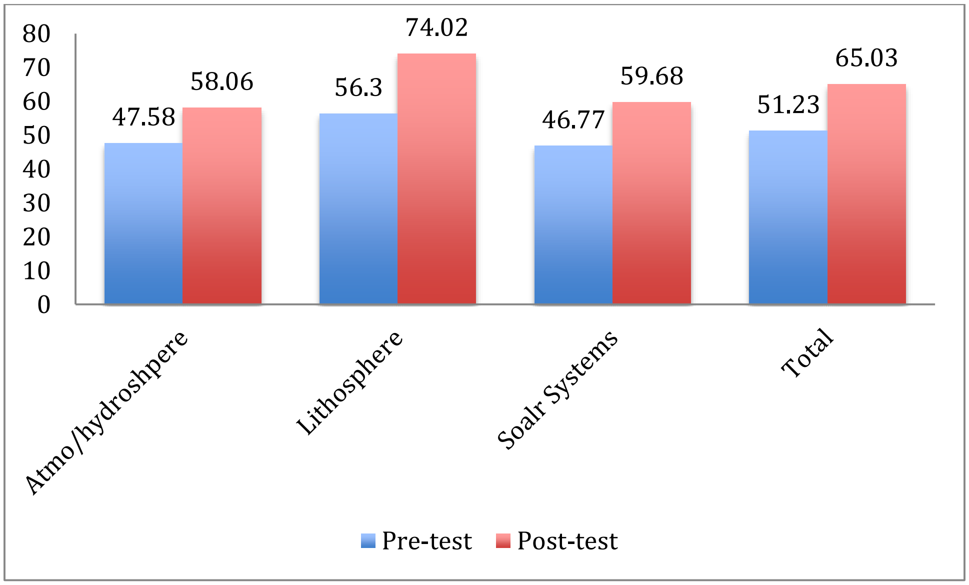
Figure 1 Pre and Posttest Mean Scores by Types of Knowledge.



The highest average score on the post-test occurred in Declarative Knowledge (72.58%). While Pedagogical Knowledge remained at the bottom during the post-test (36.45%), it reflected the largest gain (26.13%). Overall, participants' scores reflect gains across all subcategories of knowledge and an overall gain from 39.54% to 56.77% on the Types of Knowledge portion of the assessment representing a statistically significant gain at the .0000000003 level using a 1 tailed t-test.

The pre and post-assessment scores were also be separated into three subcategories of earth science and its technological applications: Atmosphere/Hydrosphere; Lithosphere; and Solar. The pre and post-assessment mean scores represented as percentages are shown in Figure 2 for each subcategory of earth science.

Figure 2. Pre and Post-assessment Mean Scores by Sub-category



The pre and post-assessment results shown in Figure 2 reveal the strengths and weaknesses of the teachers' knowledge in earth science before and after the professional development experience. The highest scores on the pre-assessment occurred in the Lithosphere (56.3%) subcategory. The participants' lowest scores on the pre-assessment were in the Atmosphere/Hydrosphere (47.58%) and Solar systems (46.77%) subcategories.

On the post-assessment, the participants' best scores were in Lithosphere (74.02%) subcategory. The participants' lowest scores on the post-assessment were in the Atmosphere/Hydrosphere (58.06%) and Solar systems (59.68%) subcategories.

Comparing the pre and post-assessment scores, the participants gained in their knowledge in life science in all three subcategories of earth science. This area of greatest improvement came in the subcategory Lithosphere 14.72% .

Overall, participants' scores reflect gains across all subcategories of earth science and an overall gain from 51.23% to 65.03% representing a statistically significant gain at the .0000009 level using a 1 tailed t-test.

Conclusion

The Advancing Science Learning (ASL) project was designed to meet the needs of elementary teachers in Northwestern Wisconsin and to support their efforts to engage students in learning science. The goals of the ASL project were to: (1) increase teachers' content knowledge for teaching science, (2) establish a relationship among participants and partners, (3) increase teacher application of content-specific pedagogy in science, and (4) improve student achievement in science.

Much progress was made toward achieving the first three goals during the third year. The pre and post-assessment results indicate that the participating teachers improved their content knowledge in earth science, particularly their knowledge of the Lithosphere. Through their experiences with scientific inquiry and the engineering design process, they have also improved their declarative knowledge, schematic knowledge, scientific inquiry and pedagogical content knowledge.

In the Summer Academy, the teachers were able to use interactive notebooks to conduct, record, and reflect on their scientific investigations and engineering designs. This evidence-based pedagogical strategy supports the teachers in their attempt to facilitate scientific inquiry, engineering design, and literacy in their science teaching.

Similarly, the teachers learned valuable lessons about the nature of engineering, and how engineers use math and science to design and create solutions to human problems. During the Summer Academy, the teachers learned that engineers utilize data to make improvements to existing and newly designed technologies. In other words, they learned that engineering is an iterative process, where testing leads to incremental progress to better and better solutions to the scientific and technological challenges we face as a society. In short, they learned about what scientists and engineers do by doing it themselves, using the Engineering is Elementary (EiE) curriculum.

These teachers have developed the tools, abilities, and confidence to engage students in science and engineering practices, with whatever science curriculum they use in their schools. Teacher testimonies reaffirm the pre and post-assessment results. One teacher commented, “I understand how to design lessons that enhance understanding and foster inquiry and science literacy BETTER than I did on the first day.” Another teacher wrote, “My knowledge of the science content I teach is STRONGER than it was on the first day of this project.” A third teacher added, “I am MORE confident that I can help every student make learning gains in science than I was on the first day.”

During the 2015-2016 school year, the teachers are implementing science notebooks in their classrooms, using the EiE curriculum units in their classrooms, and engaging students in the science and engineering practices of the Next Generation Science Standards. During the school year, there will be other professional development activities, including: the Minds-On Science PLC Workshops, classroom observations, local collegial networking within schools, collaborative exchanges between schools, and ongoing electronic communication. Through these experiences, the teachers will have multiple opportunities to share and discuss science teaching and learning with colleagues and partners from across the region. These partnerships support the teachers in applying what they have learned in their own classrooms. Together, these experiences and partnerships will help to achieve the final and ultimate goal of the ASL project, to improve student achievement in science in Northwestern Wisconsin.

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