ELECTRONIC JOURNAL FOR RESEARCH
IN SCIENCE & MATHEMATICS EDUCATION
VOL. 25, NO. 1, 5-19

Like the Kids Do: Engineering Design in Middle-School Science Teacher Professional Development

Kelly Feille
The University of Oklahoma

Morgan Stewart
Midlothian Independent School District

Jenesta Nettles
Msomi Academy for Girls

Molly Weinburgh
Texas Christian University

ABSTRACT

This study describes how 19 middle-school science teachers responded to an engineering design task in the context of water quality and environmental science professional development (PD). The study relies on teacher created prototypes, presentations, graphic organizers, and qualitative memos to illustrate the challenges and successes of the PD. In the findings, we discuss two major themes that emerged from the data sources regarding teachers' focus on resource management and pedagogical understanding. Finally, we include lessons learned as we move forward as science teacher educators in an era where teachers are challenged to continue to adapt to pedagogical paradigm shifts within science education.

Keywords: middle-school science, engineering design, case study

Introduction and Background

While the Next Generation Science Standard (NGSS) (NGSS Lead States, 2013) included engineering within practices and disciplinary core ideas, professional development (PD) that helps current science teachers develop an understanding of and instructional competence for engineering as a component of STEM instruction is important. This was made evident by a review of the landscape for K-12 engineering (Moore, et al., 2015) that provides insight into the challenges for teachers with widespread adoption of NGSS. In addition, the new initiatives suggested that subjects that have traditionally been taught separately, now be integrated (Guzey, et al., 2016). Lesseig, et al. (2016) stated that while there is still no set definition for STEM education, general agreement indicates that it should involve rigorous units, be problem based, and help build 21st century skills. More recently, STEM has been conceptualized as a "meta-discipline that bridges discrete disciplines such as science, technology, engineering and mathematics using application or processes from each to create knowledge as a whole" (Herro & Quigley, 2017, p. 416). As such, middle-school science teachers who, in many states, are generalists, are particularly challenged as they are being asked to teach a process for which they have no point of reference (Brophy, et al., 2008).

A possible starting point is to recognize that science and engineering practices differ in several ways (Feille, Nettles, & Weinburgh, 2017). Science practices focus on changing one variable at a time while engineering practices involve changing several parts of a system to improve the system as a whole. Engineering practices are cyclical with many feedback loops. This recognition is necessary but not sufficient if middle-school teachers are expected to include engineering design within their science instructional time. An additional starting point is to help teachers identify how the process of engineering design can be situated within their pedagogical paradigm of student-centered learning and instruction design. Engineering design tasks are a concrete way to implement student-centered strategies such as collaboration, open-ended products/solutions, teacher as facilitator, and metacognition (Cunningham & Carlsen, 2014). However, to encourage the use of engineering design instructional tasks, teachers need to experience authentic problems for which engineering design is appropriate (Guzey, et al., 2014; Sun & Strobel, 2013). They must also experience ways that the process of engineering design can enhance and expand the science content taught in their grade level and further support the pedagogical demands of the student-centered/inquiry-based classroom (Estapa & Tank, 2017; Guzey et al., 2014).

Thus, the science education community has been slowly building a much-needed body of research on teacher PD programs for successful K-12 engineering education (Yoon, et al., 2013). Van Haneghan, et al. (2015) found a positive correlation between teacher self-efficacy and a teacher's beliefs about their students' abilities to engage in engineering practices. In addition, Lesseig et al. (2016) found that providing opportunities for teachers to observe struggling students succeed with the more challenging engineering design tasks proved to be an important experience for many of their teachers participating in the engineering design PD. Estapa and Tank (2017) found that after a PD focusing on integrating content within engineering design, teachers were able to "identify multiple ways in which engineering design could be used as a context for integration" (p. 14). Actually accomplishing integration, however, was limited due to a multiple number of challenges. Teachers required more support in the planning and enactment of lessons to support integration of content (Estapa & Tank, 2017).

The purpose of this exploratory study is to investigate how middle-school science teachers respond to an authentic and appropriate engineering design task within a summer PD. In doing so, the research team approached the research asking what patterns emerge as teachers engage in an authentic engineering design task conceived for middle-school students?

Conceptual Framework

The overlap of socio-cultural constructivism (Vygotsky, 1986) and situated learning theory (Hung & Chen, 2001; McLellan, 1996) is used as the conceptual foundation of the study. Socio-cultural constructivism theory stresses the construction of knowledge through social interactions. From this perspective, peers and teachers provide learners with observable examples of the norms and practices of the culture. Language (as a commonly used social tool) becomes highly important within the community/culture as a means by which the individual and the community develop. Leontiev (1981) stated that an individual appropriates the socially available psychological tools of the community(ies) in which the individual resides. The teachers within this study constitute a community and work in collaborative groups. According to socio-cultural constructivism, they should exhibit new social language and actions as they integrate engineering practices into their STEM learning and instruction.

Situated learning theory has epistemological roots in the belief that learning is a contextualized, on-going process. It stresses that knowledge is created as "individuals interact with their environment to achieve a goal" (Whitworth, et al., 2017, p. 701) and that the setting in which the knowledge is used is important in determining what is learned. By focusing on the intersection of learning and social conditions, situated learning theory helps explain how professional skills are acquired (Vincini, 2003).

Research Design and Methods

This single case study investigates the response of a small group (N=19) of middle-school teachers to an engineering design task as presented in a summer PD. The teachers making up this case were all new to engineering and classroom-based engineering design tasks. The case study approach allows for more depth of study, investigates a series of connected events that occur in or over a specific time and place, and are deeply embedded in the context of the case (Flyvbjerg, 2001). Teacher design solutions, presentations, and graphic organizers paired with research team observation and qualitative memos provided the data set for the study. An emergent thematic analysis provided direction for the study and is described in more detail below.

Participants

Middle-school science teachers from a large metropolitan area in the southwest were recruited for a PD that focused on environmental science with an emphasis on watersheds and water quality. Although one district (X) was the primary focus for recruiting, advertising flyers were sent to five other districts. Interested teachers completed an application and were selected based on requirements from the funding agency (e.g., teacher of science and not meeting the federal designation of "highly qualified"). Nineteen teachers (representing three districts) of varied backgrounds and teaching assignments participated (see Table 1).

Table 1
Participant Demographics

Category	Subcategory	Frequency (n)	Proportion (%)
Gender			
	Male	5	26%
	Female	14	74%
Race/Ethnicity			
	African American	5	26%
	American Indian	1	5%
	Hispanic	2	10%
	White	11	58%
University Degree			
	Other than science or education	7	37%
	Elementary Education	5	26%
	Science	7	37%
District			
	X	17	90%
	Y	1	5%
	Z	1	5%
Years Teaching Experience			
	≤ 5	5	26%
	6 to 10	8	42%
	≥ 11	6	32%

Study Context: The Professional Development

Changing teacher's practice is difficult, taking time and often requiring multiple exposures to professional development (Luft & Hewson, 2014). Therefore, the PD providers utilized a design containing elements found to be most effective: content specific (Garet, et al., 2001), long-term (Hauck & Campbell, 2014; Loucks-Horsley, et al., 2010), and learner centered (Loucks-Horsley et al., 2010). The teachers participated in 10 days (55 hours) during the summer with an academic year follow-up. The PD providers included three college of education faculty members from two local institutions. One faculty served as a pedagogical expert in science teaching, one as a language instruction expert in teaching to English language learners, and a third as a content expert in environmental issues. This study focuses on the engineering design task, taking place over five days (day 1 and 6-9) of the summer portion of the PD and does not include the other four days of the summer PD or the academic year follow-up (see Table 2).

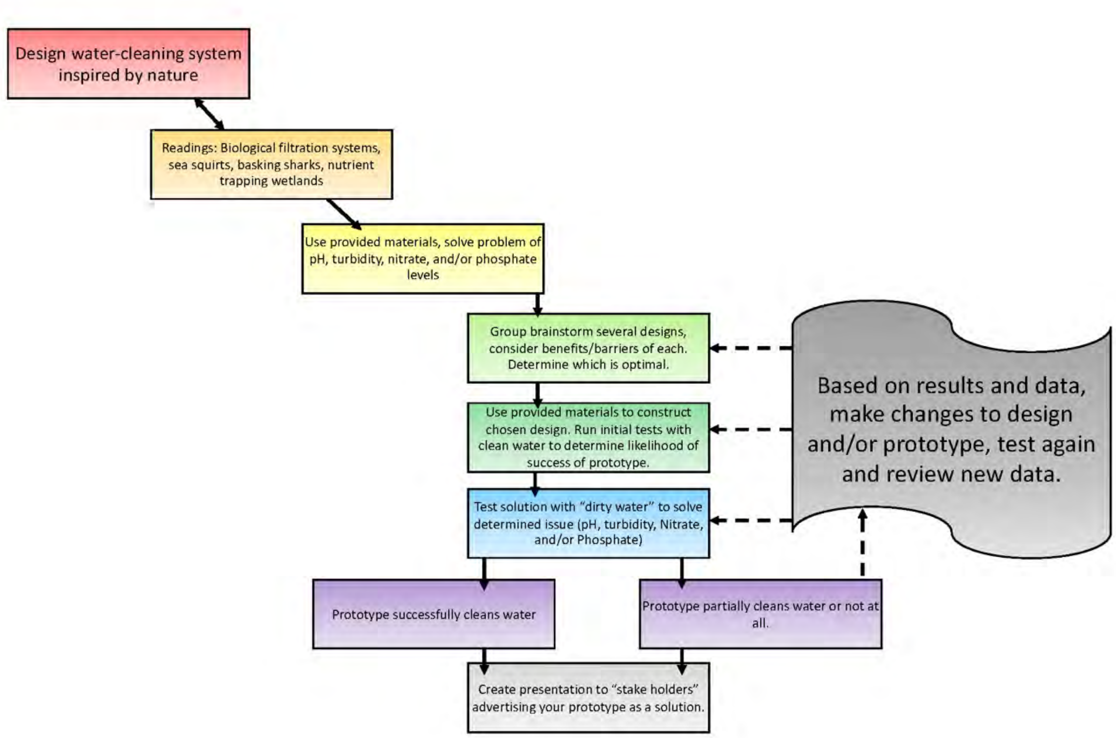
Table 2
PD Day by Day

Day 1	Day 2	Day 3	Day 4	Day 5
Watershed Introduction	Continue water testing.	ELL Topics	Field Trip – Water Treatment Plant	Debrief Day & ELL Topics
Day 6	**Day 7**	**Day 8**	**Day 9**	**Day 10**
Define the Problem	Conducting Background Research & Specify Requirements	Prototype Development and Optimization	Finalize Prototype and Present Solution	Classroom implementation & ELL Topics

The science content focused on watersheds and the environmental issues surrounding water quality including content about water contamination, how to test water for the presence of typical contaminates, and features of the local watershed. To model learner-centered pedagogical practices, in addition to ELL pedagogical support, the PD team decided to include an engineering design task that required using scientific knowledge of water and the characteristics of clean water to design a water filtration system. It was communicated to the teachers at multiple points to address the engineering design task as they thought their students might, engaging in the task as learners following the process of engineering design (see Figure 1). This same engineering design task was piloted by two members of the research team with upper-elementary and middle-school students in a week-long, University-based workshop earlier in the summer which allowed the researchers to compare the practices of the teachers with those of student learners (see Feille, Nettles, & Weinburgh, 2017)

Figure 1

Process of Engineering Design for Designing a Water Filtering System Inspired by Nature



Define the Problem

Initially, teachers were introduced to the local watershed through an interactive investigation using Google Maps and mini-lessons. Google Maps provided visuals of the local watershed. Mini-lessons provided information about the primary components of water quality including river bank evaluation, pH, temperature, turbidity, benthic macroinvertebrates, coliform bacteria, dissolved oxygen, nitrates, and phosphates. In addition, the teachers visited a near-by, human-made collection pond to collect observations and qualitative data regarding the quality of the site and interpreted student-collected water quality data for the site. Relating to questions of water quality, the teachers used a LaMotte® water-testing kit to become familiar with standard tests used to investigate and determine the quality of a water sample. The teachers followed test directions provided in the kit to learn about the significance of and practice measuring pH, temperature, nitrate and phosphate levels, and turbidity on both clean (tap water) and dirty (with added nitrates, phosphates, and soil to increase turbidity) water samples. After the content introduction the teachers were given the engineering design task requiring them to plan a system that was inspired by the water-cleaning processes of nature.

Conduct Background Research

To gain an understanding of how processes in nature work to clean water, the teachers researched natural filtering systems. They were provided sample readings about biological filtration systems, sea squirts, flamingos, basking sharks, whales, and sediment trapping in wetlands as well as conducted their own internet searches. Background research ended with table discussions about filtering techniques and possibilities for transfer to human-made systems and the ways in which humans have taken advantage of these processes to purify water through biomimicry (for example, constructing wetlands for wastewater filtration).

Specify Requirements

To address the engineering design task, the PD providers introduced the teachers to the following supplies: plastic hosing, A/C powered water pumps, plastic shoe bins, fish tank filter bags and filter media, coffee filters, sponges of various sizes, mesh bags, gravel, sand, duct tape, and twine. The PD providers asked groups to identify one or more water-quality issue to focus on for their filtration system (e.g pH, turbidity, or nitrate and/or phosphate levels). The PD providers then allowed teachers access to the above introduced materials as well as any other materials found in the classroom and supply closet that would help them meet the identified requirements for their initial water filtration prototype.

Prototype Design and Solution Optimization

Next, teacher groups designed and built their prototypes. Prior to building, it was expected that groups considered and discussed several designs. When an agreed upon design was selected, the teachers used the materials provided (and others they collected along the way) to construct their filtration devices. Once their device was built, they tested it for structural issues (i.e. leaks) with a small amount of clean water before they tested their process on dirty water. Groups then determined if their solution met the requirements defined above, what adjustments they needed to make, and made these changes to optimize their solution. Group members recorded any designs, changes, and test results in their journals.

Communicate Solutions

Once they determined a final solution, each group shared their progress and results using a multimedia presentation (such as video, PowerPoint, or Prezi). Groups were encouraged to identify the audience for their presentation; some of the presentations identified specific audiences such as policy makers or investment firms, while others indicated stakeholders who might be interested in alternate modes of water cleaning. Criteria for the presentations were not established per a rubric or checklist so that the teachers were free to communicate what they felt was important to share based on what they learned throughout the process as long as they described their goals and the methods they used to meet their goals. Their decisions made during this process provided data regarding their understanding of the purpose and process of engineering design as well as the scientific content regarding water quality.

After the group presentations, the PD providers showed videos of previous student presentations and displayed a collection of student-constructed prototypes (see Figure 2) as comparisons to the teacher-constructed prototypes (see Table 3). The influence of these videos can be seen in the teachers' discussions concerning the process of engineering design. Teachers were given time to debrief as they compared their design to the student designs as they considered the implications for classroom practice.

Figure 2

Examples of Student Prototypes

Table 3

Comparing Student and Teacher Prototypes

Student Prototypes	Teacher Prototypes
Universal use of water pumps and gravitational force	Primarily (3 out of 4) relying solely on gravitational force
Invested in multiple iterations of prototype	Often relied on first design, only adding leak prevention
Used and modified (sometimes permanently) all available supplies	Used all available supplies, but only modified those seen as disposable (e.g. water bottles, coffee filters, paper towels)
Experimented with various forms of filtration including fish tank filters and filter media (e.g. sand, gravel, charcoal).	Relied on familiar materials and filtration tools (e.g. water bottles, gravel, and coffee filters)
Primarily unconcerned with amount of materials used – not conservation minded	Primarily concerned with conserving materials and not wasting or needing to throw away products

Data Collection

Multiple sources of data were used to investigate the teachers' experiences with the engineering design task It was the intention of the research team to first mimic the experiences as provided to upper-elementary and middle-school students in the summer workshop Diving Deeper (Feille, Nettles, & Weinburgh, 2017) as well as challenge the teachers to relate their experiences as learners back to possibilities within their own classrooms. Products created by the teachers as they designed solutions to the engineering design task (journal entries, graphic organizers, prototypes, and final presentation) were combined with photos, videos, and research team memos to provide the data for this study. The research team included two of the PD providers and two additional researchers. Two members of the research team were also the designers and facilitators of the Diving Deeper workshop for students. All four members of the research team collected photographs, field observations, and memos.

Teacher Design Solutions

In groups of three to four, the teachers used the process of engineering design to approach the problem of removing contaminates from a dirty water sample inspired by the water cleaning processes found in nature. Groups were asked to develop, test, and optimize a prototype solution with a clean water sample before evaluating their solution with dirty water. Teacher prototypes were photographed, and tests were videotaped for both the research team and for the teachers to use in their multimedia presentations.

Figure 3
Teacher Constructed Products

Figure 3 shows the four final group prototypes. Throughout the process, teachers were asked to record notes of their plans, changes, trial results, and questions in their participant journals. Once each group chose and built an optimized solution, they produced a technical drawing that detailed what materials were used and how they were assembled. Each drawing was to scale and included multiple views of the prototype solution (front, top, bottom, left or right, and/or exploded views). These drawings were recorded in the participant journals.

Teacher Presentations

As a final step in their engineering design task, groups shared their prototype solution and the results of their tests in a multimedia presentation. The groups were allowed to choose the method in which they presented their goals, prototype, and findings. The presentations were videotaped, providing additional data regarding the teachers' thought processes and decision making during their engineering design task.

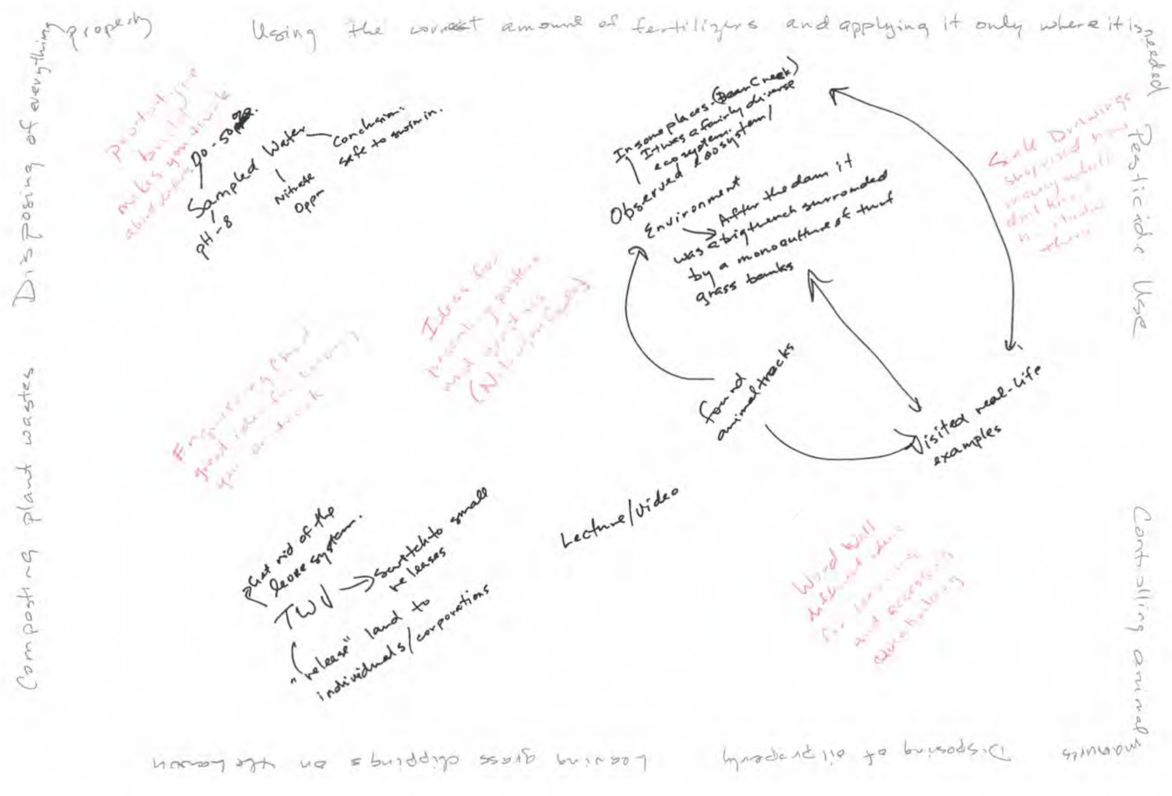
Qualitative Memos

Throughout the engineering design task, the PD providers held large and small group discussions with the teachers. During the discussions, members of the research team recorded memos detailing teacher responses and ideas. These memos provide further qualitative data regarding the teachers' ideas and thoughts concerning the process of engineering design and their experiences solving the problem.

Graphic Organizers

Over the course of the PD, teachers constructed graphic organizers around the topics and activities addressed. The graphic organizers were constructed over three completed iterations. The first iteration asked teachers to identify ways in which they could have an impact on their watershed and list these impacts along the one-inch margin of an 11x17 sheet of paper. During the second and third iterations, teachers brainstormed three to five meaningful events or topics covered through the PD using a different colored pencil for each iteration. These three to five events served as nodes within the graphic organizer. Although they were encouraged to do so, in most cases, the teachers did not identify connections of ideas or events across the graphic organizer but instead constructed several individual and isolated graphic organizers stemming from the identified nodes. Figure 4 shows an example graphic organizer. Although the graphic organizers offer some evidence of conceptual understanding of the pedagogical tool or scientific concept identified, they were not used as an assessment tool. The graphic organizers were used to identify the events and concepts the teachers found meaningful for their own pedagogical and content understanding.

Figure 4
Example Graphic Organizer



Data Analysis

This research included a number of "episodes" (Stake, 2010, p. 133) made up from the teacher constructed prototypes, presentations, graphic organizers, and research team observations and qualitative memos. Episodes are specific isolated behaviors or events. Through a reiterative process, the research team worked as individuals as well as collectively to identify "patches" of meaning within the multiple sources of data. Patches of data are the episodes that become more useful, revealing meaning within the data (Stake, 2010). The team then synthesized the patches using emergent themes regarding the teachers' responses to the engineering design task.

Emergent themes were initially identified through observations and research team memos. Throughout data collection, research team memos referred frequently to teacher use of resources, demonstrations of content understanding compared to discussions of classroom implementation. Individually, research team members analyzed the patches of data for evidence of the primary themes as well as any other secondary themes that may emerge and then compared analytical findings during regular research-team meetings (Ely, et al., 1997). Table 4 identifies these primary and secondary themes.

Table 4
Primary and Secondary Themes

Resource Management	Attention to Content
Disposable over reusable	Pedagogical focus
Modification of materials	Misconceptions maintained
Familiarity vs novelty	Feasibility of biomimicry design
Time	Process of engineering design

Several techniques suggested by Lincoln and Guba (1985) and Glesne (2006) were utilized to increase the trustworthiness of the research claims. Credibility was increased by having prolonged engagements with the teachers, multiple data sources, multiple researchers, and clarification of researcher bias. Confirmability was established through audit trails, multiple data sources and reflexivity.

Findings

Two primary themes emerged during field observations and were further investigated through the data analysis. First, the teachers were consistently mindful of resource management. This was seen in the selection of materials as well as designs for filtration systems. Second, the teachers were focused on a pedagogical understanding rather than a science content or understanding the process of engineering design.

Resource Management

Almost immediately upon being given the engineering design task, one teacher expressed the desire to use an empty water bottle, bottled water was provided as refreshment and not intended as a construction material. This resulted in other teachers selecting to use the bottles (even to the extent of drinking the water to provide an empty bottle). Like the students, the teachers were encouraged to use any available material in the room and supply closet. While the students gravitated more towards the supplies laid out on a table, the teachers actively sought out alternatives. The teachers talked about having used bottles for science experiences and how easy/cheap empty water/cola bottles were to use and proceeded to use the water bottles as reservoirs. Essentially most groups replaced water bottles for the provided plastic shoe boxes, which the teachers actively avoided. With regard to the lack of use of the shoe boxes, Ruby (pseudonyms are used) stated that the teachers viewed the bins [shoe boxes] as reusable which dissuaded them from selecting that material for modification and use.

Unlike the students, the teachers did not modify any of the materials. After viewing the student products, Ruby reflected on the differences between the way the students utilized their provided materials versus the teachers' use of them. She stated that where the students spent time talking about supplies, the teachers used coffee filters right away. She determined this was due to the lack of prior knowledge on filtration system construction for the students (memo). Rather than experimenting with less familiar materials (i.e. Buchner funnels, disassembled fish tank filter components), the teachers used materials such as coffee filters, water bottles, gravel, sand, and strainers to construct science-in-a-bottle filtration systems. The teachers did not see the materials as novel and went directly to materials they knew would accomplish the task rather than experiment with the possibilities.

Amanda observed the lack of pumps present during the teacher models, "I didn't notice if anyone in here used a pump, but a lot of students used them. Maybe they wanted to figure them out" (memo). Instead of the pumps, the teachers used gravitational force to move the water. While the teachers did not compare the advantages of the electric pumps, gravity was presented as a component of a wetland. It is unclear if mimicking this feature of wetlands was intentional, as only one group stated in their presentation that they were "mimicking natural processes."

An overarching concern in resource management was time management. For teachers who have a designated amount time each class period, thinking about how much time students would need helped dictate the selection of materials. The teachers discussed that materials that are easily accessible and manageable were important considerations for the filtration designs when thinking about incorporating such tasks in their own classrooms. When it was time to debrief about the week, Joe stated, "We [teachers] are so used to 43 minutes to put this together, get results, clean up and get to next group."

Attention to Content and the Process of Engineering Design

As the week progressed, researchers observed that teachers were paying attention to pedagogical understanding versus content understanding (like the students). The content goals of the PD included biochemistry of water quality issues, biomimicry, and engineering design. The teachers' lack of content focus became apparent during the final presentations on the last day of the PD. The engineering design task included two content related criteria. The system was to address a clearly defined water quality issue and to be inspired by biological systems.

Teachers were given the same instructions and expectations as the students for presenting their final product. Out of four presentations, one group did not provide any information as to which specific water quality issue their prototype addressed. Instead, they presented a sales pitch for their final presentation, seeming to gloss over the results of their trials and tests. A second group indirectly stated how the prototype will change the water quality in time. A third group presented at length how they hoped to both raise and lower the pH. A common source of confusion surrounding the study of pH related to the fact that a lower pH equals a more acidic substance. So, as the group attempted to lower the acidity of the water, they really aimed to raise the pH. At least one member of the group did not understand this distinction and created confusion during the presentation. The fourth group specifically stated what effect their prototype had on the water quality.

Following the presentations, Joe noted that the students came closer to biomimicry than the adults and Sarah added that the adults focused on making the water drinkable and not biomimicry since people "wouldn't drink out of wetlands." This focus may have prevented the teachers from looking at the task as the students did. Joe noted that the teachers were focused on the time limits, rather than the experience. Where the students looked at the task as "Hey, that's cool," the teachers approached it as "How could we use it" (Sally).

Regarding the practices of engineering design, Sarah pointed out "Their (the students') set ups were more advanced." When asked if she meant more advanced or more complicated, she clarified, "More advanced." In general, the teachers saw the student designs as better responding to the engineering design task. Only one of the teacher groups spent time optimizing their design solution compared to the students who disassembled and reassembled their prototypes multiple times. One teacher group made several changes to their design and their final presentation relied on significant upgrades to their original prototype. This understanding that the process of engineering design requires the team to constantly reevaluate available designs to identify the best solution was not demonstrated by any of the other groups. When asked how they would incorporate what they learned from the week into their own classrooms, Sarah replied, "We would incorporate a budget to limit waste." Sarah's response and the group consensus further illustrates a focus on the pedagogical implications included in management of resources rather than an understanding of the process of engineering design.

Discussion

While the teachers participating in this study are not necessarily beginning or developing teachers, they were novice to the process of engineering design. Yet, current shifts in the expectations described in the NGSS (NGSS Lead States, 2013) set the expectation for the incorporation of more engineering experiences within education. Despite this national push, engineering is not predominately featured in the state standards of the teachers at the time of this study. Until the process of engineering design becomes part of the instructional process, teachers will continue to hesitantly navigate the difficult inclusion of engineering processes within science content.

When planning and implementing professional development, it is important to remember that even though teachers may be ready to learn, teachers have trouble staying in the role of learner (Cunningham & Carlsen, 2014). The teachers' focus on resource management and pedagogy more so than the content is understandable as they try to apply these unfamiliar engineering practices to the realities of their classrooms. By filtering much of the science content out of their presentations and in some cases demonstrating a clear lack of understanding of the concept of pH, the teachers did not demonstrate understanding engineering design or issues surrounding water quality. This minimizes the chance that the teachers would link this process to an enrichment of their students' conceptualization of science content and the ability to apply it in problem solving situations. Additionally, this phenomenon demonstrates the challenge of content-integrated engineering practices within the science classroom. As the teachers themselves struggled to keep the content integrated within the novelty of the engineering task, they may face difficulty in their own classrooms in future engineering task planning and implementation.

To address the teachers' difficulty with the conflicting roles of teacher and learner, Cunningham and Carlsen (2014) suggest providing teachers with windows of time dedicated to their implementation concerns. This allows PD providers the opportunity to contrast those windows with their experiences as a learner of engineering design and its content applications. By doing so, PD providers create a concrete way for teachers to facilitate student-centered/inquiry-based teaching within the constraints and demands of a science period. Given this complexity, a single exposure to engineering practices is not enough. These single exposures make the pedagogical moments difficult to connect beyond the professional development to the classroom.

Yet, planning applicable PD can only get us so far. Unless PD developers can find a way to help teachers explore beyond their reliance on the familiar, teachers will struggle to facilitate and guide their own students through engineering practices upon returning to their classrooms. In the end, it is not the product/solution (like the teachers in this study thought) but the journey (like the students experienced prior) that is key to understanding engineering design.

Without follow-up interviews, it is difficult to discern if the teachers gravitated to known, readily available, cheap supplies (for example small water bottles and coffee filters) solely due to time and budget concerns. The use of coffee filters made cleanup easy as did the use of the water bottles. Water bottles are cheap materials for teachers to acquire. Even though the teachers noted the students' use of plastic bins and water pumps, it is possible that the teachers saw these materials as beyond the budget of their classroom supplies. As districts expect teachers to incorporate new unique solutions (engineering) into their classrooms, the science supply budget does not increase. With limited supplies, teachers may adopt a scarcity mentality and gather what is readily available to use. Classroom management styles may also have come into play. By limiting supplies to what could easily be accessed or replenished, teachers limit potential resource management issues. Instead of dividing attention between passing out supplies, guiding students through the engineering process, and supervising, teachers only need to focus on the latter two.

Limitations of the Study

As a single case study, the findings of this research cannot be extended as generalizations beyond the setting of this professional development and included teacher participants. It should also be noted that the aim of the PD was not necessarily to improve the engineering teaching practices of the participants. Rather the focus was to continue to expose participants to innovations in science teaching and help to facilitate an overall improvement of pedagogy, content understanding, and confidence in science teaching within the context of environmental science with a focus on water by participating as learners in the engineering design task. Finally, there was little opportunity for member-checking beyond the noted conversations between the PD providers and the participants.

Recommendations for Future Research

This small case study leads to several future research questions and possibilities. Due to the teachers' comments and interest regarding the student developed prototypes, it may be beneficial to investigate how combining the teacher task with a student task can help inspire teachers to reach beyond what is known. In what ways does engaging in an engineering design task with students influence the ways in which practicing teachers approach the process? Second, how will an explicit focus on integrating engineering practices into the current pedagogical paradigm demands of teachers (such as state testing and/or student-centered/inquiry-based instruction) impact the ways teachers engage with an engineering design task or instructional plan? Finally, as science teacher educators, we must continue to contribute to the discussion regarding the future of science education. What role does engineering design play in light of the demands on science teachers and science learners and how better can we prepare pre- and in-service educators to respond to those demands?

This research was supported in part by funding from the ...funding by Teacher Quality Granting Program of Texas and the Andrews Institute of Mathematics & Science Education at Texas Christian University (grant number 62174).

Kelly Feille (feille@ou.edu) is an assistant professor of science education in the Jeannine Rainbolt College of Education at the University of Oklahoma. At the University of Oklahoma, Dr. Feille continues her passion for science education through her work with pre-service elementary teachers. She seeks to ensure that her students leave the University of Oklahoma with the confidence and tools to teach science in ways that engage students to ask important questions, think critically, and collect, evaluate, and argue from evidence. Her research focuses on the development of elementary science teachers and, in particular, how to encourage the development of schoolyard pedagogy, which takes advantage of the learning moments in and out of the traditional classroom.

Morgan Stewart (morgan.stewart@tcu.edu) received her doctorate in science education from Texas Christian University in 2018. Her areas of research interests include epistemic curiosity in young children, scientific models in education, and understanding pre-service and in-service teacher attitudes towards science education. She currently teaches kindergarten thru 5th grade English as a Second Language through the lens of science and social studies in an elementary school in Texas.

Jenesta Nettles (jenesta@icloud.com) is a science education researcher and educator. After teaching high school biology, she earned her PhD in science education. Her primary research interest is the

use of student-centered teaching practices to facilitate educational equity and empowerment. She believes that the education of women and girls is important for social justice and equity, but also crucial to the progress of human society.

Molly Weinburgh (m.weinburgh@tcu.edu) is the Andrews Chair of Mathematics & Science Education and Director of the Andrews Institute of Mathematics & Science Education in the College of Education at TCU. Her research focuses on equity issues in science, especially equity for language learners, and teacher professional growth. She teaches undergraduates and graduates in the College of Education and the College of Science & Engineering. She is an active member of ASTE, SSMA, NARST and ICRSME.

References

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classroom. *Journal of Engineering Education, 97*(3), 369-387. DOI: 10.1002/j.2168-9830.2008.tb00985.x

Cunningham, C. M., & Carlsen, W. S. (2014). Teaching engineering practices. *Journal of Science Teacher Education, 25*(2), 197-210. DOI: 10.1007/s10972-014-9380-5

Ely, M., Vinz, R., Downing, M., & Anzul, M. (1997). *On writing qualitative research: Living by words.* Falmer Press.

Estapa, A. T. & Tank, K. M. (2017). Supporting integrated STEM in the elementary classroom: A professional development approach centered on an engineering design challenge. *International Jouranl of STEM Education., 4*(6), 1-16. Doi 10.1186/s40594-017-0058-3

Feille, K., Nettles, J., & Weinburgh, M. (2017). Water, water everywhere! But is it clean to drink? Applying Engineering Design to the Challenge of Water Purification. *Science Scope*, *40*, 50-57.

Flyvbjerg, B. (2001). Case study. In N. K Denzin & Y. S. Lincoln (Eds.). *The Sage handbook of qualitative research* (4th ed., pp 301-316). Sage.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915-945.

Glesne, C. (2006). *Becoming qualitative researchers*, third edirtion: Boston: Pearson.

Guzey, S. S., Moore, T. J., & Harwell, M. (2016). Buidling up STEM: An analysis of teacher-developed engineering design-based STEM integration curricular material. *Journal of Pre-College Engineering Education Research, 6*(1). 11-29. Doi.oth/10.7771/2157-9288.1129.

Guzey, S. S., Tank, Kl, Wang, H. H., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3-6 for implementing engineering into classrooms. *School Science and Mathematics, 114*(3), 139-149. DOI: 10.1111/ssm.12061

Hauck, N., & Campbell, T. (2014, January). *Effects of 3-year sustained professional development on the classroom instruction of elementary school teachers.* Paper presented at the 2014 Association for Science Teacher Eeduaction International Conference, San Antonio, TX.

Hung, D. W. L., & Chen, D-T. (2001). Situated cognition, Vygotskian thought and learning from the communities of practice perspective: Implications for the design of Web-based E-learning. *Education Media International, 38*(1), 3-12. DOI: 10.1080/095239801100374

Herro, D., & Quigley, C. (2017). Exploring teachers' perceptions of STEAM teaching through professional development: Implications for teacher educators. *Professional Development in Education, 43*(3), 416-438. DOI: 10.1080/19415257.2016.1205507

Leontiev, A. (1981). *Problems of the development of mind*. Progress. *(Original work published in Russian, 1959).*

Lesseig, K., Nelson, T. H., Slavit, D., & Seidel, R. A. (2016). Supporting middle-school teachers' implementation of STEM design challenges. *School Science and Mathematics, 116*(4), 177-188.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry* (Vol. 75) Sage.

Loucks-Horsley, S., Stiles, K. El, Mundry, S., Love, N., & Hewson, P.W. (2010). *Designing professional development for teachers of science and mathematics* (3rd ed.). Corwin Press.

Luft, J. A., & Hewson, P. W. (2014). Research on teacher professional development programs in science. In N. G. Lederman & S. K. Abell (Eds.). *Handbook of research on science education* (Vol 2, pp. 889-910). Routledge.

McLellan , H. (1996). Situated learning: Multiple perspectives. In H. McLellan (Ed.). *Situated learning perspectives* (pp. 5-17). Educational Technologoy.

Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2015). NGSS and the landscape of engineering in K-12 state science standards. *Journal of Research in Science Teaching, 52*(3), 296-318. Doi 10.1002/tea.21199.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* The National Academies Press.

Stake, R. E. (2010). *Qualitative research: Studying how things work*: Guilford Press.

Sun, Y., & Strobel, J. (2013). Elementary Engineering Education (EEE) adoption and expertise development framework: An inductive and deductive study. *Journal of Pre-College Engineering Edcaiton Research*, *3*(1), 4. DOI: 10.7771/2157-9288.1079

Van Haneghan, J. P., Pruet, S. A., Neal-Waltman, R., & Harlan, J. M. (2015). Teacher beliefs about motivating and teaching students to carry out engineering design challenges: Some initial data. *Journal of Pre-College Engineering Education Research (J-PEER), 5*(2), 1. DOI: 10.7771/2157-9288.1097

Vincini, P. (2003). The nature of situated learning. *Innovations in learning.* Tufts Newsletter, February. 1-4.

Vygotsky, L. (1986). *Thought and language* [Transl. by Alex Kozulin]: The MIT Press, Cambridge, London, UK.

Whitworth, B. A., Bell, R. L., Maeng, J. L., & Gonczi, A. L. (2017). Supporting the supporters: Professional development for science coordinators. *Journal of Science Teacher Education, 28*(8), 699-723. DOI: 10.1002/jcop.21677

Yoon, S. Y., Diefes-Dux, H., & Strobel, J. (2013). First-year effects of an engineering professional development program on elementary teachers. *Journal of Engineering Education, 4*(1), 67-84. DOI: 10.19030/ajee.v4i1.7859