AC 2011-495: ELEMENTARY SCHOOL TEACHERS' ATTEMPTS AT INTEGRATING ENGINEERING DESIGN: TRANSFORMATION OR ASSIMILATION?

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Elementary school teachers' attempts at integrating engineering design: Transformation or assimilation?

Purpose of the study and research questions

The aim of this study is to examine how elementary school teachers translate what they learned from using the Engineering is Elementary (EiE) curriculum. The research questions include the following: 1) What are the teachers' first steps in developing engineering design-based science lessons? 2) What are the teachers' actual attempts at integrating the engineering design process? 3) How can we characterize teachers' attempts? The context of this research study is a university-based initiative focused on creating an engineering literate society through preeminence in P-12 engineering education research and scholarship.

Theoretical framework

Central to this study is the work of teachers, specifically the knowledge they have and the decisions they must make in order to take action within their own practice. Therefore, it is important to look at the complex interplay of teachers' content and pedagogical knowledge and the ways that these are used in diverse classroom contexts. In this study, the teacher knowledge perspective provides one way of examining how teachers know how to teach science through the engineering design process. Shulman (1986) described pedagogical content knowledge (PCK) as key in explaining how content knowledge is transformed into forms of pedagogy that are adaptive to and modified for the varied abilities and backgrounds of the students.[1] PCK represents the intersection of subject matter knowledge, knowledge of students, and the practice setting. [1,2]

Magnusson, Krajcik, and Borkos (1999) proposed a refined model of PCK for science teaching. Their model includes the following five components:

> 1) orientations toward science teaching; 2) knowledge and beliefs about science curriculum, 3) knowledge and beliefs about student understanding of specific science topics, 4) knowledge and beliefs about assessment in science, and 5) knowledge and beliefs about instructional strategies for teaching science" (p. 97).[3]

An overarching component of this model is that a science teacher's knowledge is strongly influenced by the stance or generalized orientation a teacher may take within his/her own practice. Teachers' orientations have also been described as "general patterns of thought and behavior relating to science teaching and learning".[4] This orientation to teaching science is placed in a pivotal position, influencing other components of PCK and, in turn, being influenced by these components.[3] Furthermore, it is possible that an individual teacher may have multiple different orientations.[5]

For the purpose of this study, we utilize the construct of teacher knowledge via the lens of elementary school teachers' orientations to teaching the engineering design process. It is hypothesized, that if elementary school teachers are given the necessary tools, resources, and

support, they will implement their instructional ideas for integrating the engineering design process in diverse ways, giving priority to different pedagogical or conceptual features (e.g., subject matter, academic standards, and processes).

Participants

This study is part of a larger, multi-year project that examines elementary school students' perceptions, aspirations, and identity development in engineering. The study population within the larger project includes 10 elementary school (defined as grades 1-5) teachers selected from a population of approximately 75 elementary school teachers in a large metropolitan school district in the central Midwest. Mayflower Elementary School is one of the four elementary schools in the metropolitan area. The demographic profile of the teachers at Mayflower Elementary School is: 9 females and 1 male; all White/Caucasian. Their years of teaching experience ranged from one to fifteen years.

For the purpose of this paper, we identified a sample from the larger study population and focused on three teachers and their respective work related to integrating engineering design into their practices. These teachers represent individual cases of significance from early, middle, and late elementary grades. In each teacher case, we profile his/her unique approach to incorporating engineering design in the elementary science classroom. The selection criteria for this sample included the following: 1) three or more years teaching experience; 2) attended all professional development sessions; 3) participated freely in all aspects of the data collection.

The three teachers include the following: Linda, a 1st grade teacher, Sadie, a 3rd grade teacher, and Ralph, a 5th grade teacher with 7, 11, and 15 years of teaching experience, respectively. We use pseudonyms (created by the teacher participants) to protect the anonymity of all the teacher participants.

Teacher participants in this study attended an intense three-day, hands-on workshop in the summer and a two-hour follow-up professional development session in the fall. During this time, the teachers learned about wind and the ways engineers design machines to capture wind energy; examined ways to clean water; and developed a series of standards-based science lessons that integrated the engineering design process. Once the teachers completed the summer workshop, they developed a six-week unit that included grade appropriate, standards-based engineering learning modules they would instruct during the school year.

Data collection and analysis

Data were collected via teacher interviews (n = 2 interviews per teacher; 6 interviews total), implementation plans (n = 1 plan per teacher; 3 plans total), informal classroom observations (n = 10), and supporting documents (e.g., lesson plans, teacher-developed lesson materials, and student work). Data analysis entailed the use of grounded theory and content analysis. The first step entailed open coding of the data, specifically transcripts from interviews and field notes and teachers' implementation plans, lesson plans, and reflections.[6] During this phase, we focused on identifying indicators of concepts and categories that fit the data. Repeatedly appearing categories, concepts, and events helped us construct themes based on the events leading up to the

teachers' attempts in implementing engineering design-based learning tasks. The viability of the construction of themes was then tested against other relevant data sets (e.g. field notes from classroom observations and other supporting documents). To ensure trustworthiness of the data, we informally conducted member checks with each teacher by sharing analytic notes from interviews, classroom observations, and supporting documents.[6,7]

Results

Findings from this study were organized into two categories: 1) teachers' starting points and 2) teachers' actual pedagogical attempts. First, we describe the teachers' preliminary steps in developing their ideas for engineering design in their respective classrooms. In this section, we start by illustrating what all ten teachers reported then elaborate further on responses from Linda, Sadie, and Ralph. Second, we describe the pedagogical attempts the teachers made at integrating engineering design activities in their classrooms. Here, we describe what Linda, Sadie, and Ralph did in their respective classrooms and the science concepts, process skills, and objectives they incorporated into their lessons. Data presented in this section include excerpts from teachers' interview transcripts, implementation plans, and field notes from informal classroom observations.

Teachers' starting points

We were most interested in learning from the teachers from where they would begin developing their ideas for incorporating engineering design in their practice. We asked the teachers the following question: "When planning your unit, what kinds of materials, resources, or guides will you use?" The most frequent responses reported by the larger study population of ten teachers were the following: 1) existing science curriculum; 2) academic standards; and 3) resources from colleagues.

Sadie (3rd grade) preferred starting with her science lessons first before tapping into other resource materials. She stated:

> I have some really good lessons on force and motion that I did last year. I also have some fun lessons on simple machines. So I could start with these lessons then bridge ideas from these lessons with a particular engineering design activity. Once I know which science lesson I want do then I will decide on which engineering activity to do…either marvelous machines (EiE) or an introductory Lego activity using or building a simple machine…that would be good (Sadie, Interview #1, Fall 08).

The 5th grade teacher, Ralph, thought the standards could help direct the design of his unit yet not without looking carefully at his existing science curriculum first. Ralph stated:

> We have a unit on rocketry that has been quite successful and that might be a good place to integrate the engineering design process. We can have students build their own rockets, and design them and look at maybe how to improve them in some way to show them the complete design process. We would also have the state benchmarks that give us

> at least an outline of what it is that the students need to know about force and gravity (Ralph, Interview #1, Fall 08).

Linda, a 1st grade teacher, positioned her students' abilities as central to her starting point. In her interview she stated:

> I think for us (1st grade teachers) it's going to be very important to look at where our kids are at academically so we can do a unit that they are able to understand and it's not completely over their head (Linda, Interview #1, Fall 08).

By exploring the teachers' practical starting points, we were able to observe first hand how the teachers began thinking about and planning for the integration of the engineering design process. Each response was unique to the teacher's beliefs about how students learn or how teachers teach. Underpinning each teacher's plan was the need to leverage his/her knowledge and wisdom gained from practice.

Teachers' pedagogical attempts at integrating design tasks in the elementary classroom

Following participation in the summer professional development program, the teachers were then encouraged to develop an implementation plan. The plan was designed to help the teachers map out relevant science concepts and benchmarks, outline explicit design challenges, and identify assessment strategies. Table 1 provides an overview of the three teachers' units. Each unit includes the grade level, a science concept related to the unit, science process skills, engineering design objectives, and a brief description of a design task to be implemented.

Table 1: Overview of teachers' engineering design units

Teacher	*Grade*	*Science Concept*	*Science Process Skills & Objectives Related to Engineering Design*	*Design Task**
Linda	1	States of Matter – solids, liquids, & gases	Observation; Generate questions; Plan and conduct investigations; Analyze and reflect on investigation results Identify and sort objects by observable attributes Know and identify the three states of matter and their properties Use the engineering design process and data from investigations to demonstrate how matter can be changed	*Engineering a better play dough* Task: Using an existing procedure, can you re-design and improve upon this procedure to make better play dough? Client: Kindergarteners who wanted new colors and scented play dough.
Sadie	3	Force – Force is any push or pull Simple machines	Relate a change in motion of an object to the force that caused the change of motion. Identify different types of simple machines. Give examples of simple machines. Use Lego simple and motorized machines	*Birds busting a beat* Task: Can you create a pair of Lego dancing birds that can rotate and sing? Use and apply knowledge of structures and forces, levers, wheels, axels, gears, and pulleys. Client: Toddlers in need of toys
Ralph	5	Forces affect the motion and speed of an object.	Distinguish between contact and noncontact forces. Use the engineering design process to design, construct, test, and optimize a model of a crawler. Correctly program the "Mindstorm" brick to move the crawler on the intended path with success.	*Crawler creations* Task: Can your team construct a Lego crawler that can support and move a model of your rocket to a pre-determined launch area? Client: Aeronautical engineers

*All of the tasks included the use of an "engineering notebook," "design journal," or "mission log" that served as a way of chronicling students' engagement in the engineering design process.

Sadie (3th grade) and Ralph (5th grade) focused on the use of robotics in their respective units. Linda (1st grade) focused on states of matter using professional development resources (EiE curriculum) and existing science lessons.

In all of the above approaches, the design challenge is viewed as a competition in which student teams compete, not with each other, but with the design specifications (e.g., client's needs, goals, and constraints). A design goal such as, "Can you construct a crawler to transport a rocket to a launch pad?" sets a challenge, dares the students to test their skills and their knowledge and see if they can design a crawler that fulfills all the requirements.

In the following section, we elaborate further on how each teacher reflected on his/her integration of the engineering design process within his/her respective lessons. Our analysis revealed three recurring features in their descriptive accounts. These features included the following: 1) the role of the engineering design process; 2) the role of science concepts; and 3) the use of feedback.

Role of the engineering design process

Central to each teacher's attempt was the role of the engineering design process. Several teachers stated that they used this as a "jumping off point" or "starting point" to initiate their lessons. Other teachers commented on using the engineering design process as a "recurring theme" or "central pathway" for students to re-group and re-evaluate what they were doing (What is the goal?) and why (Who is the client? What are the client's needs?). Sadie, on the other hand, used the design process as a classroom mantra.

> You could probably hear my students chanting it from down the hall…ask, imagine, plan…if you think about it, it's pretty straightforward. First you ask some questions, imagine possible solutions…I think my students needed to see it that way. If you think about it, you could use this approach to solve practically any problem (Sadie, 3rd grade teacher, Interview #2, Spring 09).

Ralph and Linda commented on using the engineering design process as a means of helping students solve problems throughout the task or challenge.

> I wouldn't say that I spent a lot of time on teaching my students the actual steps. Like I didn't have them chant it every day or something like that. I just thought it was better for them to just dive into a design task, stop for a moment, and say, 'Hey, so what do you think the problem is here? What are some questions you might have?' And then I would say, 'Okay, what do you think about coming up with a plan?' I guess I tried to make more subtle…not very obvious…I guess you could say that I guided them…I wanted them to direct their own learning (Ralph, 5th grade teacher, Interview #2, Spring 09)

> I thought it was important that my first graders see how the process works by actually engaging in each step. I created engineering notebooks and on each page students would write down the step they were working on and then draw a picture of what they were doing. When they got stuck on a step or if their dough was not working, I would say, 'why don't you draw a picture of what is happening and write down three words to describe what is going on.' I also remember asking them, 'What do you think an engineer would do in this situation?' I thought it was important for them to think like an engineer rather than recite something or write it all out every week (Linda, 1st grade teacher, Interview #2, Spring 09).

Role of science concepts

An essential component of the engineering design process is the application of scientific concepts. We were interested in learning from the teachers if and how science concepts played a role in their attempts at integrating engineering design. In Sadie's (3rd grade) case, science concepts were not essential to her design-based activities. She stated:

> ...We talked about what is a simple machine and identified an example or two but we really didn't spend a lot of time on the 'science' behind it. I think might have done one activity from the marvelous machines unit (EiE). I really thought my students needed to spend more time on making a dancing bird and using the program (Stacy, Interview #2, Spring 09).

In some cases, using a science concept was an important entry point for their students. For Ralph and his 5th graders, the concepts of force and motion were first and foremost.

> We first learned about what a force is, the difference between contact and non-contact forces, and then the relationship between force and motion. We created Newton's Laws of Motion books to get some working knowledge and terminology in place so when we went to build the robot we could use those words as we were learning about the robot as far as the friction of the carpet or the table, and the motion and the way the motion of the wheels need to turn the right way….Once they learned how to make the robot move and how to explain that movement, they had to use the engineering process to design a program that would take the robot [which we call the crawler] and carry a rocket as in NASA to the launch pad. So I thought it was important for them to know and use the science principles first then engage in the design process (Interview #2, Spring 09).

Linda (1st grade) initiated her engineering unit of play dough process by instructing students to create a "matter journal" and recording what they thought was a solid, liquid, and gas. Linda's students performed inquiry-based activities such as, sorting different images of solids, liquids, and gases; observing ice melting; and classifying matter based on its physical attributes (shape, size, or color). "Then I introduced the problem that Mrs. Smith's class wanted a better play dough and that we were going to use what we knew about the properties of matter to help design a better play dough" (Linda, Interview #2, Spring 09).

Use of feedback

The teachers in this study described one or more occasions when they purposefully interacted with student teams by giving them feedback on their respective design tasks. Interestingly, several teachers described, in detail, how giving students feedback or allowing students to give each other feedback was instrumental to their attempts at integrating the engineering design process. For example, Ralph (5th grade teacher) stated:

> I found it important to provide each team with some time to reflect on what they did and revise and improve their designs. When I did this, I thought I got better designs from my students…I also thought the students were getting more out of the lessons and activities,

> than I expected...I saw one team stop building their crawler and talk about how they should re-design and test it…I saw some teams recording the time it took their crawler to perform different tasks and then calculating the average and asking another team if they got the same results. I didn't teach them that…they pretty much did that on their own…which was neat (Ralph, Interview #2, Spring 09).

Linda (1st grade teacher) described ways they encouraged students to give feedback to one another.

> Once students developed a plan for better play dough, I then asked them to share their plans with another team and to make a note of what that team recommended. I also asked my students to share their actual designs of better play dough with another team. Some teams actually tested the designs of dough and told teams what they needed to improve on. I would hear things like, 'remember who our client is…this is too wet, maybe it should have more flour…how about testing it by rolling it between your hands' (Linda, Interview #2, Spring 09).

Sadie, on the other hand, indicated that she did not emphasize the use of feedback in her design activities. What follows is a vignette from Sadie's interview conducted after the design lessons were implemented.

> Sadie: The Lego bird design activity was a lot of fun. My students were very busy working through the program (software), building and re-building their birds…
>
> Interviewer: In what ways did you observe your students interact with one another and/or with other student teams or groups during this activity?
>
> Sadie: Well…I saw them talk with one another but not a lot. I think everyone had their own job. I think when they were talking with someone in their team, they were generally asking for directions. Did student teams talk with other teams…not really.
>
> Interviewer: Did they share their prototypes with one another?
>
> Sadie: Yes…they did that at the end. Each team went up in front of the class and showed what their bird(s) could do.
>
> Interviewer: At that time, did students give each feedback, perhaps ways to improve or change their designs? If so, did students use this feedback.
>
> Sadie: Yes, the kids did feedback to one another. It was very informal…like, 'hey that was good…did you think about programming your bird to spin in the opposite direction?' or 'what about having both birds spin at once?' I think the students were quite intrigued to see one another's models. I also think they liked getting feedback. Did they use the other kid's suggestions or ideas to improve or change their models?…no, not really. I think it did make them think a little bit about the design process and how we help each other in coming up with different solutions (Sadie, Grade 3, Interview #2, Spring 09).

Based on the teachers' accounts, it was important that ongoing formative assessment played a role in helping students engage in the engineering design process. By testing one another's designs, students were given the opportunity to learn about testing procedures, in general, as well as to see if and how their own designs meet clients' needs and requirements.

Likewise, while receiving and giving feedback, they were not only learning about the pluses and minuses of their own model; they were learning how to present their ideas clearly and simply so that others may understand and how to focus on the main ideas. They were also learning from the comments given to their peers' models, who may have thought of something that they did not.

Based on the teachers' attempts, it is clear that each teacher took his/her individual approach to blending the engineering design process within his/her own practice. In some cases, teachers used the design process as an instructional tool to introduce students to a particular design challenge while other teachers used the process to guide students through the design challenge. Additionally, several teachers commented on using the design process as a means of formative assessment to direct or re-direct students' learning as well as inform themselves of their own instruction. In other cases, the design process took more of a secondary role whereby science instruction took place first with the understanding that students would use their new science knowledge to engage productively in the design process.

Discussion

Characterizing teachers' attempts at teaching science through engineering design

Central to each teacher's attempt were several key elements: 1) the role of the engineering design process in curriculum; 2) the role of the engineering design process in instruction; 3) the role of science concepts; and 4) the use of feedback. Using these elements, we developed a continuum or phase model to characterize the teachers' attempts at incorporating design-based activities into their practice (e.g., instruction and curriculum) (See Figure 1).

Reading the continuum from left to right, we attempt to illustrate how teachers' attempts at integrating engineering design shift from one dimension or phase to another. On the far left end of the continuum are features that best depict little to no change in a teacher's practice based on his/her attempt at integrating the engineering design process. This variation best represents a traditional, more conventional approach to teaching science using the engineering design process. Teachers placed on this end of the continuum took what we coined, an "add the design process then stir" approach, with little attention to building on existing curriculum ideas. Additionally, teachers in the conventional phase depicted the engineering design process as a linear process, often taught through rote memorization. In this manner, teachers systematically worked with students to identify, practice, and recall each step of the design process (i.e., ask, imagine, plan, create, improve). For example, third grade students in Sadie's class completed fill-in-the-blank worksheets using the steps of the engineering design process as well as recited aloud the steps "ask, imagine, plan,…" prior to engaging in every design-related activity. Lastly, teachers in this phase did not fully incorporate formative assessment and/or scientific concepts.

Figure 1: *Features of teachers' attempts at integrating the engineering design process and their variations*

Feature	**Variations**		
Role of the engineering design process in curriculum	Added on top of existing curricular materials	Blended with curricular materials	Invented or re-invented new, innovative curricular materials
Role of the engineering design process in instruction	Incorporated as a linear, rote, static process	Incorporated as cyclical process	Incorporated as a dynamic, iterative process
Role of science concepts	Absent	Limited role	Embedded, used to drive learning of science and design
Use of feedback	Absent	Limited role	Integral part of design activities; used to reinforce student learning of the design process
	Conventional ←– – – –→	***Assimilation*** ←– – –→	***Transformation***

Moving along the continuum were features that represented more constructive attempts of integrating design by teachers. We characterized this variation as "assimilation" whereby teachers made purposeful attempts at incorporating design into their practices. This included teachers adapting and merging what they learned in the professional development with their existing curriculum resources. Teachers in the assimilation phase described their use of the engineering design process as a repetitive process. Teachers also described the use of science concepts; however, it was limited to teachers instructing students about the concepts with little opportunity for students to apply concepts in the design tasks. Finally, teachers in this phase may have used formative assessment but did not let it drive or direct either their own learning or their students' learning of the engineering design process.

On the far right end of the continuum were features that we characterized as "transformation." Teachers who re-invented their own engineering design-based tasks, immersed their students in the design process without direct instruction, and reinforced scientific concepts throughout each task were teachers who we considered transformed their practices. Ralph and Linda serve as good examples of teachers who described their use of design as a fluid, transparent approach to learning science. They purposefully developed new and innovative lessons that built on existing curriculum units (e.g., rocketry and states of matter) and extended students' learning of concepts, such as force, motion, rocketry at the 5th grade level and physical changes to matter at the 1st grade level. Additionally, these teachers described formative assessment as critical to their students' learning of the design process itself.

It is important to note that this continuum represents a spectrum of different approaches. To this end, it is possible the teachers in this study exhibit more than one feature and, in some cases,

reside in more than one phase depending on his/her attempt. For example, as previously stated, teachers, such as Sadie, used rote memorization and reinforced the idea of engineering design as a linear or static process. However, each of these teachers blended what they learned in the professional development with existing curriculum and implemented design-informed lessons. Teachers, such as Sadie and Ralph, introduced their engineering design-based lessons using key science concepts. In sum, these teachers integrated engineering design.

To extend our phase model further, we used the data to place the three teachers' attempts along the continuum. Here we illustrate three different points of interest: 1) partial assimilation; 2) partial transformation; and 4) complete transformation (See Figure 2).

Figure 2: *Placement of four teachers' attempts at integrating the engineering design process and their variations along the phase model*

Feature	**Variations**				
	Conventional	←– – – –→	***Assimilation***	←– – –→	***Transformation***
Role of the engineering design process in curriculum			Sadie (Gr 3) Ralph (Gr 5)		Linda (Gr 1)
Role of the engineering design process in instruction	Sadie (Gr 3)				Ralph (Gr 5) Linda (Gr 1)
Role of science concepts	Sadie (Gr 3)				Ralph (Gr 5) Linda (Gr 1)
Use of feedback			Sadie (Gr 3)		Ralph (Gr 5) Linda (Gr 1)
		Partial assimilation *(Sadie Gr3)*		Partial transformation *(Ralph Gr 5)*	Complete transformation *(Linda Gr 1)*

By applying the continuum to our data set we begin to see how individual teachers' attempts transect multiple features and more than one phase. In Sadie's case, she attempted to build on existing science lessons (i.e., inquiry activities on force and motion) when incorporating her design task on simple machines. However, she instructed the design process as a linear, step-by-step process. On occasion we observed her students reciting the steps and completing worksheets that required students to basically recall the steps. Sadie discussed science concepts specific to her unit as well as incorporated the use of feedback in her design lessons; however, there was no clear indication that these features were fully embedded in her lesson activities. Hence, we characterized Sadie's attempt at *partial assimilation*.

Ralph, on the other hand, shared observations of and classroom experiences with his students fully engaged in the design process, applying science concepts, and optimizing their prototypes by incorporating feedback from other students. Furthermore, Ralph reinforced the notion of

design as an iterative process with his students and guided his students through the process. In this case, we characterized Ralph's attempt at incorporating design as *partial transformation*.

Finally, we characterized Linda's attempt as *complete transformation*. What makes Linda's work unique from the other teachers profiled in this study is that Linda invented her respective lesson activities. She embraced what she learned in the professional development sessions, placed important consideration upon who her students were and how they learned, and created lessons that were innovative and effective. She placed emphasis on key scientific concepts most suitable for her first grader students and fully immersed her students in the practice of giving each constructive feedback that supported her students' understanding of design.

These results support the literature on teachers' orientations and furthermore, reinforce the notion that teachers may have different orientations.[4,5] The pedagogical attempts made by Ralph, Linda, and Sadie provide evidence that integrating the engineering design process is complex in nature and teachers' attempts must involve clarifying, confronting, and expanding ones' pedagogical ideas, strategies, and practices for effective engineering design-based instruction.

It is important to note that these variations are based on data generated by the teacher participants in this respective study. We do not want to suggest that these variations and/or corresponding features represent a comprehensive view of how *all* teachers should integrate the engineering design process in the elementary school setting. However, the purpose of this work was to make visible the pedagogical attempts teachers made and to characterize them accordingly. These characterizations may serve as a frame of reference for other engineering and science educators who work directly with practitioners and aim to provide effective, productive professional development experiences. By recognizing traditional or more conventional approaches early on, an engineering educator can better assist teachers by modeling for teachers more transformative features, and hence, provide teachers the opportunity to change, if not enhance their normal practice.

Conclusion

Findings from this study suggest that there is no universal approach to translating the engineering design process into the elementary science classroom. Integrating the engineering design process is a complex activity that requires teachers to consider the resources they have available, knowledge necessary to understand and apply the design process, and understanding of how students can learn and engage in the engineering design process effectively and productively.

Teachers in this study took different orientations to incorporating design in their science lessons. Our findings suggest a continuum of approaches from assimilating (partially blending existing ideas with new ones) to transforming (changing or reinventing one's practice completely). The orientations presented in this paper were characteristic of different features including the role of the engineering design process, the role of science concepts, and the use of feedback.

Attention must be given to teachers' professional development and transformation toward the inclusion of engineering design-based instruction and curriculum in order for engineering education to be fully realized in the elementary science classroom. Results from this study

suggest that additional research is necessary to learn more about how best to support elementary school teachers' efforts in incorporating the engineering design process in their respective practices. Examples of possible inquiries may include, but are not limited to, the following: What are the sources of the teachers' orientations? Do teachers' orientations change over time? In what ways do teachers' beliefs about students and learning about engineering design influence their orientations? How can we conceptually map out teachers' instructional decision making and implementation of design? In what ways can professional developers support teachers to revisit and refine their orientations?

One aspect of this approach to characterizing teachers' orientations that may serve useful to engineering educators is the charge to explore how these variations in instructional practice influence student learning. Ideally, it is our aim as educators to encourage teachers to enhance their normal practice through the integration of engineering design and further more have a predictable and positive effect on how students learn. Research on the correlation between teachers' orientations and student learning is clearly warranted.

We encourage engineering educators to be reflective about their own design decisions by attempting to make their individual orientations explicit to themselves and their colleagues. Together engineering educators can discuss whether or not the recognized orientation is even a desired or intended orientation for the professional development program. Research on teachers' attempts and respective orientations is clearly warranted. Future research will seek to understand the nature of teachers' orientations with engineering design and the relationship between teachers' orientations, teacher knowledge, behaviors, and anticipated professional development outcomes.

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