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Utilizing Teacher Noticing within a Representation of an Elementary Engineering Lesson to Support Responsive Teaching in the Classroom

Anne Estapa (Professor) [1*], Kristina M. Tank (Professor)[2], Michael DuPont (Researcher)[3]

[1] University of Iowa, anne-estapa@uiowa.edu

[2] Iowa State University, kmtank@iastate.edu

[3]Krell Institute, michael.d.dupont@gmail.com

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Abstract: Teacher noticing has been termed consequential to teaching because what you see and do not see impacts decisions made within the classroom. Further, how a teacher responds to student thinking depends on what a teacher sees in student thinking. Within this study we sought to understand what teachers noticed within an engineering lesson and the decisions made as a result of that noticing. Findings indicate that student teachers and cooperating teachers drew on their pedagogical knowledge for decisions, rather than taking up the integrated content of student thinking and understanding. These findings serve as a guide for the experiences needed to engage in the complex work of teaching or, more specifically, implementing engineering into instruction through a responsive teaching frame.

Keywords: Elementary Engineering, Noticing, Responsive Teaching
MESC Classification: 97D40, 97B50
MSC2010 Classification: 97C70

I. INTRODUCTION

Engineering is increasingly being incorporated into the elementary classroom. Given the limited experience and preparation elementary teachers have for teaching engineering (Banilower et al., 2013) there is a need to better understand how to support elementary teachers to integrate this novel area in their classrooms (Brophy, Klein, Portsmore & Rodgers, 2008). Such efforts have illustrated that professional development (PD) supports elementary teachers with the integration of engineering in their classrooms through

*Corresponding Author: anne-estapa@uiowa.edu

developing an understanding of engineering, STEM integration, and curricular implementation focus (i.e., Guzey, Tank, Wang, Roehrig, & Moore, 2014; Estapa & Tank, 2017; Capobianco & Rupp, 2014; Crotty et al., 2017; Custer & Daugherty, 2009). Watkins et al. (2018) expressed however, that little research has been done on practices teachers need to learn about teaching engineering or how they might learn it. Further, current reform efforts call for teachers to utilize research-based pedagogical approaches that support student learning (National Council for Teachers of Mathematics [NCTM], 2000; National Research Council [NRC], 2001; 2009; 2012; NGSS Lead States, 2013). Within these reforms teachers are called to engage students in inquiry-based learning that lends itself to productive discourse of ideas. Responsive teaching is an instructional approach in which teachers base their pedagogical moves on student understanding (Hammer, Goldberg, & Fargason, 2012; Robertson, Scherr, & Hammer, 2016). Teachers, within a responsive approach, focus on what their students are saying and doing rather than following a scripted plan. Teachers elicit students' ideas, interpret and assess disciplinary aspects of students' reasoning, and respond with pedagogical decisions based on their interpretations (Robertson, Atkins, Levin & Richards, 2016; Sun & van Es, 2015; Wendell, Watkins, & Johnson; 2016).

Within a responsive pedagogical approach, teachers need to understand students, as learners, in addition to the content and integrated learning. Luna, Selmer, and Rye (2018) highlight a need for research specific to teacher's noticing of student thinking given that prior work within science has focused on "teachers' noticing science content rather than around students' thinking surrounding that content" (p. 150). To address this area of need and extend it into the engineering context, we created an opportunity for teachers (preservice student teachers and inservice cooperating teachers) to view a representation of engineering instruction in order to analyze what teachers noticed and the decisions made based on that noticing. In this way, we sought to understand if teachers noticed the integrated content of student thinking and if responsive decisions were made based on that noticing. We ground this work in the professional noticing literature and align our research design with the Stages of Engineering Implementation (Diefes-Dux, 2014) to better understand teacher noticing within an engineering context with a goal to help teachers develop practices of responsive teaching in engineering. The specific research questions that guided our study are: (1) What do student teachers and cooperating teachers notice specific to teaching and learning within a representation of engineering in the elementary classroom? (2) What decisions and rationales do student teachers and cooperating teachers make based on their noticing from the representation of practice? And, (3) How are student teachers and cooperating teachers noticings similar or different within the engineering context?

II. THEORETICAL FRAMEWORK

Across disciplines responsive teaching is an essential element for successful implementation of the current reform vision for effective teaching. Teachers that strive to be responsive in their pedagogy must attend to student thinking through the ideas and strategies they share to monitor reasoning and assess disciplinary knowledge as it progresses in a lesson (Ball, Lubienski, & Mewborn, 2001). As Luna, Selmer, and Rye (2018) express, “teachers need to actively notice those pedagogically important components of classroom activity” (p. 150). In this way, responsive teaching hinges on teachers’ noticing abilities (Colestock & Sherin, 2016). Therefore, given that how a teacher responds to student thinking is dependent on what the teacher sees in that student’s thinking (Colestock & Sherin, 2016) it is imperative that we understand what teachers notice within teaching contexts. Specific to this study, we focus on the teaching of engineering in the elementary classroom with teachers who are new to engineering and the engineering design process within university coursework and professional development programs.

Teacher noticing is not a new construct of research. In the early twentieth century, under the child study movement and the development of progressive pedagogy, beginning teachers were encouraged to watch closely the children they taught (Erickson, 2001). During this time the importance of teachers learning about their students to better their capability to teach the students was stressed. van Es and Sherin (2008) defined noticing as “(a) identifying what is important in a teaching situation; (b) using what one knows about the context to reason about a situation; and (c) making connections between specific events and broader principles of teaching and learning” (p. 245). Noticing plays a critical role in responsive teaching given that a key aspect of responsive teaching is perceiving student thinking and understanding what that thinking means in terms of student understanding and engagement. However, Chase, Malkiewich, and Kumar (2019) state a persistent problem of implementing engineering activities in the classroom is the so-called “design–science gap” (Vattam & Kolodner, 2008) defined by learners focusing on the concrete or procedural aspects of building out their engineering designs, *instead* of thinking deeply about the content that underlies their designs. Therefore, we sought to understand what teachers noticed within an engineering context to better determine how to best support their learning of responsive engineering instruction. Noticing as a construct allowed us to analyze what teachers attended to and how such noticing was similar or different based on experience. We outline key literature in the next section as it informs both our research and design.

III. LITERATURE REVIEW

Noticing has been used to better understand aspects of teaching such as teacher learning (Estapa, Pinnow, & Chval, 2016; Barnhart, & van Es, 2015), student learning (Lesseig, Casey, Monson, Krupa, & Huey, 2016; Stockero, Leatham, Van Zoest, & Peterson, 2017), and teaching practices (Benedict-Chambers, 2016; Estapa et al., 2016; Sun, & van Es, 2015). Much of the research on teacher noticing, across disciplines, highlights the important idea that teacher noticing can be improved or developed. For example, Estapa and Tank (2017) demonstrated that the use of multiple media (video and animation) created a shift in teacher candidates' focus from general pedagogical aspects to more specific nuances of teaching. Further, Barnhart and van Es (2015) focused on preservice teachers' science noticing as a result of participation in a learning to notice course. Findings from the study illustrated that participants of the course noticed student thinking more robustly compared to others who did not take the course. The participants continued to engage in this practice when assessed three-months after completing the course. Similar to these findings, Amador et al. (2017) found that a focus on noticing during clinical experiences within a teacher education program positively impacted a teacher within her own classroom. Specifically, within science instruction that teacher began to interpret student thinking more deeply and started making in-the-moment changes to her instruction. Such results make noticing a powerful tool to support teacher learning, novice and expert, of effective teaching practices.

1. EXPERT AND NOVICE NOTICING

As discussed above, noticing impacts teacher learning and practice during preparation and extending to classroom instruction. However, differences in teacher noticing, based on experience have also been revealed. More experienced K–12 teachers notice differently than novice teachers, utilizing experiences and knowledge to analyze teaching and learning (Auerbach, Higgins, Brickman, & Andrews, 2018; Kellman & Massey, 2013). Berliner (2001) noted that expert teachers can distinguish between important and unimportant information in a complex situation, reason about what they observe and use this analysis to make more informed teaching decisions. Through their experience and knowledge, experienced teachers pay more attention to student thinking and to the relationship between teaching strategies and student thinking (van Es & Sherin, 2008; van Es, 2011). In contrast, novice teachers are often more descriptive in what they notice, void of reasoning or reflection (Amador et al., 2019; van Es, 2011). Novice teacher noticing is often fragmented, with limited focus on the substance of student thinking

(Barnhart & van Es, 2015; Dreher & Kuntze, 2015). Given these differences, research has focused on tools to further develop novice teacher noticing (i.e., video clubs). Through such effort, noticing continues to be an aspect that can be enhanced and developed. Yet, little work has explored noticing in the context of engineering activities. Chase et al. (2019) provide a compelling argument that noticing of scientific structures plays an important role in student performance of engineering tasks and transfer of science content. Therefore, a focus on teacher noticing and ways to further develop both novice and experienced teacher noticing within and across disciplines is worthwhile. Specific to this study, we present noticing research within engineering.

2. TEACHER NOTICING WITHING ENGINEERING

Dalvi and Wendell (2017) reported that engineering teaching responsiveness involves at least three critical aspects: noticing the science ideas that students bring into an engineering design project, noticing students' engineering design practices, and responding productively to support the further development of those ideas and practices. Given that noticing is a precursor to responsive practice, we see great importance to examine how teachers take up student thinking within engineering instruction and what decision they make based on their noticing. Chase et al. (2019) noted that many designers of engineering activities are aware of the *design–science gap* and use a variety of scaffolds to support science learning from engineering activities. "However, none of them [engineering activities] are designed to explicitly invoke noticing processes, and without training one's perception, for instance, learners may not even see the deep scientific structures embedded in the engineering tasks, which means they may not reflect on or test the relevant variables, making potential scaffolds less effective" (p. X). Given the design of engineering activities and the novelty of engineering instruction to many elementary classroom teachers, current research specific to noticing and engineering centers around three main aspects: content, integration, and implementation.

1) Content related to engineering

A key factor for successful implementation of engineering into the elementary classroom is the development of teachers' knowledge about engineering and the work that engineers do (Katehi, Pearson, & Feder, 2009, Guzey et al., 2014). However, within elementary grades, engineering is taught in an interdisciplinary manner and most often within science or math. Thus, the content for engineering instruction often spans within and across the science, technology, engineering and mathematics (STEM) disciplines. Researchers, such as Daugherty and Custer (2012) examined the knowledge needed for teachers to engage in engineering instruction. Results indicate an emphasis on knowledge of STEM content, engineering tools (i.e., software programs), engineering design process and interpersonal skills. Therefore, the content knowledge needed for teachers to notice student engineering thinking is related to the science or math content ideas that students bring into an engineering design project, as well as a knowledge of engineering and engineering design. Johnson et al. (2017) found that teachers with no formal background in engineering can notice disciplinary aspects of their students' engineering design. Through the noticing construct, with a content lens, what teachers notice can enhance or deepen content understanding within student thinking (van Es & Sherin, 2008; Estapa et al., 2016).

2) Integration of engineering

Research examining successful integration of engineering into classroom instruction has also focused on how teachers conceptualize the integration of engineering into STEM content into instruction. For example, McCormick, Wendell, and O'Connell (2014) investigated how inservice teachers attend and respond to classroom-based engineering design tasks, trying to understand how they envision the interaction prior to teaching them. Participants viewed a video of students engaging with an engineering design task and then completed an interview. The researchers found that teacher attention was spread across many interactions within the classroom and that reporting responses based on a video or based on one's own classroom evoked different responses. Similarly, Radloff and Guzey (2017) explored preservice teacher noticing of integrated STEM to analyze for gains of deeper understanding of integrated STEM. Results indicated that with the use of video and prompted reflections, preservice teachers (PSTs) became more informed in their conceptions of integrated STEM both in regards to pedagogy and content. The researchers noted the importance for content learning before the intervention to allow teachers to build their conceptions. Estapa and Tank (2017) examined teachers' conceptions of STEM integration through three phases of implementation. Results indicated that teachers attended to integrated approaches across all phases, but the implementation of such aspects were seen more in lesson plans rather than classroom observation. It becomes imperative then that teachers engage in learning around engineering and STEM content and ways to integrate across the disciplines.

3) Implementation of engineering.

Research has also looked at the implementation of engineering instruction in regards to teacher noticing. Much of this work has further illustrated the importance of the previous two aspects, in addition to highlighting a very critical piece for the pedagogical success of engineering instruction – understanding the practices for implementation and student thinking within implementation. Luna, Selmer, and Rye (2018) analyzed teacher noticing of student thinking through artifacts of their science work within a garden-based learning experience. Results indicated that teachers initially described what students were doing and later used language as it pertained to specific practices of science and engineering instruction. Through specific learning tasks, teachers were able to more robustly attend to student thinking through artifacts. Additionally, Wendell et al. (2016), through video, examined the moment-to-moment assessments and decisions that engineering teachers encountered during a lesson. Findings illuminated a need for increased attention on how teachers manage the different disciplinary practices and goals within not only engineering, but also STEM instruction, particularly when adopting a responsive teaching approach. Johnson et al. (2017) examined what teachers noticed about their students' engineering work with teachers new to engineering. When the researchers asked the teachers how they would respond to the students in the video, teachers either provided specific engineering knowledge or directed the students' work to mirror their own thought process rather than focusing on student thinking and understanding. Further, teachers often noticed the social dynamics in the student groups, while more experienced teachers attended to how students were communicating with each other, but their interpretations of these interactions often included aspects of engineering design practice. Tank, DuPont, and Estapa (2020) noted that a teacher's focus on a specific aspect of the engineering process impacted a lesson in varying ways. Through the noticing construct, these findings outline the need to further support teacher development of not only engineering understandings, but a focus on the pedagogical supports needed to integrate engineering into the elementary classroom.

IV. RESEARCH METHODLOGY

1. RESEARCH CONTEXT AND PARTICIPANTS

This study was part of a larger National Science Foundation (NSF) funded project examining the use of a model for STEM teacher education that adds an engineering graduate student to the traditional cooperating teacher and student teacher pair, making a group of three or triad. The participants of focus for this study included nine student teachers participating in their 16-week student teaching experience and the nine classroom teachers who were serving as their cooperating teachers. All nine of the student teachers attended the same Midwestern elementary teacher preparation program, with three of the nine student teachers having completed a science methods course that included an introduction to engineering and design. All nine of the cooperating teachers taught grades 3-5 in the same urban, public school district. Three of those teachers had previously participated in the larger project and therefore had one semester of prior experience with engineering. All of the teachers had been teaching for more than 5 years, although some were newer (2-4 years) to their current teaching grade level. Participants self-nominated into the larger project and were selected based on criteria of interest and ability to collaborate within a triad model. To see more about the larger project please reference (Estapa & Tank, 2017).

2. PROFESSIONAL DEVELOPMENT

As part of this larger project, all participants attended a two-day PD workshop prior to the start of the teaching experience, with a follow-up, full-day workshop that occurred mid-way through the 16-week student teaching experience. In following recommendations from the research on effective PD (i.e., Desimone, 2009; Garet et al., 2001; Guskey & Yoon, 2009), the initial two-day PD workshop focused on building knowledge around science and engineering and developing pedagogical knowledge in science and engineering. As part of that work, participants were engaged in hands-on activities that were centered around engineering design, and that modeled ways to integrate engineering into their current science instruction. Part of that work included engagement in a life science engineering unit around plants' needs and designing a package for a plant (www.eie.org). This initial workshop was run by an interdisciplinary team of science and math educators as well as three outside experts from a college of engineering. Prior to the follow-up professional development workshop that occurred midway through the experience, participants were asked to work as a triad to implement at least one engineering design lesson in their classroom.

The follow-up PD was a full-day session that occurred partway through the semester and was designed to build on the experiences of the participants. This included building upon what had been done in the summer PD, experiences from their classrooms as noted in field observations, and recommendations from the Stages of Elementary Teacher Development with Engineering Education (Diefes-Dux, 2014). From these considerations, the follow-up PD engaged teachers in a Batteries and Bulbs science activity and showed how that activity could lead into an Engineering is Elementary Designing Alarm Circuits unit. This specific content was selected due to its relevance to standards across the 3rd, 4th and 5th grade classrooms. The PD focused on the concept development portion of lesson design within the batteries and bulbs science lesson and practices for how science and math learning could be embedded within engineering design activities. Our focus within this study is on the Noticing Task participants engaged in during the follow up PD. We provide an overview of this task in the next section.

3. THE NOTICING TASK

After participation in the follow-up PD session described above, the participants were presented with a video clip (approximately three minutes long) of part of a third-grade engineering lesson focused on the *Designing a Lighting System* unit from the Engineering is Elementary curriculum (www.eie.org). In this particular unit, students are asked to think like optical engineers and explore how light interacts with different materials. They use what they learn about the properties of light as they design a system to illuminate hieroglyphics in a model tomb. We purposefully selected this video as it provided the participants with a representation of practice that depicted an elementary engineering lesson and highlighted effective teaching practices and student collaboration within engineering. Specifically, the video segment illustrated students engaged in multiple phases of an engineering task. The video segment provided opportunities to hear students' ideas for how light will respond in the tomb environment, to see how they illustrate their thinking, and how they test their solution and calculate scores for the challenge based on provided criteria. Further, the science content of the video and grade level focus were similar to those of the participants. For additional detail of the clip please see Appendix A.

After watching the three-minute video, participants were asked to independently respond, in writing, to a series of prompts (see Appendix B). The prompts align to the constructs of noticing to elicit what participants attended to and what connections were drawn on for decisions related to this elementary engineering lesson. The first prompt, Step 1, asked, "what did you notice in the video that was pivotal to teaching or student learning?" The second prompt, Step 2, asked participants to then make an instructional decision about "what should happen in the next minute of class to best promote student thinking and learning?" The third and final prompt, Step 3, asked participants to explain their reasoning behind that instructional decision with the question, "why do you think that should happen next?" The prompts used were purposefully selected to capture who and what participants attended to in the video and illustrate interpretations, connections, and instructional decisions that followed, similar to Estapa et al. (2018). We intentionally selected open-ended prompts so we could analyze teacher noticing following participation in the PD and as learning was occurring. Participants recorded their work independently during the PD experience.

4. DATA COLLECTION AND ANALYSIS

The data for this study included the student teachers' and cooperating teachers' written responses to the series of prompts that were included as part of the Noticing Task. The task was administered at the end of the follow-up PD session and the written responses were collected following completion of the task. The data was then deidentified and the responses were added to a spreadsheet for analysis. Using the teacher noticing construct that grounded this study as a starting point for the analysis, data were analyzed using a cyclical process with several rounds of coding, comparing, and condensing the data to allow for the emergence of patterns and themes (Miles, Huberman, & Saldaña, 2014) related to who and what the participants noticed. Each instance of noticing was coded. We defined an instance as the focus on a specific actor (teacher, student, or group of students) or aspect (i.e., action or knowledge). A set of provisional codes was used as a starting point for deductive coding in the first round of analysis, as suggested by Miles, Huberman, and Saldaña (2014), as it allowed for the analysis to be grounded in the constructs of noticing (van Es & Sherin, 2008) including who the teachers attended to (teacher or student) and what aspects the teachers attended to when watching an engineering lesson. This approach also allowed for the codes to be applied in the first round and then examined closely and assessed for fit and revised, deleted, or expanded as necessary. The first prompt was explicitly designed to elicit aspects of noticing and therefore closely followed the provisional coding described above. Analysis of the second and third prompts, examining what the teachers would do next and their reasoning for why they would choose to do that, started with the same provisional codes, but followed a more inductive coding approach allowing room to identify other concepts or insights that might arise from the data (Miles et al., 2014). Thus, the coding helped to identify aspects of teacher noticing and decisions that were seen across each step of the task and subsequent rounds of coding led to the grouping the data into smaller categories and themes related to noticing and similarities and differences among teacher and student teacher noticing. We provide definitions and examples of the categories in Table 1. The data were analyzed individually by three researchers and differences were discussed and reconciled during our initial coding process until agreement reached 85%.

Following the initial rounds of coding, analysis revealed the need for an additional cycle of coding to dig deeper into the data to take a closer look at how engineering was represented within what was noticed and the decisions provided. An additional round of coding was done to provide a deeper analysis of what aspects of engineering the teachers were attending to and including in their written responses. The coding began with a list of provisional codes based on the engineering design process utilized by the

Table 1. Coding Dictionary

Coding Category	Example from Data
Student Action: The focus is on what the student did or is doing	**[Students] had to bring up their plans and get their materials. Explain why they need their materials.** Explain their planning and building of the plan. Students are testing the information and talking about why the light bounced and where it went.
Student Knowledge: The focus is on describing or interpreting student thinking or understanding.	Student can explain what they are doing. Referring to drawings as they are working in groups. **Seemed to have prior knowledge, filling out their budget, and recording observations.**
Teacher Action: The focus is on what the teacher did or is doing.	**Teacher passing out supplies,** small group learning and discussion around light reflection with a mirror. Group is discussing light reflection. How does the light bounce off the mirror? Need to understand what reflects light and what attracts it. Students know how to work in groups. They know what points on the paper it needs to hit. They get to test their predictions. [They] measure light intensity. The problem has been clearly stated and identified.
Teacher Strategy: The focus is on a specific strategy a teacher uses and its pedagogical benefit	**Teacher was an objective observer who facilitated the dispersal of the supplies**. Students used materials/prior knowledge to set up their models. Students were then given a light to test out their hypothesis. Respectful debates with reasoning happening, student driven inquiry.
Group Work: The focus was on students working in groups or needing to be in a group	**Students were in groups**. Teacher was passing out materials. Matching students' drawings/plans to the actual creation. Teacher explaining next steps and her expectations. Math - integration - pricing.
Lesson Materials: The focus in on materials used by the teacher and/or student during the lesson	**Students have a binder/folder with information in it they previously learned.** Allowing students to experience and learn whether the experiment will work. Having the students compare work and answer promotes growth and allows for the sharing of ideas.
Lesson Content: The focus is on the content or concepts being taught in the lesson	Teacher passing out supplies, small group learning and discussion around light reflection with a mirror. Group is discussing light reflection. How does the light bounce off the mirror? **Need to understand what reflects light and what attracts it**. Students know how to work in groups. They know what points on the paper it needs to hit. They get to test their predictions. [They] measure light intensity. The problem has been clearly stated and identified.
Content Integration: The focus is on content or concepts that support or extend the lesson content	**Using Coordinates- Math**. Having labels in the boxes with clear expectations, and clear directions. Knowing how to work in common groups, what materials [are available], and that they needed grids in boxes. Having models and folders with sheets, [students] **needed to measure**, and needed to know how to fill out sheets.
Physical Environment: The focus is on physical aspects of the classroom	1. Hands on activities 2. Multiple learning styles acknowledged. 3. Students materials seemed organized. 4. Collaboration between students. 5. Independent (not teacher focused) learning. **6. Engineering design poster in the background.** 7. Content is integrated.

curriculum (www.eie.org) and Moore et al. (2014) *Framework for Quality K-12 Engineering Education*, but then followed a more inductive approach. Since these aspects of engineering were in response to a portion of an engineering lesson that participants watched, each researcher independently watched the video clip and noted aspects of engineering observed before coming together to discuss a set of provisional codes that might appear in the data based on the video. Those provisional codes served as a starting point for this additional round of coding, but also left room for alternative codes to arise during analysis (Miles et al., 2014). The researchers met to discuss their individual analysis and reconciled differences, before identifying the following categories related to how aspects of engineering were mentioned by participants: (a) the exploration and consideration of materials and constraints, (b) the importance of a plan, (c) the building and testing stage of a solution, and (d) the integration of content with engineering. After this deeper analysis of the data, the researchers analyzed findings to determine similarities and differences for responses of student teachers (novice teachers) and cooperating teachers (experienced teachers).

V. LIMITATIONS

We note two important limitations of our study. First, the video representation the teachers viewed was focused on one phase of engineering lesson and was an edited segment of classroom teaching. Therefore, participants were not afforded the opportunity to see an entire task from beginning to end. Further, aspects for how long different phases of the lesson took were not accurately represented. As a result, we note our data is limited in its scope specific to engineering. However, we see value in understanding the role student thinking played within engineering, even within a narrow scope, to better inform responsive teaching practice.

VI. RESULTS

The purpose of this paper focused on teachers' noticing in regards to an engineering lesson. Analysis of the participant responses across the Noticing Task yielded important similarities and differences between student teachers and cooperating teachers. We organize our findings sequentially through each step of analysis as we gain understanding of teacher noticing within a representative engineering lesson. Our findings demonstrate: (a) similarities in who and what was noticed by student teachers and cooperating teachers,

(b) the overall absence of engineering or science concepts (i.e., properties of light) from participants' decision making, and (c) participants use of more general pedagogical knowledge in place of pedagogical knowledge and decision-making that was focused on supporting the further development of engineering ideas and practices.

Step One: Who and What was Noticed

Upon watching a video clip of an elementary engineering lesson, participants were first asked in Step 1 to write down what they noticed in the video that was pivotal to teaching or student learning. Upon the initial coding of responses for who was noticed, participants most frequently noticed individual students within the video with this occurring in 69% of the instances. The noticing of groups of students or the teacher were much less common with 14% and 17% respectively. We report details on who participants noticed in Table 2. These data represent all instances of noticing from the first round of coding and it is important to note that some participants shifted their noticing within the response and therefore noticed multiple subjects in the video. For example, they first might have noticed the teacher and then focused on a group of students. This response would have been coded for teacher and group of students.

Table 2. Instances of who participants noticed

Participants	Individual Student	Group of Students	Classroom Teacher
Student Teachers	20	4	5
Cooperating Teachers	25	5	6
Total	**45**	**9**	**11**

Across all responses, the student teachers and cooperating teachers not only tended to notice individual students with more frequency, but also had similar noticing across all three groupings for who was noticed after watching the representation of an engineering lesson.

After analyzing who participants noticed, we wanted to understand what their attention was focused on specific to the student(s) or teacher. In this analysis we found that participants were attending specifically to student actions (e.g. [students] had to bring up their plans and get materials) and students' math or science content knowledge (e.g., students understand angles) after watching the video. To a lesser extent, participants noticed the actions of the teacher generally (e.g. the teacher is passing out materials to students) to pedagogical strategies utilized (e.g. teacher explained their next steps and expectations). We report results from our first round of coding for what participants noticed in Table 3 and similar to above, participants could notice multiple aspects.

Table 3. Instances of what participants noticed

Participants[a]	Stuednt		Teacher		Lesson				
	Action	Knowledge	Action	Strategy	Group work	Materials	Content	Integration	Physical Environment
Student Teacher	8	5	3	7	2	2	1	2	1
Cooperating Teacher	8	5	1	8	2	4	1	3	2
Total	**16**	**10**	**4**	**18**	**4**	**6**	**2**	**5**	**3**

[a]n=18

As we did for who participants noticed, we again found similar trends for what student teachers and cooperating teachers were focused on during their noticing. For example, when a cooperating teacher was asked what they noticed their response was:

> The students were working with the materials, making their own plans testing adopting all on their own. Students are working in tandem. Students are explaining their process and their thinking. They regrouped together and discussed observations/strengths and weakness.

This highlights an instance where the cooperating teacher is focused on the students and described what the students were doing in the video.

The second round of coding focused on what specific engineering aspects were articulated within the noticing response and led to the following larger themes around engineering: (a) the exploration and consideration of materials and constraints, (b) the importance of a plan, (c) the building and testing stage of a solution, and (d) the integration of content and engineering. For example, when asked what they noticed in the video (Step 1) a cooperating teacher stated “accountability with students’ sheets” referring to a budget worksheet in the students’ activity booklet. This response was coded material exploration and constraint exploration as the participant was able to recognize the sheet as important to teaching and/or student learning within engineering. Across all participants, all but one provided responses that aligned with at least two of the four engineering categories. There was one participant whose responses aligned to all four categories. We report these findings in the Table 4.

Table 4. Participant response and engineering aspect alignment

Participants[a]	Material Exploration and Constraint Exploration	Importance of a Plan	Building and Testing Stage	Content Integration
Student Teacher	8	7	7	6
Cooperating Teacher	8	3	7	3
Total	**16**	**10**	**14**	**10**

[a]n=18

These data showed a range in how participants mentioned or reported the engineering aspects within their response. In some cases, participants utilized engineering vocabulary in a very general way, merely making mention of the word criteria or that students used materials. In other instances, however, participants had more specific responses within the categories that connected to other pedagogical ideas within engineering design. For example, four of the 18 participants noticed a building stage present within the video while 12 of the 18 participants noticed the testing. As a general example, a student teacher responded that students ".. tested materials - seeing if their plan worked and graded their own design." This response was coded for the building and testing stage aspect in the same way as the following response was:

> "… students test their design /plans as they are following the engineering design process." Again, both of these responses were coded for the same aspect but the second response illustrates a connection between the testing of designs and the engineering design process.

Step Two: Teacher Decisions for Next Steps

Participants were asked in Step 2, following identification of who and what they noticed related to teaching and learning, to write down what should happen in the next minute of class to best promote student thinking and learning. They were prompted to write specific questions or actions that they wanted to implement next—not predicting what they thought actually happened in the video, rather what they would do if this was their own classroom. When looking across the participant responses, three common suggestions for next steps were found: (a) sharing results within and between groups, (b) finalizing the testing stage, and (c) participating in redesign. For example, a student teacher stated "I think I would have groups discuss what they were observing in their tests to compare similarities and differences and possibly gain deeper understanding from each other." Additionally, a cooperating teacher stated, "Share between groups what data was gathered. Compare similarities/differences of the data gathered. Redesign to gather data from what was expected to what actually happened. Whole group discussion. What info did you call? Why was this info different from what you expected? What changes could you make to your design?"

Largely absent from these next steps was an integration of science content that connected the engineering activity with the science concepts being tested and developed. One of the student teachers recommended a review of new vocabulary words learned and one cooperating teacher wanted students to specify "what important parts of science content helped them in their designing of a solution and if their mirror angle reflected the light on the correct spots?" This cooperating teacher's response was the only one that had a connection made to the properties of light being studied or how the designs illuminated hieroglyphics in a model tomb.

Participants overwhelmingly recommended a variety of group-based activities common in elementary classrooms to continue with what they had noticed in the video segment related to instruction, such as having students share or discuss ideas within the small groups, having small groups pair up to share their design with each another, or having the whole class reconvene for one large sharing discussion. What was anticipated to occur in these sharing activities varied from just observation of another group's solution, to reporting, to comparing, and finally to justifying the group's work and decisions; participants had multiple purposes with their anticipated actions. Reporting to another group was the most common (coded 13 times), while comparing (6) and justifying (6) had similar but smaller occurrences. About a third of the participants suggested that within the next steps there should be time to finish testing with no detail about the specifics around how or what related to the testing. The last of the common suggestions for Step 2 was seen with participants recommending that after completing the testing or sharing that some sort of redesign should occur. When looking more closely at the suggestions for redesign, there was a range as some redesigns resembled large group summative discussions about what went well and what could be improved while others included participation in a physical redesign that asked individual groups to review their testing results, make changes to their design solution, and retest. An example of a response, student teacher, that included participation in a redesign was:

> Students should make their plans/design better after testing them. Students should discuss as a group what they think needs to be improved *and then they should redesign*. The teacher should be explicit about stating students are working in the "make it better" phase and ask why this phase is important.

In other redesign examples, the response mirrored more of a discussion about redesign or included redesign only if time permitted. A student teacher wrote, “After assessment, groups partner up and compare results. Then, share with the class, rank (responses) and discuss what worked, what didn’t, and problem solve strategies. *As time allows, redesign phase/improvement phase.”* These examples represent the range of responses when participants’ next steps included redesign.

Step Three: Teachers Reasoning for Next Steps

In Step 3, participants were asked to rationalize why they thought their actions in Step 2 should happen. In our initial analysis of the responses we found that participants often felt their decisions for next steps in the lesson should happen because it encouraged learning. The responses that centered on learning often noted reflection as part of their rational. For example, a student teacher said “Reflection is a part of life. Students need to work on that skill in general. Engineers are able to reflect and share ideas with others in order to improve ideas or processes.” Within this response the participant notes a need for reflection and how it benefits students while also making a connection to what engineers do. When participants focused their rational on a teacher action it embodied an aspect of classroom management or knowledge for the teacher. For example, a cooperating teacher said “It allows the teacher to see how on task the class is. Is there actual learning or just messing around? It allows the groups to see if their results are similar to their classmates. It allows the teacher to correct any misconceptions.” The last category of rationales included responses that were more general in nature connecting to aspects such as the real world or constraints of their articulated next step. Across each of these categories we found aspects of pedagogy and engineering. Therefore, to further understanding the responses we coded to determine if they illustrated a more general understanding of pedagogy as compared to espousing a lens from engineering pedagogical decisions. For example, one student teacher reported that their next step should happen:

> To ensure that the students have a good understanding of a concept being learned. It’s also important to check/improve the design so that the students can use engineering. The cost applies the student’s knowledge of the math and money.

Additionally, a cooperating teacher stated, “In the engineering design process the next steps are test and redesign. The students in the video are ready to take on the next steps in the process.” In these responses, the participants’ reason their decisions for next steps with direct connections to engineering and therefore were coded as engineering pedagogical lens. In other responses however, decisions were connected to more general pedagogical ideas. For example, a cooperating teacher stated, “doing the activity is not the goal, learning from activity is.” Another cooperating teacher explained, “Students need to have the opportunity to demonstrate and share their ideas and findings. They also need to be able to explain the “why” so the teacher can clear up or guide students if any needs to be done.” In these examples, the participants did not make connections to engineering when rationalizing why their next steps should happen, and therefore the response was coded with a general pedagogical lens. We highlight these results in Table 5 to represent both what aspects of engineering were evidenced in participants next steps (Step 2) and what the primary pedagogical lens was for why this should happen (Step 3).

Table 5. Decision-making lens for next steps

	Material Exploration & Constraint Exploration	Importance of a Plan	Building and Testing Stage	Concept Development	Primary Pedagogical Lens
ST03	*	*		*	General
ST04	*	*	*		General
ST07	*	*	*	*	General
ST08	*	*		*	General
ST09	*	*	*	*	General
ST11		*		*	General
ST14	*****	*****	*****	*****	**Engineering**
ST17			*	*	General
ST20	*****	*****	*****		**Engineering**
T05		*			General
T06		*****	*****		**Engineering**
T10		*	*		General
T12		*****	*****	*****	**Engineering**
T13	*	*			General
T15		*	*		General
T16	*****	*****	*****		**Engineering**
T18	*****	*****	*****		**Engineering**
T19		*	*	*	General
Total	**10**	**17**	**13**	**9**	

Note. * = aspect of engineering identified in response. Pedagogical lens identified as engineering is boldface. ST = Student Teacher. T=Cooperating Teacher.

Results indicated that all participants included aspects of engineering in their next steps (Step 2) however, the decision-making process for such actions differed across participants. Specifically, we found two larger decision-making paths that participants utilized. First, most participants justified their actions through general pedagogical foundations. One student teacher suggested in Step 2 to have a snowball discussion between groups lead into a large group redesign conversation and rationalized their action by saying, “This would promote reflection and sharing within the students’ group. Reflection would allow students to gain more knowledge.” Although this participant did recommend another aspect of the engineering design process, their decision-making and rationale was rooted in a more general pedagogical approach that would be true for most activities regardless of if they were specific to engineering education. Seven student teachers and three cooperating teachers utilized this type of thinking by rationalizing that “students should have the opportunity to reflect.” “students need to have the opportunity to demonstrate and share their ideas and findings.”and “it would encourage students to think about how the information is always changing.”

Second, and often times in addition to the first decision-making path, one-third of the participants rationalized their actions within the habits of what engineers in the real world do or by following an engineering design process. For example, a student teacher suggested in Step 2 that “students would explain their understanding and thinking to other students. Students would test one at a time and then in front of all students” and rationalized this decision by writing that, “[this] helps students explain the process and continue to work as a class to share their ideas and redesign possibilities.” This participant showed a more explicit and congruent action step by naming the next phase of the engineering design process and rationalizing that a discussion about the testing phase would help students in the redesign phase. A cooperating teacher shared, “in the engineering design process the next steps are test and redesign.” A final example from a student teacher exemplifies this more engineering-focused decision-making by sharing, “...that’s also what engineers do in the real world—reflect and improve.” This final phase of analysis provided insight for not only what participants articulated should happen next and why, but what knowledge they drew on for such decisions.

VII. DISCUSSION

In this study, we sought to understand teacher noticing after participants viewed a representation of an elementary engineering lesson. Our analysis focused on student teachers and cooperating teachers noticing, decisions around such noticing and comparisons based on teaching experience. In our initial research question, we sought understanding of student teacher and cooperating teacher's noticing from an elementary engineering representation. We reported in findings differences of who and what was noticed, but draw attention to the fact that student teachers and cooperating attended to similar aspects of the lesson. This finding informs what we know of noticing, as researchers have demonstrated that the skill of noticing is initially fragmented with novice teachers. Within our findings we see that novices and experienced teachers attend to similar actors and aspects of the classroom representation. van Es and Sherin (2008) note that experienced teachers will make better sense of a classroom and interpret or evaluate instances. However, within our study novices and experts noticed in similar ways describing what was seen with little interpretation of content or student understanding, reflecting what is more typical for novice teachers.

Berlinger (1994) explains that "transfer across contexts and domains of knowledge appears to be very difficult and does not often appear spontaneously" (p. 21). The cooperating teachers within our study were experienced teachers, but novice to engineering. Their decisions were based on pedagogical practices to which they had experience with, but absent of engineering processes and therefore fragmented in efforts to support student learning of engineering concepts. Their teaching expertise did not automatically transfer into the new context of engineering. Windschitl et al. (2011) noted similarities and differences between preservice teacher practices and first year teachers within science models and inquiry. We add to this research base as this shift occurred with experienced teachers when implementing new and/or integrated content. Participants within our study drew on what they knew about the practice of teaching, rather than engaging in responsive pedagogy and basing their pedagogical decisions on understanding of engineering and how to support engineering as expected from experienced teachers. This finding, specific to engineering, is important as we work to support teachers, across the trajectory of their career, to engage in engineering instruction through responsive teaching. Further research focused on the role of content and student understanding within teacher noticing is needed to determine the types of prompts, representations or approximations needed for teachers to shift their focus and see student thinking across different and new contents. Dreher and Kuntze (2014) noted that experienced teachers are not necessarily experts when it comes to theme-specific noticing. Therefore, more attention on novice and experienced teacher noticing within the engineering context will provide direction for ways to support learning for both content and pedagogy.

In our second research question we focused on the decisions and rationales of the teachers as we sought understanding for responsive teaching in the engineering context. The work of responsive teaching requires teachers to attend to student thinking and base decisions on student thinking. Teachers within our study made decisions based on pedagogical practice more often than based on student understanding of engineering or science concepts. It cannot be reported if the teachers had misconceptions of the content but it can be stated the novice and expert teachers within our study made limited responses specific to content, integrated within engineering, in their decisions for next steps. Some teachers used practices of engineering as reasons for their decisions, but not in connection to student content learning. Therefore, it becomes important to provide teachers time and support with not only STEM content, but also, experiences for what student content thinking and understanding will look like or should look like within engineering if exemplary teaching includes the ability to attend to and respond to student thinking (Ball & Forzani, 2011; NRC, 2001; Watkins et al., 2018). Specific to the participants in our study, they experienced the engineering design process as a learner and were asked to consider how to develop concepts through engineering design tasks. However, they had not explored what student thinking or understanding might look like within such experiences. Research has shown that framing influences noticing, and therefore it is important to consider the context or framing of learning experiences (Levin, Hammer, & Coffee, 2009; Russ & Luna, 2013). Within our study, teachers made decisions based on a pedagogical frame, rather than engaging in responsive teaching based on the engineering frame. We hypothesize that such lack of responsiveness in instruction could limit student learning and encourage more tinkering of engineering in the classroom. Research to support such learning and explore the trajectory of key integrated content within engineering would be helpful to support teacher learning of not only the teaching practices, but also student learning. Further, the results of this work provide a starting place for future efforts. Teachers use of general pedagogical strategies for their decisions provides a place to begin conversation and support learning. For example, when a teacher noticed aspects that related to engineering, such as the students' budget sheets, but did not connect this to the constraints of engineering they have noticed something that relates to engineering but void of pedagocial connections. Therefore, efforts to further develop a rationalization that is grounded in an engineering pedagogical content knowledge lens could be helpful. Future efforts within PD that focus on these ideas will maximize teachers' pedagogical ideas and develop their engineering learning. Further it informs the field for a basis of when a focus on design process is preferred or more appropriate then content. This understanding will support efforts centered on the *design-science gap* (Vattam & Kolodner, 2008) in material creation and implementation.

Our last research question allowed analysis across student teacher and cooperating teacher data to understand how experience impacted noticing. We found that the two student teachers who rationalized their decisions with engineering were both paired with a cooperating teacher who also did. As we work to engage and support teachers in the practice of responsive teaching, we must also consider how to support the noticing of student content thinking and/or understanding. Research on teacher noticing allows us to capture and interpret decisions teachers make within the classroom context. However, within the engineering context understanding what concepts teachers attend to within student thinking becomes imperative as we work to support best practice in the classroom. Across the novice and expert teachers of our study there were common practices utilized. For example, reflection and group discussion were common practices enacted either nested within engineering or not. These practices provide an opportunity for teachers to utilize their pedagogy as they explore engineering PCK approaches. Efforts to understand how to continue to build from this are important as we build deep pedagogy and content understanding for teachers and students.

VIII. CONCLUSION

Research on responsive teaching indicates, as a pedagogical approach, use of it can support students' engagement with disciplinary practices (Hammer et al., 2012) as well as their understanding of concepts (Carpenter, Fennema, & Franke, 1996). Since teachers need to be prepared to listen and respond to students' thinking the responsive teaching approach has great potential for understanding engineering within the elementary context. Noticing and engineering research, have started to illustrate how being responsive to aspects of students' thinking within an engineering task is challenging but critical as efforts to meet the reform visions are made. Teachers need to be able to attend to student thinking across all disciplines. To support this work, we conclude that work with novice and expert teachers can focus on similar pedagogical practices to support integrated content learning and implementation within the classroom.

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Appendix A: *Summary of Video Clip shown to participants.*

Summary of *Designing a Lighting System/ Grade 3/ Fairfax, VT: 8:15 – 10:20* https://eie.org/eie-curriculum/resources/designing-lighting-system-grade-3-fairfax-vt	
Time	**Description**
8:15	Students communicating what materials they need
8:18	Cut to student talking to their group about needing string for reasons
8:27	Three students working in a group putting a mirror in their box. One student rationalizes what they are doing at that moment. Able to see another group working in the background.
8:36	Cut to student putting a mirror in a box and a group member goes to check their plan
8:51	Cut to another box where a student in miming how the light will travel through their box before the solution is built
9:02	Hear audio of teacher saying 1, 2, 3, and then cut to teacher encouraging students to continue building, pick up a flashlight, and then test.
9:17	Cut to a new angle where teacher shows a testing filter for the design. 3 students in view listening
9:22	Cut to two students looking at their desks while listening to instructions
9:30	Cut to teacher (with 3 students listening) giving final instruction about counting materials used
9:35	Cut to covered box with a student attempting to look into it and/or test the light
9:40	Three students on the ground writing in their workbooks their results and also clarifying what results they all observed
9:57	Cut to student holding light filter to the camera showing what filter they could or could not see light
10:01	Cut to three students writing in their workbooks with one student mentioning the cost of their solution
10:04	Cut to worksheet about group’s cost score, intensity score, and total score
10:21	END

Appendix B: *The Noticing Task.*

Engineering in the Elementary Classroom

For this activity, you will watch part of a 3rd grade-engineering lesson that focuses on *Designing a Lighting System*. In the unit, students think like optical engineers as they explore how light interacts with different materials. Students use what they learn about the properties of light as they design a system to illuminate hieroglyphics in a model tomb.

You will then answer a series of questions following the video.

Step 1: What did you notice in the video that was pivotal to teaching or student learning?

Step 2: If you were the teacher of this class, what should happen in the next minute of class to best promote student thinking and learning? What specific questions or actions would occur? To be clear, you are not being asked to predict what actually happens next rather you are creating what happens next.

Step 3: Why do you think that should happen next?