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Elementary Teachers' Responsiveness to Supporting Students' Engineering Design Feedback

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Abstract: Using engineering design to teach science requires teachers to engage in noticing, interpreting, and responding to students' needs in real-time. While research has begun to focus on how elementary teachers do so, less is known about how teachers instructionally support and optimize students' ideas through engineering design feedback. In this study we investigate what instructional moves two elementary teachers' employ to leverage students' ideas and reasoning and create opportunities for students to exchange design feedback. Data were gathered using classroom observations of teachers' implementations of a design task focused on sound and energy transformation. Observations were coded for teachers' use of high-leverage practices, and event maps were created to chronicle teachers' implementation of the task from start to finish. Event maps were analyzed and compared for discrete instructional activities and modes of classroom organization that supported opportunities for feedback. Findings suggested that while teachers used similar instructional moves, how and when they created opportunities for student design feedback differed, resulting in diverse ways of assessing and supporting students' understandings. Implications suggest design feedback as both a purposeful and naturally present phenomenon throughout the design process, reflective of the nature of engineering design.

Keywords: *Engineering design, elementary science, teacher education.*

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Introduction

As the integration of elementary STEM instruction continues growing internationally, so does the call for educators to utilize more equitable and responsive science teaching methods (Lee et al., 2014). This means recognizing students as individuals with their own unique backgrounds, cultures, and beliefs that are brought to bear in the science classroom; teaching to all students (Meyer & Crawford, 2015; Rodriguez, 2015). As such, equitable teaching involves learning to foster student reasoning and reflection using discourse-based practices aimed at leveraging student thinking (Windschitl et al., 2018). These practices center on noticing, interpreting, and responding to students' ideas in real-time (Watkins et al., 2018; Wendell et al., 2017), skills that are especially important as students work collaboratively toward providing design solutions to open-ended and real-world STEM problems (Capobianco et al., 2018; Cunningham et al., 2018).

To meet this challenge, teachers need to provide space and time for students to grapple with their formative STEM understandings as they engage in engineering design (Wendell et al., 2016; Wendell et al., 2019), in ways that benefit both students and teachers (Guzey & Aranda, 2017; Haverly et al., 2018; McFadden & Roehrig, 2019). This means offering students regular opportunities for reflection, decision-making, and feedback around their collaborative and rapidly evolving design ideas throughout the design process (Rahman et al., 2019). Yet, research focused on understanding *when* and *how* elementary teachers provide and respond to student design feedback throughout the design process is lacking. This study aims to investigate elementary teachers' instructional strategies across classrooms for affording students opportunities to reflect upon and assess their engagement in planning, testing, and evaluating their formative design solutions as they engage in an elementary engineering design task focused on sound.

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Literature Review: Elementary Engineering as Responsive Teaching

At the heart of this study is elementary teachers' capacity to enact responsive science teaching (Ball, 1993; Hammer & vanZee, 2006; Gotwals & Birmingham, 2016; Robertson et al., 2016; Watkins et al., 2018; Wendell et al., 2016; Wendell et al., 2019). A responsive approach to teaching requires teachers to adapt, discover, and execute instructional moves in response to student thinking (Robertson et al., 2016). In this approach, teachers initially elicit students' ideas about a particular phenomenon (Gotwals & Birmingham, 2016). From there, the teacher's role is to support students' engagement and attend to and/or take up students' thinking by building on their ideas and encouraging engagement in discourse that demonstrates their capacity to reason, evaluate, and optimize their understanding (Wendell et al., 2016). Teachers may, for example, invite students to assess one another's ideas, draw connections between students' ideas themselves, encourage students to design and conduct experiments to test their ideas, or develop a plan for a design solution that takes up a student's question (Jordan, 2014; Rahman et al., 2019; Wendell et al., 2019; Yilmaz & Daly, 2016).

Considerable attention has been given to the practices of responsive teaching, including 'attending and responding to student thinking' among 'high leverage' or 'ambitious' practices (Ball & Forzani, 2009; Capobianco et al., 2018; Lampert, et al, 2010; Thompson et al., 2013; Windschitl et al., 2012;). Scholars established four high-leverage core practices centered around the contextualization, elicitation, and interpretation of students' ideas that include: (i) constructing the "big idea", (ii) eliciting students' ideas to adapt instruction, (iii) helping students make sense of material activity, and (iv) pressing students for evidence-based explanations (see Grossman, 2018; Thompson et al., 2016; Windschitl et al., 2018). Together, these practices serve to foster student reasoning and the creation of evidence-based claims through engagement in collaborative inquiry (Braaten & Sheth, 2017).

In this study, we draw from the work of Windschitl et al. (2012, 2018) on ambitious science teaching to identify and document the instructional power of ambitious practices in the context of engineering design-based science instruction. Ambitious engineering design-based science teaching serves multiple instructional goals, such as fostering productive scientific discourse and argumentation, promoting participation in science and engineering practices, and enhancing students' conceptual understanding (Capobianco et al., 2018). Science teachers, specifically elementary teachers, balance a range of instructional goals, and they select and foreground ideas and activities for a variety of reasons (Capobianco, 2014; Clandinin & Connelly, 2000; Thompson et al., 2013;), not always because of their substance and connection to disciplinary ideas and practices (Capobianco et al., 2020). In this study, we aim to uncover the different types of instructional activities teachers employ that support and optimize students' ideas through engineering design feedback.

Methodology

Research Goal

Our main research question was the following: What kinds of instructional moves do elementary teachers employ to support and optimize students' ideas through engineering design feedback? As elementary teachers begin to plan for, select and prioritize core disciplinary ideas, cross cutting concepts, and science and engineering practices, consideration must be given to the instructional moves teachers will make in an effort to meet these dimensions. Underpinning the convergence of these dimensions is the larger goal of maximizing student engagement in science through engineering design. Hence, the instructional moves teachers make indicate the different trajectories teachers may take to meet the larger of goal of enhancing student learning through design feedback.

Sample and Data Collection

The context of this study is a large, multi-year, school and university, math and science partnership called the *Science Learning through Engineering Design (SLED) Partnership* (see: sledhub.org). The primary goal of the partnership is to improve student science learning in grades 3-6 using engineering design and support teachers through a content-rich, interdisciplinary, STEM university faculty-supportive professional development program. Teachers participate in an intensive two-week summer institute (~80 contact hours) focusing on the integration of engineering design in the elementary/intermediate school through immersion in and collaborative development of design experiences. University STEM faculty assist teachers by immersing the teachers in authentic design experiences. As a result, teachers prepare multi-day implementation plans, formative reflections on implementation expectations and anticipated challenges, and proposed action plan to address challenges in their own classrooms (Capobianco & Rupp, 2014). Teachers spend the following school year implementing two or more design experiences while chronicling their lived experiences through online reflections and semi-structured interviews. During times of implementation, members of the research team conduct classroom observations on teachers' enactment of these design tasks (e.g. classroom organization, instructional activities used, time spent per phase of engineering design) and provide teachers with support as needed (e.g. resources, advice). Team members then schedule follow-up meetings with the teachers designed to gather feedback concerning their implementation of design tasks, as well as their broader experiences with the partnership.

The current study utilizes data gathered in years three and four of the partnership that center on two third grade teachers' enactments of a single engineering design task. Carol and Patty (pseudonyms) were third grade teachers in the same suburban elementary school with seven years of teaching experience. Both teachers joined the partnership in its first year and served as active participants for the duration of the project. The composition of their respective third grade classrooms mirrored that of the school demographics: 67% White Caucasian, 17% Hispanic, 10% African American, 6% Multi-racial.

The third grade task featured in this study is entitled Musical Instrument (Merwade et al., 2013). The goal of this task is to design, construct, and test a musical string instrument that can produce a pattern of three different pitches. The task's storyline involves a rock band needing help with developing a prototype of a string instrument that was damaged during travel. The science big ideas include energy and energy transformation with attention to the crosscutting concepts of cause and effect as well as energy and matter (NGSS Lead States, 2013). Students worked in teams using different materials including cardboard boxes, balloons, rubber bands, string, tape, cups, and plastic wrap to create their instruments.

Data were gathered multi-day classroom observations. Classroom observations entailed detailed field notes of types of classroom organization, time spent during different design phases, teacher moves and questions, and levels of student engagement. Researchers conducted classroom observations from the beginning to the end of the implementation of the design task.

Analyzing of Data

Data were analyzed using open coding and event mapping of teachers' implementations of the design task from start to finish. Event mapping serves as a timeline of teachers' implementations and represents a visual illustration of teachers' enactment of a given design task (see Appendices A & B; Capobianco et al., 2018). Observation data were analyzed using open coding (Creswell & Creswell, 2017). This involved reading and re-reading of the observations with a focus on when and how teachers' provided opportunities for feedback throughout the design process. Observations were coded independently by the researchers who then met to review codes and establish interrater reliability (IRR = 90%) (Saldaña, 2015).

Classroom Observations

Researchers observed and recorded teachers' instructional activities, classroom organizational structures, students' level of engagement, and design process codes (see Capobianco et al., 2018 for full list of codes; Appendices A & B for a legend). Observers met weekly to clarify these codes (Saldaña, 2015) that emphasized teachers' verbal and physical classroom practices. Instructional activities were denoted by codes such as "HANDS" for teachers engaging students in hands-on activities such as constructing and testing their prototypes, "INSTR" for when they gave instructions to students, and "DISC" for when teachers facilitated classroom discussion. These were purposeful activities implemented to engage and guide students as they moved through the design process.

Classroom organization codes denoted how students were situated as they engaged in design: "I" for individual work, "G" for group or teamwork, and "WC" for whole class. Design process codes represented which design phase a teacher was in at a given time in the design task (e.g. "PS" for problem scoping, "PL" for planning, "TEST" for testing, "AN" for analysis, "COM" for communication, and "RD" for redesign). Design phases represent cycles of: information gathering (PS), solution formulation (PL), solution production and performance (TEST, AN), communication and documentation of results (COM), and optimization (RD) (Capobianco et al., 2018).

Findings / Results

To answer the first research question, we deconstructed Carol and Patty's implementations of the Musical Instrument design task into their constituent pieces (classroom organization, instructional activities, time spent per design phase). Results from classroom observations indicated the following: (i) teachers employed a suite of instructional moves aimed at leveraging student engagement and design feedback, and (ii) how these practices were used across the design process served to support diverse types and opportunities for students to gather and provide design feedback. First, we provide a macro view of how teachers employed instructional activities supportive of design feedback. Then we present a micro view by using vignettes of interactions the teachers had with students during key phases of the design process to highlight exemplars of how elementary teachers deliberately foster student design feedback.

Instructional moves promoting feedback

Teachers integrated two distinct approaches to promoting design feedback: 1) how they organized the students during different phases; and 2) what moves teachers enacted during these phases. Teachers utilized similar classroom organization and instructional activities. Both Carol and Patty arranged students in groups or teams ("G"; 59%), followed by individually ("I"; 25%) and as a whole class ("WC"; 17%).

Carol and Patty also employed a similar set of instructional practices that allowed for continuous feedback between teachers and students. They instructed students to use design notebooks (NB; 32%), hands-on activities (HANDS; 29%), and engaged students in class discussions (DISC; 27%); activities that allow for the elicitation, exchange and exploration of students' ideas, from sketching and discussing their prototypes to building, testing, and evaluating their design solutions in teams or as a whole class (Rahman et al., 2019). Teachers additionally asked students to read (READ; 10%) and gave direct instructions (INSTR; 1%) when introducing the Musical Instrument design task.

Structuring feedback during design

We compared teachers' events maps and identified when during design, teachers employed discrete instructional activities and how these instructional moves facilitated design feedback (Figure 2). During the initial phase of problem scoping (PS), Carol and Patty employed more teacher-directed instruction such as reading (READ) and giving instructions (INSTR). As Carol and Patty moved students to plan (PL) their musical instruments, students engaged in notebooking (NB) and discussion (DISC). These activities involved students planning, sketching their designs and then sharing and gathering feedback from their peers and teachers.

During phases of constructing (CON) and testing (TEST), teachers utilized hands-on activities (HANDS). Students worked in teams to construct and test their prototypes while Carol and Patty took on the role of facilitators, providing verbal feedback as needed. Teachers employed discussion (DISC) throughout the phases of analysis (AN) and communication (COMM), allowing for feedback as students evaluated and communicated their performance results. They again utilized a combination of notebooking (NB) and discussion (DISC) to guide students' through redesigning (RD) their prototypes.

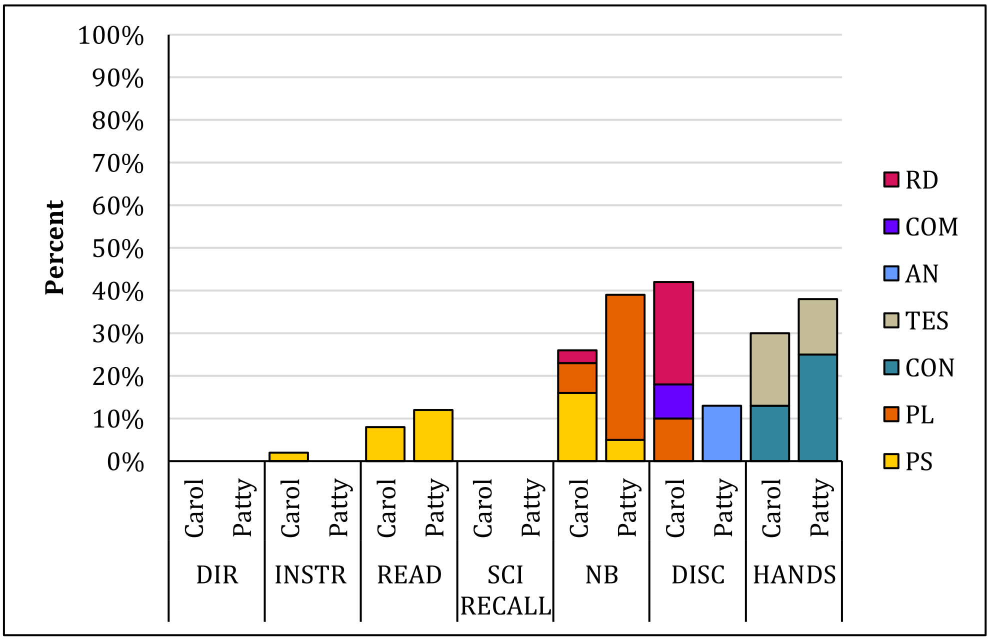

Figure 1. Use of instructional activities throughout design, by teacher

Overall, Carol (n = 205 minutes; 4 lessons) allotted significantly more class time for the task than Patty (n = 120 minutes; 2 lessons). Carol also engaged students significantly more often in discussion (DISC) and did not move through the design phase of analysis (AN). We speculate that spending less time analyzing results was indicative of Carol's recognition of the nature of the task itself, whereby students' prototypes either "worked" or "did not work". Simply put, students' instruments met the criteria (e.g. produced three pitches) or did not, an aspect of the task that may lead to less time analyzing results than a design task with a wider range of outcomes. In contrast with Carol's use of discussion, Patty instructed students to work more often in their notebooks (NB). While Patty did spend time facilitating the analysis of students' designs, she did not engage the students in redesign. Notebooking and discussion offered different ways of integrating feedback, from more asynchronous (notebooking) to more real-time and immediate (discussion).

These trends were further supported by patterns in teachers' classroom organization (Figure 3). Students alternated from working individually to collaboratively in teams (e.g. during individual and group planning). Working in design teams offers students ongoing sources of peer and teacher feedback, specifically as they move from problem scoping to creating and testing their designs (Rahman et al., 2019). Teachers in this study addressed students individually (I) and as a whole class (WC) more often during problem scoping (PS) and planning (PL) at which point they both shifted to organize students into small groups (G). Percentages reflect teachers alternating between multiple forms of classroom organization during the same design phase (e.g. "G and WC"); hence, frequencies, in some cases, totaled over 100%.

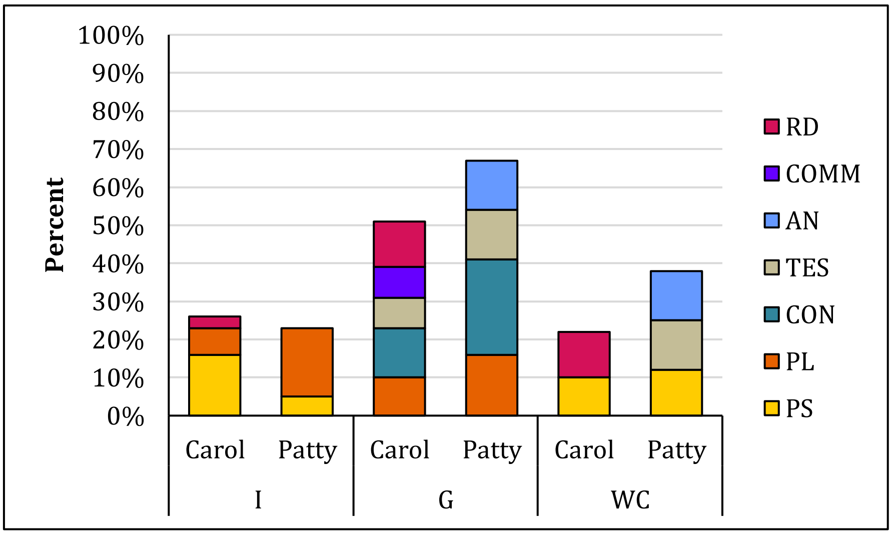

Figure 2. Percentages of classroom organization throughout the design process, by teacher

Types of feedback

When we examined individual classroom teachers' enactment of design-based pedagogies, we noticed interesting moves teachers made that supported productive student feedback. Carol and Patty demonstrated productive attempts at eliciting student feedback primarily during whole class discussions and during team planning, constructing, testing, and/or communicating (presenting their designs). What follows are brief excerpts from transcripts of classroom observations that serve as exemplars as sites of student design feedback.

Targeted yet supportive team feedback

During class session #3, Carol's third graders were constructing their musical instruments using cardboard boxes, rubber bands, string, and additional materials. Carol actively walked around the room and checked in with each design team. She asked questions, such as: "Does this design meet the criteria? Is your team meeting the client's needs? How is your team working within the constraints?" We refer to this as anchoring (see Capobianco et al., 2018). As the students completed construction, we observed Carol make a deliberate instructional move that encouraged students to engage in feedback.

Teacher: *I see some of groups are finished or almost finished. Once you are done, I want your team to sit and talk with another team. Share your prototype with the other team and ask one another: Did we meet the criteria? What do you like about our design? What is one thing we need to work on?*

Here Carol purposefully instructs students to *share ideas* to gather feedback. Students are encouraged to determine if the team has met the criteria; place a value another team's design; and suggest a way to optimize the design. This instructional move is designed to encourage teams of students to interact rather than a whole class. Students start to move away from the tables and gather together. The following is an exchange between two teams.

Team #1: *So, we just used a Kleenex box that has two rubber bands attached. There are two different sounds because of the two different lengths of the rubber bands. (Student plucks each rubber band)*

Team #2: *Yeah…but don't you have three different sounds. Remember the criteria was three different pitches. What are you going to do for a third sound?*

Team #2: *We used three different balloons. One is really fat, the other is not as fat, and the last one is skinny. Maybe you need to think about another rubber band but maybe a really fat one?*

Team #1: *Yeah, we talked about it and we know we need another rubber band, but we didn't have enough time to finish. Because two of them are different lengths, we were thinking about adding another one that was even longer.*

Team #2: *That might work really well…where could you put the last rubber band?*

Here we observed a student from Team #2 provide targeted feedback that identified an immediate flaw to Team #1's design. Instead of waiting for a response from Team #1, a student from Team #2 shares her team's design while suggesting a way to improve Team #1's design. Though Team #2's feedback was direct, it appeared to confirm for Team

#1 that there design did not yet meet the criteria and provided space for Team #1 to share their idea for addressing the design flaw. Team #2 also appears to see the potential is Team #1's re-design.

Constructive and distributed whole class feedback

On the second of two extended class sessions, Patty's third grade students gathered together as a whole class to present their designs. What follows is an exchange among students as they presented their prototypes.

Teacher: *Okay…which team is going to go first? Now…remember…we are going to listen and watch their presentations then ask questions. This is your team's chance to give and to get feedback on your designs. Tomorrow, we will use this feedback to re-design. You will need to be patient if you are not presenting…Roger…your team can go first…*

Student A: *We made a guitar and we put these strings as strings.*

Student B: *Are the strings the same size or width?*

Teacher: *Good question, Beth?*

Student A: *No…they're different. (Plucks each string)*

Student C: *Do it again…I only heard two.*

Student A: *We had to cut the strings in half.*

Teacher: *Class…why do you think the team needed to cut the strings in half?*

Student D: *It looks like you were trying hard to keep it from folding in half.*

Student A: *Yeah…we tried.*

Teacher: *Are there any other questions?*

Student D: *I looked at your design notebook and there were neat sketches there. Was this your original design?*

Student A: *Yeah…we all wanted to do a guitar.*

Teacher: *Class…how many think the team met the criteria? (About half of the class raises their hands).*

Teacher: *What kind of suggestions do you have for this team?*

Student B: *I like the idea of a guitar…I think you might want to add another string and make it really tight.*

When Patty inventories the class about why the team cut the strings, she is not only *distributing the participation* among other students in class, but also *pressing for an explanation*. This results in a student from another team *confirming* for the team that cutting the strings were out of necessity. When Patty encourages others to ask questions, student D inquires if the team's original ideas aligned with their final design. This provides space for the team to affirm their conceptual to actualized design solution. By polling the class about the criteria and encouraging suggestions, Patty continues to *elicit student ideas*.

Discussion

Findings revealed design feedback as both: (i) linked to the teachers' use of instructional moves, and (ii) connected to the nature of engineering design. While Carol and Patty employed similar instructional strategies, the frequencies and instances when they utilized these approaches varied across the engineering design process, and they each appeared to support design feedback in different ways.

Instructionally, Carol and Patty employed several strategies that allowed for constructive feedback throughout the design process. These included engaging students with sketching and later reflecting in their notebooks as they designed and deliberated over their prototypes. The teachers also arranged students in teams to construct, test, and evaluate their designs. Organizing students in teams aligns with the social nature of engineering by fostering collaborative ideation (Bucciarelli, 2001; Lawson & Dorst, 2013; Valkenburg & Dorst, 1998), decision-making (Fortus et al., 2004; Razzouk & Shute, 2012), and reflection using design language (Adams et al., 2003; Adams et al., 2011; Aranda et al., 2018; Wendell, Wright, & Paugh, 2017). These choices allowed for frequent discussion and feedback to occur among students as they grappled with their formative understandings and reasoning about new science and engineering concepts (Rahman et al., 2019). Using hands-on activities meant students were able to apply and test their new knowledge as they built and optimized their prototypes (Wendell et al., 2019).

These instructional approaches represented purposeful and diverse methods of eliciting and leveraging students' understandings (Grossman, 2018; Thompson et al., 2016; Windschitl et al., 2018). Evaluating students' designs in real-time versus after the task was completed offered very different opportunities for Carol and Patty to gather and provide feedback to students. Patty, for example, used discussion (DISC) to poll the class for their ideas as she engaged students in analyzing their results (AN), encouraging students to share or exchange feedback on their designs. Carol, on the other hand, encouraged feedback as teams of students planned solutions (PL). Carol also spent significantly more time engaging students with the task than Patty, which could have also contributed to differences in opportunities for feedback (Capobianco et al., 2018). The junctions between teachers' instructional strategies and classroom organization are important to consider as teachers learn to implement and assess students' engagement in design.

Results also revealed feedback as naturally occurring across the engineering design process (Daly & Yilmaz, 2015; Yilmaz & Daly, 2016). Engineering design requires students to work together over time to grapple with and optimize their design solutions (Brophy et al., 2008; Pleasants & Olson, 2019). As such, engaging in design reflects a series of decisions (Batrouny, 2019; Dias & Blockley, 1995; Fortus et al., 2004; Roozenburg & Dorst, 1998) and an ongoing appraisal of the design problem and possible solutions (Dorst & Cross, 2001; Dorst, 2011). In essence, each phase of problem scoping, planning, testing, and evaluation presents multiple opportunities for feedback to occur. Thus, feedback is embedded within the nature of engineering (Karatas et al., 2011). This is not to suggest teachers' practices cannot affect students' engagement and opportunities for design feedback, but rather that design intrinsically presents opportunities for engaging with feedback (Bjorklund et al., 2004; Darling & Daniels, 2003; Eekels & Roozenburg, 1991; Lewis, 2006; Vinck, 2003). Findings from this study instead indicated a shift in the role of the teacher from a guide to a facilitator, allowing space for diverse solutions and rich discourse among students (Boud & Molloy, 2013).

Closely examining teachers' exchanges with students also showed similarities and differences in their integration of feedback, as well as different *types* of feedback connected with teachers' classroom organization. Carol focused on gathering and providing team-based, supportive feedback. Through close interactions with student design teams, she was able to support small groups of students and promote diverse design solutions, while still anchoring students in the design parameters (e.g. constraints, criteria). Patty, on the other hand, focused more on gathering and providing whole-class feedback. Whole-class interactions allow teachers to elicit and gauge students' understandings all at once and modify their instruction as needed (Windschitl et al., 2018), as well as to distribute feedback among students (Wallace & Loughran, 2012). Both types of feedback offer valuable insights into students' reasoning and understandings as they engage with engineering design (Wendell et a., 2016), as well as teachers' beliefs about how to best support their students' acquisition of engineering knowledge and engagement in design (Borrego et al., 2013).

Conclusion

The current study explored how and when third grade teachers integrated opportunities for student design feedback throughout the design process. Results indicated that teachers employed a suite of ambitious features that facilitated student feedback, and that these varied between teachers. The use of hands-on activities, notebooking, and discussion through students' planning, testing, and evaluation of design solutions offered several entry points for students to engage in individual and peer assessment.

Elementary teachers' use of ambitious practices may contribute to variation in the quality and frequency of design feedback. For example, team planning might be an ideal phase for students to engage in reflection and reasoning with their designs and for teachers to elicit student ideas and press for explanations (Wendell et al., 2017). Likewise, teachers may explicitly structure feedback through the use of curriculum materials such as graphic organizers or feedback forms (Rahman et al., 2019). As illustrated through our results, engineering design is an adaptable process that presents instances when feedback is more likely to occur (Hynes, 2012).

While somewhat inherent to the design process, design feedback offers teachers important indicators of students' needs and how to best support them as they work together to produce design solutions. Within the context of responsive teaching, it presents teachers with tangible anchors for noticing, interpreting, and supporting three-dimensional learning, and thus needs to be purposefully considered and integrated into the science curriculum.

Recommendations

Elementary teachers need access to professional learning that emphasizes areas of feedback throughout the design process and how teachers may capitalize upon these to enhance student engagement in design. This means modeling different types and methods of design feedback that can be used to elicit and leverage students' ideas and reasoning and when they can be effectively employed. Learning when and how design feedback may occur could, in turn, improve teachers' ability to notice, interpret, and respond to students' design progress.

Likewise, more research is needed to understand teachers' scaffolding of design feedback throughout the design process and how this relates to students' science understandings. By studying the relationship between teacher design feedback and student science learning, researchers can identify the practices necessary to promote proactive feedback that increases student science achievement.

Limitations

There are several limitations to the study to consider. First, this study focused on the implementation of design experiences across two teacher classrooms. Data collection across multiple grade level classrooms may make the results more generalizable. Second, the context of the study included a limited description of teachers and students. Attention needs to be given to acknowledging and bridging students' cultural nuisances as science learners with the teachers' instructional goals and strategies for science instruction. Lastly, this study emphasized the resultant actions of the teachers. Further research is needed to explore how these teachers' pedagogical actions influenced students' learning of science through design.

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Appendix A

Event map for Carol's iteration of the Musical Instrument design task

Time (1 minute intervals)															
Session 1															
Anchoring															
L1	WC	WC	WC	WC	WC	WC	WC	WC	WC	I	I	I	I	I	I
L2															
Activity	READ	READ	READ	READ	INSTR	INSTR	INSTR	INSTR	INSTR	NB	NB	NB	NB	NB	NB
Anchoring															
L1	I	I	I	I	I										
L2	NB	NB	NB	NB	NB										
Activity															
Session 2															
Anchoring															
L1	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	I	I
L2															
Activity	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	NB	NB
Anchoring															
L1	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
L2															
Activity	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
Anchoring															
L1	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
L2															
Activity	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
Anchoring															
L1	I	I	I	I	I	G	G	G	G	G	G	G	G	G	G
L2															
Activity	NB	NB	NB	NB	NB	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G					
L2															
Activity	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC					
Session 3															
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
L2															
Activity	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G/WC	G/WC	G/WC
L2															
Activity	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS
Anchoring															
L1	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC
L2															
Activity	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	DISC
Anchoring															
L1	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC	G/WC
L2															
Activity	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC

Session 4															
Anchoring															
L1	I	I	I	I	I	I	G	G	G	G	G	G	G	G	G
L2															
Activity	NB	NB	NB	NB	NB	NB	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
L2															
Activity	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
L2															
Activity	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC
Anchoring															
L1	G	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC
L2															
Activity	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC
Anchoring															
L1	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC					
L2															
Activity	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC					

Legend:

Design Phase	Problem Scoping	Planning	Constructing	Testing	Analyzing	Redesign	Communication
Color Legend							

Classroom Activity	Directions	Instruction	Reading	Scientific Recall	Notebooking	Discussion	Hands-on
Code	DIR	INSTR	READ	SCIR	NB	DISC	HANDS

Classroom Organization	Individual	Group	Whole Class
Code	I	G	WC

Anchoring	

Appendix B

Event map for Patty's iteration of the Musical Instrument design task

Time (1 minute intervals)															
Session 1															
Anchoring															
L1	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	I
L2															
Activity	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	READ	NB
Anchoring															
L1	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
L2															
Activity	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
Anchoring															
L1	I	I	I	I	I	I	I	I	I	I	I	G	G	G	G
L2															
Activity	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
L2															
Activity	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
Session 2															
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
L2															
Activity	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
L2															
Activity	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
L2															
Activity	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS	HANDS
Anchoring															
L1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
L2															
Activity	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC	DISC

Legend:

Design Phase	Problem Scoping	Planning	Constructing	Testing	Analyzing	Redesign	Communication
Color Legend							

Classroom Activity	Directions	Instruction	Reading	Scientific Recall	Notebooking	Discussion	Hands-on
Code	DIR	INSTR	READ	SCIR	NB	DISC	HANDS

Classroom Organization	Individual	Group	Whole Class
Code	I	G	WC

Anchoring	