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It's Not a Perfect Thing: Facilitating an Independent Engineering Fair with Fifth Grade Students

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ABSTRACT

Elementary science education calls on teachers to facilitate student learning of the content of science while they engage in the work of scientists. Additionally, recent national and state standards incorporate the practices of engineering into science education throughout grades K-12. However, many practicing teachers receive little to no professional development related to this shift in educational practice for the science classroom. To exasperate the issue, elementary teachers are generalists by nature without content or practical expertise in science and engineering content or practices. This study investigated how two fifth-grade teachers experienced co-facilitating an independent engineering fair with their students. The findings from this study can inform the ways in which teacher educators can support the incorporation of authentic engineering practice in the elementary classroom.

KEYWORDS

elementary, engineering, science, engineering teaching self-efficacy, teacher experience

Elementary teachers face significant challenges when incorporating engineering instruction into the science classroom (Moore et al., 2015). Recent national standards incorporate the practices of engineering into science education to facilitate students' learning of the content of science while they engage in the work of scientists (NGSS Lead States, 2013). However, many practicing elementary teachers have received little to no pre-service or inservice professional development related to this shift in educational practice for the science classroom (Banilower et al., 2013; Pleasants, et al., 2020; Sun & Strobel, 2014). To exasperate the issue, elementary teachers are generalists by nature without content or practical expertise in science and engineering.

This study relies on teacher interviews and research team memos to describe the ways in which two fifth grade teachers' thinking about and knowledge of science and engineering teaching practices, teaching engineering self-efficacy and outcome expectancy, and relationships with student learning emerge and shift through a grade-level, co-facilitated independent engineering fair (IEF) project. We ask:

1. How do Janet and Jessica describe the experience of facilitating an IEF fair with their students?
2. In what ways are teaching engineering self-efficacy and outcome expectancy influenced and described through the lived experiences of Janet and Jessica?

BACKGROUND

This work is informed by a constructivist understanding that teachers' lived experiences inform what they know and what they do. This foundation centers much of what teachers learn around the experiences that take place daily in their classrooms. While teachers bring into their teaching practices past learning and lived experiences, what happens with students in the classroom adds to the depth and complexity of their pedagogical content knowledge (PCK). Therefore, investigating a particular aspect of teaching (such as engineering teaching practices) is best informed when taken in consideration with the experiences of the teacher within the context of the classroom and alongside the learners (Sun & Strobel, 2014). To that end, the research team (Kelly and Annie) worked in

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collaboration with the instructional team (Janet and Jessica) to construct stories of experience throughout the facilitation of an independent engineering fair with fifth grade students.

Teaching Engineering

Engineering, as defined by the Framework for K-12 Science Education, means “any engagement in a systematic practice of design to achieve solutions to particular human problems” (NRC, 2012, p. 11-12). For students in third through fifth grade, engineering practices focus on defining problems within given constraints, researching and considering multiple solutions, and working to improve or optimize proposed solutions (NGSS Lead States, 2013). The primary step to incorporating the practices of engineering in the elementary classroom relies on teachers understanding the value of and opportunities for engineering in elementary education (Estapa & Tank, 2017; Guzey et al., 2014). However, previous work has shown that elementary teachers approach engineering teaching with a lack of experience, anxiety, and limited outcome expectancy related to the incorporation of engineering-based tasks in their instruction (Cunningham, 2008). While arguments for the inclusion of engineering practices are well-supported by intentions to improve the 21st century skills of students and increase student performance and interest in science, technology, engineering, and mathematics (or STEM) fields (Moore et al., 2015), curricular and professional support for educators is not wide-spread nor well-established in most districts.

Engineering tasks can highlight student-centered collaborative problem-solving through authentic tasks rooted in scientific content and the processes of engineering design (Cunningham & Lachapelle, 2014). However, it is important that as engineering is incorporated into the classroom, it is not presented as stand-alone tasks or events but instead is integrated into and supported by the science curriculum (Moore et al., 2015). This requires from teachers a deep understanding of both the nature and processes of engineering as well as scientific content. To support the inclusion of engineering into the elementary classroom, teachers need to see students struggle through the engineering process (Lesseig et al., 2016), experience authentic problems themselves that are appropriate for engineered solutions by students (Guzey et al., 2014; Sun & Strobel, 2014), and feel confident that the practices of engineering can enhance science content (Estapa & Tank, 2017; Guzey et al., 2014).

Teaching Engineering Self-Efficacy

Self-efficacy is related to a person’s conception of their ability to successfully accomplish a task. Outcome expectancy describes the outcomes of the task (Bandura, 1977, 1986). When self-efficacy and outcome expectancy are applied to the task of teaching, teacher efficacy is a teacher’s belief in their ability to affect change in student learning (Guskey & Passaro, 1994). While there are extensive studies that investigate the general or science-specific self-efficacy of teachers, only recently have scholars begun to examine their engineering self-efficacy (Coppola, 2019; Hammack et al., 2017; Nesmith & Cooper, 2019; S. Y. Yoon et al., 2013). Findings indicate that intentional focus on engineering teaching practices in pre-service development (Coppola, 2019), long-term professional development (Hammack et al., 2017; Nesmith & Cooper, 2019), and extended partnerships with engineers in the classroom (Estapa & Tank, 2017) can support teachers’ incorporation of the practices of engineering in the elementary classroom.

In the design and validation of the Teaching Engineering Self-Efficacy Scale (TESS), Yoon and colleagues (2014) identified five potential factors that define teaching engineering self-efficacy. These factors included engineering content knowledge self-efficacy, instructional self-efficacy, engagement self-efficacy, disciplinary self-efficacy, and outcome expectancy (Yoon et al., 2014). Deconstructing teaching engineering self-efficacy into these factors can help to identify the particular ways in which teachers may excel or require additional support in incorporating engineering instruction.

Teacher Narratives

Teacher narratives can provide an understanding of teachers’ beliefs, knowledge, and experiences (Carter, 1993; Conle, 2000; Connelly & Clandinin, 1990; Drake, 2006). Allowing the space for Janet and Jessica to tell their own stories of experience provides an opportunity for the reflected on and retold lived experiences to reveal novel understandings for both the researchers and the storytellers themselves. Reconstructing the stories of teacher experiences through a collaborative partnership of practitioner and researcher, we reveal the stories of participant teaching and learning merging with the story of the researcher “holding possibilities for both researchers and teachers and for those who read their stories” (Connelly & Clandinin, 1990, p 12).

METHOD

At the end of the spring semester of 2019, Kelly (university science education faculty) and Annie (science education doctoral student) partnered with Janet, Jessica and their colleague (not a participant of this study) to co-facilitate an Independent Engineering Fair (IEF) with 90 fifth-grade students at Chapparal Elementary (pseudonym). Chapparal Elementary educates 513 students in a suburban setting the central United States. Janet has 16 years of teaching experience in fourth and fifth grades. Jessica has 14 years of teaching experience in second through sixth grades. The participants for the project were selected based first on their willingness to facilitate the IEF as fifth grade teachers at Chapparal Elementary and later consent to participate in the research study.

Kelly and Janet imagined the IEF the year prior as a means to expose fifth-grade students to immersive and authentic science learning experiences. While traditional science fairs can provide authentic science experiences for students (Bellipanni & Lilly, 1999; Dionne et al., 2012; Schmidt, 2014), we wanted to avoid the frequent inequities realized in science fair assignments (Carrier, 2006; Magee & Flessner, 2012). It was the goal of the team to mimic, but enhance, an experience similar to a science fair while at the same time incorporating novel practices of engineering.

This manuscript highlights one part of a qualitative, single-case study that investigated how participation in and facilitation of an IEF project can affect perceptions of teaching and learning in the elementary science classroom. The study relied on the partnership of the research team (Kelly and Annie) to act as participant observers, filling the role of support personnel as needed for the teaching team (Janet and Jessica) while they facilitated the IEF project work with their students. Over the course of two weeks, students identified problems, conducted background research, and then worked to design and improve a drawn prototype solution. Students did not complete the engineering design process by building and testing their prototypes, but instead presented their prototype designs and their decision-making process during the grade-level IEF (see Feille et al., 2021a). The IEF allowed students to understand science as a tool for explaining the natural world and positively influenced their perceptions of science and engineering as well as their ability to engage as scientists and engineers (Feille & Wildes, 2021).

Data

The data sources for this study include research team observational notes, memos, and interviews with Janet and Jessica. Field notes (or research memos) serve as an "active reconstruction" of events as viewed through the researcher's lens of experience and expression (Connelly & Clandinin, 1990, p. 5). Semi- or unstructured interviews are used as a means to allow for the situational re-telling of experience by the participant, allowing the researcher insight into the meaning made through lived experiences.

Research Memos

For each 30-minute to one-hour class period where students worked on their IEF projects, Kelly and Annie acted as participant observers. They fielded questions, provided scaffolds and prompts, and discussed class and student progress with Janet and Jessica. During this time, they recorded research notes and memos related to student and teacher interactions and to describe the procedural aspect of the project (see Feille & Wildes, 2021). Additionally, Kelly audio recorded reflective memos after each class period. Each memo was hand transcribed and included in the data for this study.

Teacher Interviews

After student presentations, Kelly conducted interviews with Janet and Jessica via Zoom. Interviews were video and audio recorded and then transcribed by Annie. The semi-structured interviews included questions related to teaching self-efficacy, student outcome expectancy, and the experience of facilitating the IEF. (The complete interview protocol can be found in the Appendix.)

Analysis

Transcribed teacher interviews were analyzed by Kelly and Annie using an eclectic coding approach (Saldaña, 2013). Meaningful units of data within the teachers' narratives were first identified using in vivo (or literal) coding by both members of the research team independently. Each In Vivo code was then re-analyzed and assigned descriptive codes that were identified using the interview questions as well as additional themes that emerged from the data. These codes resulted in three primary themes including Reflection, Students as Science Learners, and Science Teaching. Within each primary theme, sub themes were then identified using secondary and occasionally tertiary descriptive codes (see Table 1). The research team (Kelly and Annie) assigned descriptive codes independently and then reached consensus through multiple research team meetings. Transcribed research memos served the role of triangulating the research team's interpretations of teacher interviews and narratives of experience. Janet and Jessica's narratives of experience as described through their interviews and research team memos were used to construct a single narrative describing the facilitation of the IEF. Janet and Jessica provided member checking for the final narrative by reading their respective constructed narrative. No corrections to research team interpretations were requested or required.

Table 1. Descriptive Codes and Example Data

Code	Example from Data
Reflection	I think the most part is just, uh, reflecting on it and looking back of what can I do to improve upon it (Interview with Janet)
Reflection: Feelings about IEF	Fear, um (laughs and smiles) (Interview with Jessica)
Students as Science Learners	So, a lot of the kids that are super shy and quiet and don't seek out attention all the time, I was really able to make better connections, like relationship wise with them because they were able to show me what they were interested in and what they wanted to learn about (Interview with Jessica)
Students as Science Learners: Student Process	I think what we did was perfect for what they are capable of. Um, I think for a lot of them, they were able to kind of, they got that beginning of information, they looked at it in that research aspect of it. (Interview with Janet)
Students as Science Learners: Contribution to Student Success	And so, being able to tie it back to what they're learning is important. (Interview with Jessica)
Students as Science Learners: Contribution to Student Success: Practices	I think it's important for them to know that it's not a perfect thing. There's mistakes that are made. (Interview with Janet)
Students as Science Learners: Impactful IEF	I think it kind of making these connections, um, into, you know, the stuff we're trying to practice and preach with them about, you know, making mistakes and not everything has to be perfect. It's okay to go back to the drawing board. I think that's important for the kids to see. (Interview with Janet)
Science Teaching	So, I wouldn't say that I was scared of science or bad at teaching science. Like, I like science and I remember loving science growing up, too. So, I wanted kids to like science, too. (Interview with Jessica)
Science Teaching: Teaching Practices	I don't think science can be taught in a text book. I think it's good for reference information, but I think students, especially kids, need to feel, and touch, and see it, and manipulate it and see that things don't always work and you go back and you try it again. (Interview with Janet)
Science Teaching: Teaching Practices: Facilitation	And then there were others that we might have had to hold their hand a little bit. As much `as we could, almost like riding your bike "we're going to hold onto you and help ya, but eventually, you know, you're going to go off on your own (Interview with Janet)
Science Teaching: Teaching Practices: Changes	I feel like, reframing the way I start teaching science at the beginning of the year will be very helpful to be able to do the engineering fair project again next year. (Interview with Jessica)
Science Teaching: Goals	I mean, and at (school) especially, like, working with the service club, and things like that, we try, or at least I try to instill, like making the world a better place. And I think it kind of, this is a perfect example of doing that. (Interview with Janet)

Table 2. Factors of Teaching Engineering Self-Efficacy

Factor	Definition	Example from the Data
Engineering pedagogical content knowledge self-efficacy	Teachers' personal belief in their ability to teach engineering to facilitate student learning, based on knowledge of engineering that will be useful in a teaching context.	I think it's teachable moments in the classroom, um, where, like this is a perfect opportunity of what I've talk about making a mistake or going back or it doesn't work or let's reflect on it. Um, which I think is important for the kids to see. It's not just something they're doing, but it's something that happens in our daily lives as well. (Interview with Janet)
Engineering engagement self-efficacy	Teachers' personal belief in their ability to engage students while teaching engineering	Jessica was still hesitant, kind of stayed back. Would re-read questions, but didn't really offer a lot of input on what she thought students should do. We had a conversation about what her role should be and I encouraged her to just let the students lead the way. (Research memo)
Engineering disciplinary self-efficacy	Teachers' personal belief in their ability to cope with a wide range of student behaviors during engineering activities	I think, I got ways I can improve it next year with them. Um, but from there, going through having the notebook, having the slides where they kind of in put their information was good. I wish, and I think we already discussed this, like there were a couple more people to maybe help out with it (Interview with Janet)
Engineering outcome expectancy	Teachers' personal belief in the effect of teaching on student learning of engineering	We still have the same end result, you know, they learned what I need them to learn. So, figuring that out myself, like it's okay if the end product looks different. That was a big learning (pause) shift for me, too. (laugh) (Interview with Jessica)

Note. See Yoon et al., 2014, p. 479

To describe the teaching engineering self-efficacy of Janet and Jessica throughout the IEF, an additional coding cycle was used. Original In Vivo codes from interviews and research memos were coded using factors of teaching engineering self-efficacy which describe teachers' belief that they can positively affect student learning of engineering (Yoon et al., 2014). These factors include engineering pedagogical content knowledge self-efficacy (the combined factors of engineering content and pedagogical knowledge), engineering engagement self-efficacy, engineering disciplinary self-efficacy, and engineering outcome expectancy (see Table 2). To avoid potential bias, Janet and Jessica were not participants in the analysis of data but did provide member-checking related to the research team's interpretations. To honor their voices throughout the study they have been included as participating authors.

FINDINGS

In their narratives of experience, Janet and Jessica were asked to reflect on their feelings about the IEF, how the IEF project impacted their students as science learners, and their science teaching beliefs and practices. Their stories and the reconstruction of events as told through research memos provide the tools to understand Janet and Jessica's experiences and teaching engineering self-efficacy as influenced by the IEF.

Reflections of Experience

Janet and Jessica reflected thoughtfully on their experiences of facilitating the IEF. Feelings of angst and excitement accompanied their initial approach to the novel teaching practice. As the teacher responsible for bringing engineering into the fifth-grade classrooms at Chaparral Elementary, Janet saw opportunities and felt excited to see how students would engage in the engineering fair. On the other hand, Jessica was apprehensive about her role in facilitating the engineering task, approaching the project with feelings of fear.

> When I first got the packet, and started reading through it, honestly, I was confused. And I was not sure how I was going to be able to facilitate the learning and steer them in the right direction on some of the questions that they had. (Interview with Jessica)

Despite approaching the IEF very differently, both Janet and Jessica reflected continuously about the process throughout and improvements for future iterations. Recognizing that the IEF was "great for the students" and "something everyone can benefit from" (Interview with Janet), encouraged both teachers to consider the ways to work practices of engineering into their science teaching throughout the year. While Janet considered structural and practical changes in approach, Jessica's reflections included revelatory moments recognizing that the variation in end product was a benefit for her students' learning rather than a hinderance and that "giving yourself permission to fail" is important (Interview with Jessica).

Students as Science Learners

When describing the IEF related to their students as science learners, Janet and Jessica focused on the students' process of completing the IEF, the contributions to student success, and their perceived impact of the IEF. Additionally, the affective aspects of the project seemed to be an important feature for both. Jessica saw the experience as a way for her to better understand her students as learners and "make better connections" through her students' "acts of passion" (Interview with Jessica). She also saw this end-of-year experience as something more than "normal end of year stuff" and rather as something she sees her students "talking about for a long time" (Interview with Jessica). Janet viewed the IEF as a catalyst for her students as an experience that "ignites a passion for them with science" where they can build on the experience and see the opportunities to "go beyond the box of science" (Interview with Janet).

Process for Students

The process allowed space for students to connect with Janet and Jessica in new ways because of the students' focus on a problem that was interesting to them, something they were passionate about. Asking students to imagine the possibilities, without relying on the constraints of physically making their prototype, created the space for students to dream big and consider a future as engineers. Additionally, requiring students to work on an independent project not only engaged all students but allowed for the teachers to see the progress and growth of their students as individuals.

> I don't even know if I could even say one was better than the other because I think, for that individual student, they were able to create something. They were able to go through something. And I think, for them, again, like I said, it's that self-discovery that I think is so important for them to see at this level. (Interview with Janet)

Contributions to Student Success

Janet and Jessica emphasized allowing students to follow their individual interests. They contributed student perseverance and engagement with the task to the fact that students had autonomy over the problem they identified to solve. Additionally, due to the timing of the IEF at the end of the spring semester, the teachers were able to help students connect their ideas to science content that they had learned throughout the academic year. By providing opportunities for students to relate their own real problems to content that is often abstract, Janet and Jessica saw students making significant connections to their learning.

Both Janet and Jessica attributed students' success to the school-wide messaging related to persistence and growth mindset. Additionally, students' failures and opportunities to improve their plans were seen as important tools for them to take with them into upper grades and professional life.

> I think it's important for them to know that it's not a perfect thing. There're mistakes that are made. I think that fits along with, especially at [Chaparral] Elementary, with our growth mindset … And you can always go back and redo it. And I think that's important for them to see. (Interview with Janet)

Impact of Engineering Fair

The impact of the IEF on their students was a point of emphasis for both Janet and Jessica. Jessica identified ways that her students had different educational needs to be successful on their project than the other classes. She was able to capitalize on her students' strengths and adjust her expectations to allow them room to succeed. This shift allowed Jessica to feel relieved, but also eased the angst of her students who were struggling. Realizing that, in engineering especially, there are multiple approaches to a problem served as a lightbulb moment for all of them.

> I could breathe a sigh of relief because it finally clicked…I guess, my class was a lot more gray-area than black and white. It's not right or wrong, I want to know what you see. (Interview with Jessica, emphasis in speech)

Science Teaching

Janet and Jessica came into the IEF feeling positive about their role as science teachers and wanting their students to leave their class with an appreciation for science. Both teachers focused on helping students to see and "understand that science is all around us" (Interview with Janet) and tied to "real world things that [students] are seeing today" (Interview with Jessica). They worked, often collaboratively, to find ways to engage their students in the practices of science, moving beyond "open a textbook, read a passage, here's an experiment" to seeing the "rhyme and reason" of science learning (Interview with Janet). Facilitating the IEF allowed both teachers to uncover the ways that engineering supports science content and incorporate the practices of engineering into their teaching of science topics.

Goals

Beyond appreciation, Janet described wanting her students to come away from the project seeing the ways engineering is realized in their everyday life. She hoped to move the processes of engineering out of the abstract and into a realistic possibility for her students. "I think, my goal for them was to broaden their understanding of science. Of engineering. To make connections to their daily life" (Interview with Janet). Additionally, Janet saw the project as a way for her students to realize the opportunities ahead of them to make the world a better place.

> It wasn't just something fun you wanted to do; it was improving life for people. And I think that's what I wanted them to get out the most. I definitely wanted them to learn the engineering design process and things like that but coming back to making something better for other people. (Interview with Janet)

Teaching Practices

The IEF allowed the teachers to reexamine their role in instruction. Focusing on the processes of engineering and helping her students see themselves as "inventors" helped Jessica consider that she is "preparing these kids for problems and jobs that aren't necessarily even there right now" (Interview with Jessica). When the project began Jessica was "scared of the word 'engineer'" but began to recognize that she needs her students to "be these outside the box thinkers to solve these problems that we have," broadening her conceptions of science (Interview with Jessica).

Through the project, the teachers were able to more easily move into a facilitator role rather than a traditional instructor role due to the nature of the individual projects.

> I enjoyed kind of, here's the information and I'm going to facilitate it for you and I'm going to give it to you, but you're going to take as much out of this as you want. I think that was important for me, but I also think for the other teachers. (Interview with Janet)

This shift in practice was different from ways they taught during their science block throughout the year. Because students were involved in individual projects, large and small group demonstrations or lectures related to specific problems or projects were not feasible or warranted. Constraints such as materials and timing were not limiting factors to the pedagogical approach of Janet and Jessica due to when the project began, additional facilitation help from the research team, and the lack of physical manufacturing of student prototypes. Therefore, the teachers were free to scaffold each student as they worked through their projects, focusing on individual strengths and areas for growth. The opportunity to individualize instruction was novel and relied on different pedagogical strengths from the teachers.

Teaching Engineering Self-Efficacy

Janet and Jessica's teaching engineering self-efficacy can be described in relation to their engineering pedagogical content knowledge self-efficacy, engineering engagement self-efficacy, engineering disciplinary self-efficacy, and engineering outcome expectancy as revealed through their individual interviews and the researcher field memos.

Engineering Pedagogical Content Knowledge Self-efficacy

Janet and Jessica's beliefs about their ability to capitalize on their own knowledge of engineering to facilitate student learning was represented throughout the two-weeks of the IEF. While Janet relied heavily on her prior professional development experience and the timeline and planning packet provided to the students, she deliberately scaffolded students through the process. However, Jessica's apprehension in the beginning of the project created space for her to step back and learn alongside her students resulting in a very individualized process (Research memos). Incorporating outside resources such as trade books allowed Jessica and her students to begin to see and capitalize on the connections between engineering (or "inventing") and science learning (Interview with Jessica). Potentially the most important revelation for both teachers and students was the emphasis on the value in failure. The recognition that the process is "not a perfect thing" and making a mistake and reflecting on ways to improve it happens in daily lives, "It's okay to go back to the drawing board" (Interview with Janet).

Engineering Engagement Self-efficacy

Janet and Jessica incorporated much of the same practices of engagement that they relied on for science teaching, which informed their beliefs about their ability to engage students while facilitating the IEF. However, Jessica stressed that she would not have volunteered without prompting from her colleague, she remarked, "I feel like it stretched me even professionally and I realize I can do a lot more with these kids than what I thought I could" (Interview with Jessica). While Janet was excited to capitalize on the encouragement of the district and state standards and incorporate the practices she gleamed from limited professional development (Interview with Janet). Both teachers demonstrated a confidence and ability to move engineering design from an "academic" construct to a process that their students engaged fully in (Interview with Jessica). Jessica's incorporation of trade books about inventors and engineers helped her to change the paradigm for herself and her students that capitalized on her students' creativity within their prototypes (Interview with Jessica, Research memos). Recognizing that her students had unique needs to engage them in the process gave Jessica the permission to break from the structure prescribed and create room for her students to thrive (Research memos).

Engineering Disciplinary Self-efficacy

Janet and Jessica incorporated experiences of guiding independent student work and took advantage of additional facilitators in the classroom throughout the project. Their beliefs in their ability to respond to various student behaviors seemed to relate closely to their individual classroom cultures. Janet was very comfortable to let students move through their project independently and counted on them to come to her when they struggled or were stuck, and many did (Research memo). She took advantage of the structured planning packet for her students but recognized that, for some students, she needed to "hold their hand a little bit…almost like riding a bike" (Interview with Janet). Jessica had multiple students who struggled in ways unique to those in the other classrooms. However, she realized "that it's okay to completely reframe something to fit how my students learn best" and gave herself "the permission and the freedom to allow their learning to happen however they learn best" (Interview with Jessica).

Engineering Outcome Expectancy

Janet and Jessica's personal beliefs in the effect of the IEF on student learning of engineering varied. Janet entered the project with the expectation that the work would be meaningful for her students, perhaps due to her own learning experiences (Research memos). But as the project progressed, she began to acknowledge that the effect of the IEF was more than a class experience and was an opportunity for her students to understand, through going through the process, that there is value in "improving something that's already been done or making someone's life easier" (Interview with Janet). Janet remarked on taking students out of their comfort zone of working with a group or partner and instilling in them the confidence to push through "their own personal feelings about science" with the opportunity to "do what they [want] to do and put in their own thoughts and ideas" (Interview with Janet).

Jessica, once relieving herself from the pressures of "getting it right", helped her students benefit from knowing there is not "right or wrong" and that wherever her students ended up was important. She placed emphasis on the value of the process and that "we did something meaningful [that] they will take with them and remember" (Interview with Jessica). Additionally, the IEF helped Jessica conceptualize the ways to incorporate the processes of engineering throughout the schoolyear, imagining the impact on her future students she said, "I can't imagine the growth I'm going to see next year. I'm really excited about the potential to see more growth" (Interview with Jessica).

DISCUSSION

Janet and Jessica's narratives of experience of facilitating an IEF with their fifth-grade students provides an understanding to the ways in which elementary science educators may implement novel pedagogies in their classrooms, such as teaching the processes of engineering. Personal retelling of the challenges and successes embedded in the two-week project illustrates the ways in which teacher educators can support the pedagogical development of practicing teachers in response to changes in national standards or theoretical approaches to teaching. The ways these two teachers' teaching engineering self-efficacy were influenced by their personal and shared experiences can highlight the changes in teacher identity that experienced teachers face while adapting to new pedagogical demands. Although a small sample size, the narratives of individual experience can provide insight into the experiences of fellow teachers facing similar challenges.

Teacher Experiences

While Janet and Jessica were tasked with implementing the same IEF, in the same school, in classrooms mere feet apart, their individual experiences were unique and meaningful when considering how teachers may incorporate novel pedagogical tools or teaching reforms. Below, their stories of experiences are reconstructed and presented side-by-side in Table 3.

Table 3. Stories of Experience

Janet is a site science leader and before the IEF attended a district-level professional development regarding resources for engineering instruction. She helped introduce the grade-level teachers and students to the processes of engineering through large-group brainstorming sessions and design challenges. Her excitement to implement the IEF fueled her confidence. After helping construct the student resources, she incorporated the student planning packet deliberately. Each day, Janet checked in with her students to align their plans with the planning checklist, identifying those who required individualized attention and inviting others to share their questions, concerns, and ideas freely. As her students engaged with their individual ideas, moving beyond their own science boxes, Janet began to see the ways they could grow from the process. She began to point out to each student how they were improving a process or product, making someone’s life a little better. Janet’s students constructed their presentations of prototype with pride, confident they had met the goals of the IEF. Their new ideas, they knew, could change the world. And as her students shared their work, Janet already was considering the ways to broaden the experience aiming for more impact and more growth in future years.	Jessica values science teaching and finds multiple ways to build science into her students’ experiences including using read-alouds and student-focused media in addition to inquiry-based science experiences. However, Jessica’s only introduction to teaching the processes of engineering came from her colleague, Janet. The multi-page student resource added to her apprehension of implementing the IEF, making “engineering” feel increasingly academic and out of reach. While learning alongside her students, Jessica began to see the ways that the diverse areas of interest and expertise of her students inspired creativity in their work. Inviting in a diversity of approaches, she abandoned the notion of right or wrong and encouraged her students to do the same. Jessica’s students, many of them crippled by similar concerns with getting it right, began to loosen their self-imposed reigns on the process and see themselves as inventors - engineers of the future. Her heightened awareness of the struggles her students faced allowed Jessica to identify alternative avenues for success. Navigating the paradigm shift alongside her students illuminated the ways Jessica would improve her teaching in the future. She felt confident in the ways to help her future students peel back the mystery of engineering processes and situate them in her science teaching practices.

Teaching Engineering Self-Efficacy

Janet and Jessica developed a teaching engineering self-efficacy that was informed by their own learning experiences and further constructed alongside the learning of their own students. Janet’s initial engineering pedagogical content knowledge self-efficacy was informed by limited professional development experiences and Jessica’s by what she learned from her colleague. While Janet brought to the experience an understanding of the nature of engineering and the engineering design process, her pedagogical experience for teaching the processes of engineering was minimal. Through scaffolding her students and also her colleagues through the IEF, she was able to identify the tools and practices that supported teaching the processes of engineering. Jessica’s content and pedagogical knowledge of teaching engineering developed in tandem. By relying on supports from her colleague and the research team and her deep understanding of student needs, she identified the practices that best supported her students as they navigated the IEF.

Engineering engagement self-efficacy corresponded with each teacher’s engineering pedagogical content knowledge self-efficacy. As they both deepened their understanding of the nature of engineering and the pedagogical practices that supported student learning of engineering processes, the ways in which they envisioned their ability to engage their students in the task changed (Guzey et al., 2014; Pleasants et al., 2020; Yoon et al., 2013). Janet entered the IEF informed and confident in her ability to engage her students in the task. Yet, she seemed to strengthen that belief as she identified the ways in which her students were finding the ways they could improve life. It was not until Jessica could see that her students needed to understand the value in embracing failure (therefore embracing her own potential failure) that she seemed to believe that she was able to engage her students in the process. Experiencing the struggle alongside her students contributed to her own self-efficacy.

It is unclear how the teachers’ engineering disciplinary self-efficacy varied from their approaches to classroom culture or management. Both Janet and Jessica demonstrated comfort in allowing students the freedom of individual approaches to the problems posed by the IEF. They embraced classroom noise to varied extents but relied on existing classroom norms of how students worked and requested and received help. Both teachers seem to encourage and value the creativity of their students, and the IEF created an additional space to support student autonomy and creative thinking by capitalizing on the role of failure in engineering (Stretch & Roehrig, 2021).

Most striking regarding Janet and Jessica’s teaching engineering self-efficacy is in relation to their teaching engineering outcome expectancy. By the conclusion of the IEF, both teachers described long-lasting impacts of the IEF on their students. With ambitions to change student perceptions of science, inform course selection and career paths, and encourage students as change-makers, Janet and Jessica were confident they had facilitated an experience their students would remember for years to come. They saw the ways in which all of their students, even those who traditionally struggled, persevered through challenge and complexity to find various ways to be successful (Lesseig et al., 2016). Janet and Jessica had facilitated learning for inventors and engineers, and the next year they had plans do it again.

CONCLUDING REMARKS AND LIMITATIONS

Janet and Jessica did not implement the IEF after a long-term professional development or partnerships with engineers (Estapa & Tank, 2017; Hammack et al., 2017; Nesmith & Cooper, 2019). However, they did engage in teaching engineering with the support of a learning community (Guzey et al., 2014) while witnessing their students struggle through the engineering process (Lesseig et al., 2016), sometimes engaging in that struggle themselves. Their stories of experience contribute to the understanding of the ways in which elementary teachers may incorporate engineering into their science teaching practice. While their situation is unique and not generalizable, their experiences can help teacher educators and administrators support experienced teachers as they incorporate novel teaching practices into their classrooms. Providing Janet and Jessica with the opportunity to identify for themselves the value of and opportunities for teaching engineering for their students as well as the providing the freedom to fail contributed positively to both teachers’ teaching engineering self-efficacy and commitment to engineering teaching throughout their science classroom experiences.

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APPENDIX

Interview Protocol

I'd like to thank you once again for being willing to participate in the interview aspect of my study. As I have mentioned to you before, my study seeks to understand how participation in an individual engineering fair project affects student perceptions of science? and How does facilitating an individual engineering fair project affect teacher perceptions of teaching science? The aim of this research is to encourage the inclusion of individual engineering fair projects for upper-elementary students as a means to improve their perceptions of science and themselves as scientists and to improve teacher self-efficacy in science teaching. Our interview today will last approximately one-two hours during which I will be asking you about your experiences before, during, and after the facilitation of the engineering fair project.

Earlier, you completed a consent form indicating that I have your permission (or not) to audio record our conversation. Are you still ok with me recording (or not) our conversation today?

___Yes ___No

If Yes: *Thank you! Please let me know if at any point you want me to turn off the recorder or keep something you said off the record.*

If No: *Thank you for letting me know. I will only take notes of our conversation.*

Before we begin the interview, do you have any questions? [Discuss questions]

If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.

Questions below are to be used in an open-ended format, probing participant for clarification and elaboration as needed:

1. How would you describe yourself as a science teacher before the engineering fair project?
2. What were your feelings about facilitating the engineering fair project prior to its beginning?
3. What do you think contributes to student success in science learning?
4. What role do you as the teacher play in student success in science learning?
5. What of your own practices do you personally feel contribute the most to student science learning?
6. What moments of the engineering fair project were the most impactful or memorable for you and why?
7. How did facilitating your students work on their own self-determined engineering fair projects influence the way you saw them as science learners?
8. Would you describe yourself as a science teacher differently now after the engineering fair project? If so, in what ways?
9. Did facilitating the engineering fair project for your students change the way you see yourself as a science teacher? If so, in what ways?
10. Is there anything I didn't ask you that you want to tell me about your experience facilitating the engineering fair project?