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This study examines the perspectives of three generations of elementary teachers learning to teach science using engineering design and the risks associated with implementing this innovative type of reform-based science instruction. Data were gathered using semi-structured interviews, classroom observations, and teacher reflections. Data analysis entailed open coding and document analysis. The findings indicated that there were four types of perceived risks: practical, pedagogical, conceptual, and personal. First-generation teachers exhibited conceptual risk-taking behavior, while second- and third-generation teachers reported practical, pedagogical, and personal risks. Benefits of risk-taking included increased student engagement in science, improved self-confidence in teaching science, and greater teacher collaboration across generations. By exploring the experiences of these three generations of teachers, we aim to make transparent the uneven shifts in thinking and practice, and the associated risks elementary school teachers took as they enacted engineering design-based science instruction.

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Recently, considerable national attention has focused on the role of science, technology, engineering, and mathematics (STEM) education in supporting the United States' high standard of living and capacity for innovation. Although much less developed as a school subject than its three STEM counterparts, engineering is gaining ground as a content area in K–12 classrooms (NRC, 2012). The *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) represent strategic efforts to highlight engineering practices as a productive means of learning and using science. According to the National Research Council (2012), students need to actively engage in these practices to understand core ideas in science. For in-service elementary school teachers, this means challenging their existing beliefs about teaching science, as well as modifying existing pedagogical techniques to accommodate more progressive approaches that facilitate creativity, innovation, and persistence in the science classroom (Capobianco, Delisi, & Radloff, 2018; Moore et al., 2014; Roth, 2014). For pre-service elementary science teachers, this requires early exposure to engineering design-based science instruction and appropriate field experiences where they can develop, implement, and test their ideas in classrooms where engineering design-based science instruction is practiced and/or supported (Cunningham & Carlsen, 2014; Radloff & Capobianco, 2019).

Embedded in these anticipated changes is the inevitable expectation that teachers, both in-service and pre-service, will need to take risks in their practice. Risk is frequently defined in relation to ideas of danger, loss, or damage (Yates & Stone, 1992); but on occasion, there have been positive references to accepting a challenge or opportunity to gain, achieve progress, and have new experiences (LeFevre, 2014). For teacher education, risk-taking and change are common themes in areas such as effective school-wide reform (Ponticell, 2009), novice teacher development (Clayton, 2007), and teachers' perspectives on effective instructional leadership (Blase & Blase, 1999). Together, they represent critical components of innovation and change (Jaeger, Renn, Rosa, & Webler, 2001) and are important elements to consider in processes of educational reform intended to improve student outcomes (Beghetto, 2009). Furthermore, teachers and leaders hold theories and beliefs that influence their actions toward risk and risk-taking (Richardson, 1996). Interestingly, relatively little is known about the risks elementary school teachers take in response to new reform, specifically the implementation of innovative science pedagogies and academic standards related to the integration of engineering to teach science.

The current study sought to understand concepts of risk associated with an engineering design-based, professional learning initiative for elementary science teachers. The context of the study is a large-scale, multi-year school and university mathematics and science partnership aimed at improving elementary students' science achievement through engineering design. In this study, we identify the risks elementary science teachers perceive in educational change, wherein they are being encouraged to change their teaching practices. We subsequently distinguish what factors might contribute to their risk-taking actions, as well as the perceived benefits of the risks they take when implementing engineering design-based instruction.

To do so, we present the perspectives of three generations of elementary science teachers learning to teach science through engineering design, and the risks associated with implementing reform-based science instruction. The first generation of teachers comprised two teachers who participated in the partnership at its inception and, consequently, adopted engineering design-based science teaching prior to the onset of the study. The second generation included a teacher who recently joined the partnership and was in her first year of implementation. The third generation was a pre-service teacher who also recently joined the partnership, assisted in summer professional development, participated in an independent study examining teachers' attempts to integrate engineering design-based teaching, and completed her student teaching with the second-generation teacher. By exploring the lived experiences of these three generations of teachers, we aim to reveal the uneven shifts in thinking and practice and associated risks that occurred among these teachers as they enacted engineering design-based science instruction. Taken together, our results suggest that learning to teach science through engineering design provided an opportunity for elementary teachers to take positive, practical risks that they otherwise may not have tried, given existing demands on their current and developing practice.

Conceptual Framework

This study draws from literature on the constructs of risk-taking (Le Fevre, 2014; Yates & Stone, 1992; Zinn, 2008) and teacher uncertainty (Capobianco, 2011; Floden & Buchmann, 1993; Floden & Clark, 1988; Melville & Pilot, 2014) to examine teachers' integration of elementary engineering design-based science instruction. Risk-taking is an inevitable behavior that changes constantly and thereby presents a degree of uncertainty about the future (Le Fevre, 2014). Hence, we position risk-taking and uncertainty analogous to one another and utilize these constructs as a means of explicating teachers' attempts to integrate innovative, reform-based curriculum (engineering design tasks) and associated pedagogies (engineering design-based science teaching).

Teacher Risk-Taking

The concept of risk involves the fear of possible future loss, damage, or threat (Zinn, 2008). An action or event is a risk for people involved if they perceive a potential for the loss of something of value they believe they have. The greater the perceived significance of the loss, the greater the perceived risk. Such losses might be financial, performance related, physical, intellectual, social, or aspirational. Yates and Stone (1992) characterize the three main elements of risk as: (a) loss; (b) the significance of the loss; and (c) uncertainty. Ultimately, change is about uncertainty and risk as the future becomes "suddenly much less secure" (Marris, 1986, p. 148). Therefore, to deal with this uncertainty, risk-taking involves weighing up possible gains and losses (Zinn, 2008).

As such, uncertainty plays a major role in risk-taking and has been examined repeatedly among in-service (Capobianco, 2011; Floden & Buchmann, 1993; Floden & Clark, 1988; Melville & Pilot, 2014) and pre-service (Capobianco & Ríordáin, 2015) teacher populations. Results from these studies have indicated that teachers often express uncertainty due to grappling with insufficient instructional content and practice, consequently provoking doubt, ambiguity, and, in some cases, reservations about her/his teaching abilities and influence on student learning. Alternatively, some studies have indicated that uncertainty can foster increased confidence (Berry, 2004) but can be alleviated through productive collaboration, reflection, and action research among teachers and their peers (Capobianco & Feldman, 2010; Capobianco & Ríordáin, 2015). Underpinning these studies is the simple principle that to enact and build confidence surrounding reform-based science instruction, teachers need to simultaneously embrace uncertainty and develop the disposition to take risks.

Engineering Design and Elementary Science Teaching

Recent science education reform highlights the need for teachers to engage their students in science and engineering as a set of common practices (NGSS Lead States, 2013; NRC, 2012). Engaging in these practices helps students develop a holistic understanding of and appreciation for how science and engineering knowledge is developed and practiced in the real world (NRC, 2012). At the heart of engineering practices is the construct of engineering design: an iterative, interactive process used to solve poorly structured, authentic problems (Daly, Adams, & Bodner, 2012; Lawson, 2018). Engineering design is a contextualized, recursive activity that results in physical and virtual artifacts and processes (Johri & Olds, 2011) and involves multiple phases including: problem scoping and information gathering, idea generation, project realization, communication and documentation of performance results, and optimization (Atman et al., 2007). Underpinning each of these perspectives is the idea that the engineering design process is problem-based, process-oriented, and product-driven (Pahl & Beitz, 2013) and allows for multiple possible design solutions (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004).

In the K–12 classroom, engineering design-based science instruction should reflect these characteristics (Pleasants & Olson, 2019). Students should work to provide solutions to design tasks by identifying problems and generating possible ideas, collaboratively planning and testing their solutions using existing scientific knowledge, evaluating and communicating their findings, and optimizing their original models (Brophy, Klein, Portsmore, & Rogers, 2008). Engineering design-based tasks differ from existing science curricular activities in that: (a) design problems require more complex, student decision-driven responses than typical teacher-guided scientific inquiries (Windschitl & Stroupe, 2017); (b) students must work collaboratively within constraints to develop testable and workable solutions (Johnson, Wendell, & Watkins, 2017; Lottero-Perdue & Parry, 2017; Van Haneghan, Pruet, Neal-Waltman, & Harlan, 2015); and (c) design problems lead to numerous possible solutions (Antink-Meyer & Meyer, 2016). We argue these divergences between design- and inquiry-based science instruction signify areas of risk for teachers learning to adopt engineering design to teach science.

Risks With Adopting Engineering Design-Based Science Instruction

Teaching science using engineering design represents a novel, innovative method of science instruction that requires teachers to alter their current teaching methods (Capobianco, Delisi, & Radloff, 2018; Cunningham, 2008). Consequently, elementary teachers are repeatedly found to be resistant to, and unfamiliar or uncomfortable with, adopting design-based science instruction (Hammack & Ivey, 2017; Hsu, Purzer, & Cardella, 2011; Lee & Strobel, 2010; Liu, Carr, & Strobel, 2009), and instruction has been found to differ between classrooms (Capobianco, 2011; Katehi, Pearson, & Feder, 2009).

Integrating engineering design-based science instruction is "risky" in that it necessitates new knowledge of engineering teaching, learning, and contextualization, as well as design knowledge (Hynes, 2012; McKenna & Agogino, 1998). It also requires that teachers understand how to recognize and adapt their instruction to constantly evolving student engagement in design scenarios (Martin, Baker Peacock, Ko, & Rudolph, 2015), noticing and responding to students' needs in real time while fostering diverse decision-making skills and design solutions (Wendell, Wright, & Paugh, 2017).

Given the nature of these novel instructional demands, it is our contention that when faced with these uncertain demands of design-based science teaching, elementary teachers develop behaviors that involve complex, interdependent trade-offs between the amount of risk a teacher is willing to take, and the benefits associated with those risks. We seek to uncover these perceived risks and the extent to which risk-taking may inform teachers' practice.

Research Questions and Purpose of the Study

This study examines the following research questions: (a) what risks do three generations of elementary school teachers perceive taking when implementing engineering design-based science instruction? (b) to what extent do the perceived risks relate to one another? and (c) what are the benefits expressed by the elementary school teachers as a result of risk-taking? As elementary teachers embark upon the daunting task of learning to teach science using engineering practices, it is important to examine the risks they take and the extent to which these risks impact their practice. Risk and risk-taking are critical components of innovation and change (Jaeger et al., 2001) and are essential elements to consider in processes of educational reform. Equally important is the notion that risk is defined by the context in which it is embedded. Hence, this research aimed to uncover risks expressed by teachers within an elementary school science context, and how teachers developed the empowerment to take risks.

Context of the Study

The context of this study was a large, multi-year school and university math and science collaboration called the Science Learning through Engineering Design (SLED) Partnership. The primary goal of the partnership was to improve student achievement in science through engineering design in the elementary science classroom utilizing a long-term, community-based, and reflective approach to teacher professional development (Lave & Wenger, 1991). The partnership used summer institutes, follow-up sessions, linkages with university pre-service teachers, a cyber infrastructure, and reflective practice to equip teachers with design-based pedagogical skills and science content.

The SLED Partnership consisted of a 2-week, content-rich, intensive summer professional development program developed and facilitated by design teams well-versed in teaching science through engineering design. Each STEM design team consisted of representatives from university science and engineering departments, as well as one elementary classroom teacher. Using academic standards, each design team created, pilot-tested, and implemented two to three engineering design-based science learning experiences each summer. Members of design teams also facilitated a series of half-day follow-up sessions throughout the school year. These networking sessions were designed to help teachers report and reflect on their implementation efforts. Over 90% of the teacher participants (including those profiled in the current study) had little-to-no previous experience with engineering design-based science instruction.

Prior to and after each implementation of design tasks, teachers engaged in a series of hour-long, semi-structured interviews centered on their conceptions and perceptions of engineering design-based science instruction and the SLED Partnership. Teacher participants also submitted multi-day reflections during times of implementation and completed yearly electronic surveys. During implementation, members of the research team performed multi-day observations and offered instructional and curricular support as needed. Partnership school administrators agreed to and encouraged teachers' full participation in the partnership and enactment of engineering design tasks.

Study Participants

This study is unique from the standpoint of its participants and their relationships with one another, their school, and the larger partnership. A sub-sample of four teachers from a larger sample of thirty participating teachers was identified. The participants included two fourth-grade teachers, one fifth-grade teacher, and one pre-service teacher. The sampling criteria of the four teacher participants involved the completion of all research activities and the location of study participants. Participants were located at the same rural school setting and represented three generations of teachers learning to integrate engineering design-based science instruction. Pseudonyms were used to protect the anonymity of three of the four teacher participants.

Cathy and Harold were the fourth-grade teachers. Cathy had over 20 years of teaching experience and Harold had seven years of teaching experience. Both Cathy and Harold joined the partnership at its inception and had 3 years of experience with integrating engineering design during the onset of the study. Hence, Cathy and Harold represented the first generation.

Patricia was a fifth-grade teacher with 4 years of teaching experience. During the course of the study, Patricia had recently joined the partnership and, consequently, represented the second generation.

Annie (third author) was a pre-service teacher during the study and conducted her student teaching in Patricia's fifth-grade classroom. Prior to her student teaching, Annie worked as an undergraduate research assistant during the summer professional development, conducted a review of literature on engineering design in the elementary classroom, and engaged in critical reflection on her development as a science teacher learning to teach science through design. Annie was uniquely positioned as the third-generation teacher in this study based on where she was along her career trajectory and her role in the partnership.

All four teachers were Caucasian and situated in a small, rural school located in the central Midwest. The school enrollment during the course of this study was approximately 476 students. The student demographics were 73% White Caucasian, 16% Hispanic, 5% Multi-racial, 3% African American, and 3% Asian, with approximately 25% free and reduced meals. The racial and socio-economic demographics in the classrooms affiliated with the teachers in this study were representative of the school's overall demographics.

Data Collection

Data were gathered via semi-structured interviews (two interviews/year; total = 22 interviews), teacher reflections (one reflection/design-task implementation; total = 8 reflections), and multi-day classroom observations (total ~40 hours). Additional documents, including teacher-created, multi-day implementation plans served as supplementary data sources. What follows is a brief description of each data source.

Interviews

Each teacher completed a semi-structured interview at the beginning and end of the academic school year. Additional informal interviews were conducted throughout the year as a means of establishing the validity of the data interpretation including member checking and peer debriefing (Lincoln & Guba, 1985). Each interview lasted approximately 45 minutes in length. Examples of interview questions included the following: "What did you learn from the summer institute? How do you plan to implement each design task?" and "If you were to observe another teacher in your building teaching science, how would you know if the teacher was implementing an engineering design-based task?" Additional questions, more specifically related to teacher risk-taking and uncertainty, included one or more of the following: "Describe for me some concerns you may have about implementing a design task. What steps might you take (or have taken) to alleviate one or more of these concerns?" and "Teaching science through engineering design is quite new for many teachers, which suggests that teachers will need to make changes in their practice. To what extent are you afraid of making these changes? If so, why? If not, why not?"

While the conceptual framework of "risk" was used to analyze the interview data, the word risk was not, in fact, included in the semi-structured interview questions. Rather, questions sought to gain a deeper understanding of if and how teachers adopted engineering design-based science pedagogies in their classroom teaching practices and what the benefits of doing so might be. By inserting "risk" in the interview questions, researchers were fearful of imposing a pre-determined response from the teacher participants and missing the opportunity to gather data inductively. All interviews were transcribed and stored on a secured shared drive by members of the research team.

Classroom Observations

Approximately 6 to 8 hours of classroom observations were conducted for each teacher implementing an engineering design task (total ~40 hours). Observations entailed the use of an observation protocol designed to address engineering practices as depicted in the NGSS (Capobianco, Delisi, & Radloff, 2018). The focus of this protocol was on the teacher, specifically his/her instructional practices exhibited during a given lesson or series of lessons. The indicators of teacher practice were organized to provide a metric of the following: (a) verbal practices (spoken instructional strategies) exhibited by the teacher, (b) overall organization and sequence of the lesson activities, (c) the science content taught, (d) classroom management and instructional style, and (e) kinds of investigations in which students were engaged. Observers maintained a running transcript of the teacher's movements, questions, and instructional strategies. In addition, observers recorded students' responses, activities, and engagement through the design task and coded activities according to the modified activity codes.

Teacher Reflections

In an effort to chronicle their implementation efforts, first- and second-generation teachers completed a reflection once in the fall and again in the spring. Teachers were asked to provide a descriptive breakdown of the day-to-day lesson activities from the beginning to the end of the design task. Additionally, teachers were asked to record the amount of time spent during each phase of the design process and their personal observations of what their students were doing and how they were learning. Unique to the reflection was each teacher's interpretation of work collected from two students: (a) one student who performed relatively well on the task and (b) one student who did not perform as well. This part of the reflection included photographs or images of students' design notebook entries, artifacts, and/or students working within their design teams.

Data Analysis

This research draws upon an interpretivist paradigm and uses comparative case study methodology (Sheridan et al., 2014). Interpretivism focuses on understanding teachers' thoughts and beliefs in context and how these understandings may affect their adoption and implementation of novel reform (Taylor, Taylor, and Luitel, 2012). The current study employed open coding of interview and observation data for all participants (Miles & Huberman, 1994; Saldaña, 2015; Strauss & Corbin, 2007) with a focus on teachers' risks and risk-taking behaviors (Zinn, 2008) within the context of learning to integrate elementary engineering design-based science instruction. Researchers coded data in relation to the different types of perceived risks teachers reported taking when planning, preparing for, and implementing design tasks. All teacher participants were provided with interview transcripts and observation field notes to check for accuracy. Any inaccuracies detected were then changed (Creswell & Miller, 2000).

Initial coding of data involved organizing and sorting teachers' responses to interview questions and instructional activities enacted during a design task. Codes were assigned based on the nature of the type of risk expressed by each teacher. For example, if a teacher participant described feelings of uncertainty with organizing students into design teams, researchers associated this type of risk as instructional or pedagogical. Agreements and disagreements between coders were each tallied by directly comparing the codes applied to the same (or similar) excerpts. Codes were added, collapsed, and refined to create categories that were then merged to create four distinct types of risks. Intercoder reliability was established by the participation of multiple coders coding the same interview transcripts and several iterations of coding procedures, yielding 86% coding agreement. Continuous dialogue between researchers was employed to mitigate interpretative bias (Walther, Sochacka, & Kellam, 2013) and maintain the consistency of our coding (Miles & Huberman, 1994).

Teacher reflections were analyzed using document analysis (Krippendorf, 2013). Recurring patterns across all data sets allowed researchers to identify and characterize concepts supporting the construct of risk-taking and associated benefits as expressed by the teacher participants. To ensure trustworthiness of all data sources, recurring coded patterns from the interview and observation data were compared and supported by coded data from the teachers' reflections (Oliver-Hoyo & Allen, 2006). In short, assessments of observation data and teacher reflections served to confirm our analysis and interpretation of the interview data. Assertions pertaining to the risks teachers perceived taking, the relationship between these risks among the three generations of teachers, and the benefits associated with their risk-taking were generated. The research team shared its interpretations of the data with each of the four teachers individually. These discussions confirmed that the research team had made accurate interpretations of participants' perspectives.

Findings and Discussion

Findings from the analysis revealed that elementary teacher participants in this study described four different types of risks taken when implementing engineering design-based science instruction. Interestingly, each type of risk related positively to each teacher generation. In other words, each reported risk correlated with each teacher's level of involvement in the partnership and years of teaching experience. The four types of risks included: (a) practical, (b) pedagogical, (c) conceptual, and (d) personal (see Table 1).

Practical Risks

Practical risks expressed by the teachers included issues related to the amount of time, resources, and additional instructional and administrative support required to implement the engineering design-based science tasks. Underpinning this type of risk was a sense of loss or what might be given up if more time was allocated to integrating new reform in their science classrooms. When asked what kinds of challenges faced when attempting to implement engineering design-based tasks, the teachers reported the following:

> Teaching over six subject areas a day makes it hard to devote tons of time to really big activities like these design tasks. Not just time in the day for the activity, but the time that's spent setting it up, finding the supplies, fitting it into your units, etc. (Patricia [Second Generation], Interview #1)
>
> I guess for me it would be the amount of time that it does take to do these tasks. I mean I could teach from the book in 2 weeks and these design tasks extend it at least an extra week, if not 7 or 8 days, 10 sometimes…I am almost halfway through the school year and I'm already feeling the crunch because we have to get in social studies too and we still have heat, electricity, and adaptations to cover before long. So just the time that it does take when you factor weeks, is a risk we run…but, it also helps, because they (students) remember it better. (Harold [First Generation], Interview #2)
>
> I remember when I first started teaching these design tasks, time to prep for these lessons and actually teaching them was such a big issue. I quickly noticed that I was losing time for literacy and math instruction. For me, this strain on time outweighed the changes I observed in my students. (Cathy [First Generation], Interview #1)

Concerns related to insufficient time to plan and prepare, as well as the additional time needed to instruct design-based science lessons, consistently surfaced in the teachers' interviews. These practical risks suggested threats to the amount of time necessary for not only planning, preparing, and instructing multi-day design lessons but also instructing other disciplines. By investing time in the implementation of design lessons, elementary teachers in this study felt a loss of instructional time for other subject areas, as well as "valuable time" necessary for preparing students for high-stakes testing. Though the concern for adequate test preparation time is omnipresent for many K–12 teachers, this type of time constraint is magnified in an engineering design-based science classroom. This is largely due to the fact that engineering standards were not yet incorporated in statewide assessments during the time of this study and, therefore, imposed an implicit risk of teaching out of the content area for these respective teachers. In his first interview, Harold stated:

> When I first joined the partnership and teaching design, I was so afraid of taking time away from preparing my kids for the ILEARN [Indiana's Learning Evaluation and Readiness Network] Assessment…every time I taught a design lesson I figured it was taking twice as much time from getting them ready for the test. I was also afraid that design was not yet on the test, so I remember talking with Cathy and saying…this is really risky what we are about to do this year. But we don't see it like that now…the benefits of what we saw and continue to see in our students and how they perform on

Table 1
Types of risks identified and characterized through teachers' interviews and reflections.

Type of Risk	Definition
Practical	Risks regarding uncertainty about the amount of time, resources, and additional instructional and administrative support required to implement the engineering design-based science tasks
Pedagogical	Risks centered on moving from more teacher-directed and familiar roles to more student-centered, facilitative ones; for instance, arranging and managing students in engineering design teams
Conceptual	Risks focused on actions taken by teachers to support their students' capacity to grasp and utilize both engineering and science concepts during a design task
Personal	Risks associated with being one of few teachers in the building or in their grade level implementing engineering design-based science instruction

the tasks and the tests clearly outweighed the risk. (Harold [First Generation], Interview #1)

Inherent in the teachers' practical risks was the perception that time was lost or taken away from equally important instructional activities and subjects. Though these practical risks may have been pervasive for first-generation teachers Cathy and Harold early in their teaching of engineering design, the outcomes far outweighed the potential loss of time. This was most evident in the teachers' reflections on their practice. Both Cathy and Harold included images of their students' artifacts, supplemented by gains of 10–15% on classroom-based post-assessments. Additionally, their personal reflections included the following comments: "The students who were silent are now talking and taking charge during design lessons" and "I observed my students asking more questions, contributing to their design teams, and staying engaged more often during our design lessons."

Pedagogical Risks

Pedagogical risks were identified by teachers as threats to their approach to teaching science. For example, third-generation teacher Annie shared her concern over allowing students to be more self-directed. In one of her interviews, Annie stated, "Turning over all the control to the students is definitely a risk in my student teaching." When probed further, Annie explained, "I might come across as not having control over my classroom and possibly be considered ineffective as a teacher." A signature component of engineering design-based science instruction is the formation of student design teams where students make critical decisions about the design's development, assembly, and evaluation (Brophy et al., 2008). A large majority of time is allocated to more student- versus teacher-centered decision-making. For Patricia, organizing her students into small groups remained uncertain.

> The one thing I am unsure about is how my students will do working in teams. I have some strong personalities in my class that I am worried will have a hard time working together with the team and not trying to take over the whole design. So, I have to be strategic when putting them into design teams. (Patricia [Second Generation], Interview #1)

Cathy also confirmed that early in her practice she found:

> …that sometimes balancing groups—you know, cognitively—was like playing Russian roulette…you never knew what you were going to get. It was hard to predict who is going to have the skills and who isn't based on their general academics. (Cathy [First Generation], Interview #1)

While increasing opportunities for students to be more self-directed, organizing students into small design teams appeared as risky pedagogical strategies for Cathy and Annie. Implicit in their responses is the fear of losing control of the classroom by transferring the responsibility to their students. As previously stated, risk involves the fear of possible future loss. Risk, by definition, involves uncertainty of both process and outcome. Hence, it is not surprising that what makes something a risk to these teachers is characterized by a degree of uncertainty and/or ambiguity. Collaboration is not only central to student engagement in engineering design (Lachapelle, Cunningham, & Davis, 2018) but also a discrete point of divergence between design-based and inquiry-based science instruction (Lewis, 2007). As such, more targeted attention, teacher support, and practice may be needed concerning the formation and facilitation of student design teams.

Conceptual Risks

Conceptual risks were identified by the teachers as concerns they had about their students' conceptual understanding of engineering design and how to apply their science conceptual knowledge to their designs. Harold and Cathy stated that students often grappled with engineering vocabulary (i.e., constraints, criteria, end user); however, encouraging students to apply science to inform their designs or explain the performance of their designs appeared to be equally challenging. In his final reflections, Harold described the following:

> My students continue to struggle with the design process itself…its criteria and constraints, just getting them to understand that…and we're pretty good with sketching and the other aspects of that, so criteria and constraints have really gotten us. Then when doing the actual design task or building the prototype, I can see my students having difficulty evaluation their designs. So, for example, in Slow Boat…when getting their boats to slow down, I want to hear my students use concepts like drag or resistance, but I find myself prompting them and really pushing them to use science concepts to explain what is happening. I'm certainly getting them to "use" the science concepts, but I question whether or not this is effective. (Harold [First Generation])
>
> I noticed that my students often confuse client with end user and criteria with constraints. This indicates to me that they are still trying to learn the vocabulary. My students have done quite well with the door alarm task. They recognize when the alarm is or is not working. But they continue to have trouble explaining why the simple circuit does not work. This is when I begin to question whether or not I should step in and if I should help them make the connection. By letting them go on their own,

> I am taking a leap of faith hoping they get it. (Cathy [First Generation])

Inherent in these risks is jeopardizing their own instructional effectiveness as teachers. Observation data revealed Harold and Cathy cautiously leveraging student thinking throughout their respective design implementations. They asked students questions such as: “What do you think made your boat slow down?” and “Did your alarm work? Why or why not?” and “How could drag explain what is happening here?” Their questions demonstrated purposeful attempts to bridge students’ design solutions to core disciplinary ideas. However, for Harold and Cathy, the risk of carefully scaffolding their students and letting students explore freely on their own comes at a cost of directly managing (rather than guiding) students’ science learning.

Personal Risks

Personal risks included issues associated with being one of few teachers in the building or in their grade level implementing engineering design-based science instruction. Loss of trust, friendship, and professional respect were expressed by more than one teacher as a significant personal risk. In her first interview, Annie stated the following:

> I think that the biggest challenge I anticipate is gaining administrative and teaching team support to implement these tasks since I will be far away from the actual reach of the SLED support team. (Annie [Third Generation], Interview #1)

Prior to her student teaching, Annie expressed additional personal concerns about what she planned to teach and whether or not it would be considered by her university supervisor as a legitimate form of science instruction. In her second interview, she shared the following:

> One risk is that I intend to teach at least one design lesson in the spring…and my supervisor will not have seen this kind of science teaching…so part of the risk is communicating **how** and **why** I am teaching this way…the fear of my university supervisor not understanding or accepting this as legitimate and powerful science teaching. (Annie [Third Generation], Interview #2)

Annie’s uncertainty with introducing an engineering design-based science lesson during her student teaching suggests the possible danger of being misunderstood and, consequently, evaluated unfairly by experienced teachers and school administrators. Patricia, on the other hand, expressed the following in her second interview:

> The fourth-grade teachers (Harold and Cathy) have been doing SLED for several years now and that is great…but kind of intimidating. On the one hand, you want to be as good as them, and on the other hand, you question whether or not you’re going to get the other grade level teachers on board. As the only fifth-grade teacher doing this, I’m a little concerned that I’m going to be perceived as joining the “new way of teaching science” bus and no one wants to get on board. (Patricia [Second Generation], Interview #2)

Here, Patricia communicated that her non-conformity with respect to her colleagues brought with it the risk of possible loss of acceptance and friendship.

Cathy was more than willing to take the personal risk. In her first interview, she commented:

> I’ve been in this business for a long time. I’ve taught in other schools, and I see how my colleagues respond to new initiatives coming down the pipeline. For me, this was perfect timing. Harold and I plan a lot together, we’ve been reviewing and revising our science curriculum for a long time. I think it would have been a risk **not** to switch over and adopt the design lessons. Harold and I did not care what others thought…we know the third-grade teachers do not teach science, so we thought this would really help us ramp up how our students learn and perform in science. It’s what we like to do because it’s so interesting for the teachers and we see the kids just really understanding. (Cathy [First Generation], Interview #1)

Harold reiterated his commitment to science teaching and student learning and the value of taking personal risks.

> You would think that stepping outside of the school’s status quo and doing something different in your practice would be risking your reputation. Well, it didn’t for me…joining the partnership and learning about design has been the best thing for my students. I think that it is part of my character and Cathy’s…that if we believe something is important to children and we really believe something that, we have to change it ourselves. (Harold [First Generation], Interview #2)

Harold and Cathy felt empowered to implement changes and develop the most effective practice they could by learning about design-based science teaching, while their colleagues seemed paralyzed to some extent by their perceptions of the risk involved. This sense of empowerment came through Harold’s belief in his “character”; he also viewed the issue as an ethical one, and wanted to implement the changes because they were important to his students.

Existing theory about risk and risk-taking provides some possible explanations for Cathy’s and Harold’s willingness to take risks. If perceptions of what is at stake in a risk-taking situation are outweighed by those of what can be gained, then people are often more willing to act and to take risks (Shapira, 1995). What was at stake for Patricia, Cathy, and Harold was their perception of loss of colleagueship; however, Cathy and Harold already knew what was possible to achieve through changing pedagogy. In effect, this vision of possible positive and valuable outcomes for students, which stemmed from previous experience, enabled them to exercise agency (Jaeger et al., 2001) by attempting to shape future positive outcomes for students in their school.

Cross-Case Comparison of Perceived Risks Among the Three Generations of Teachers

First-generation teachers, Harold and Cathy, expressed greater risk-taking relative to building *conceptual* learning among their students in their implementation, while second- and third-generation teachers (Patricia and Annie, respectively) described predominantly *practical* and *pedagogical* risks. Additionally, Annie, the third-generation student teacher, and Patricia, the second-generation cooperating teacher, expressed predominantly *personal* risks. We speculate that these trends relate to the teachers' level of involvement in the partnership and their years of experience teaching science. Considering both teachers were new to the partnership and situated within the same classroom, we contend that their personal risks complemented one another. When we looked further at our interviews with Annie, we observed a trend in Annie's positive attitude toward teaching science through engineering design. According to Annie, "I am not as concerned about actually teaching it…I think I am more focused on observing my students being engaged in design and enjoying it." We argue that Annie's self-confidence outweighed her fear of failing, resulting in increased personal risk-taking behavior. Student teaching provides many opportunities for growth and the development of teaching knowledge while simultaneously exposing the student teacher to an array of potential concerns and issues. Although practical experience in schools is considered by many pre-service teachers to be the most significant part of their education program, it is fraught with risks. These risks include potential failure of the students to learn the designated content, implied criticism of the host teacher if his/her teaching approach is not followed, danger of losing control over the class while using an unfamiliar teaching approach, and the risk of effects on the student-teaching evaluation if things do not work properly (Gwyn-Paquette & Tochon, 2003). In this study, Annie's resilience and persistence as a young elementary school teacher appear to propel her forward and empower her to implement engineering design-based science teaching. She exhibited a strong internal perception of security in her formative identity as a teacher, trusting herself to know what was right. Annie's case provides important evidence that perceived risk can be subjective and personal. These results parallel Le Fevre's (2014) finding that a teacher's integrity may force them to act despite any threats to their security posed by certain aspects of the external school culture.

As the teachers shifted from one generation to the next, their risk-taking behavior shifted as well. Cathy and Harold often reflected on their earlier experiences teaching engineering design-based science lessons, concluding that it could be pedagogically risky. Yet as they continued to teach and attend professional development sessions, they developed both the wisdom of practice (Feldman, 1997) and self-confidence necessary to shift their risk-taking behaviors to more conceptually demanding concerns. In this sense, teacher learning and, specifically, conceptual shifts about practice and the perceived risks associated with these shifts, were led by actual changes in those practices.

Benefits

All three generations of teachers expressed several benefits of their risk-taking behavior and, hence, positioned risk-taking in a more positive light. Teachers noticed that by taking risks in their practice, they observed higher student engagement and student ownership of their own learning. First-generation teachers critically observed and described ways students "picked up and used content more often to inform their designs." Patricia, a second-generation teacher, commented on feeling "empowered" from her own practice. She now embraces the engineering design process, sees the "long-term benefits or investment in her students' learning," and feels "empowered to take on any and all risks in their teaching." For teacher participants in this study, learning to teach science through engineering design gave them personal enjoyment and satisfaction in their practice, and helped them glean pedagogical knowledge and wisdom not gathered from other reform-based teaching initiatives.

According to Zinn (2008), the concept of risk involves the fear of possible future loss or threat. When reviewing the teachers' transcripts, we frequently asked ourselves: "If risk-taking suggests a threat to one's practice, then why do these teachers continue to take them?" We followed up with each teacher, asking them: "If you have all these concerns and/or are faced with these challenges, why continue to implement them? What makes this worth taking a risk?" The teachers reported one of two responses: (a) strong, consistent support from the Partnership and/or (b) positive academic and behavioral changes in their students and how they participate in and with science.

Distinct to this study is its context. The SLED Partnership is a large school-university partnership aimed at supporting teachers throughout the course of their learning to teach science through design. Summer institutes were designed to immerse teachers in the experience of learning to solve an authentic problem using engineering practices. During this time, teachers were able to raise concerns, ask questions, and discuss potential challenges with implementation. Teachers were provided with a plethora of instructional strategies and electronic resources including multi-day, classroom-tested lesson plans, assessments, and organizers that complemented each design lesson. In times of unanticipated challenges, the partnership teachers received additional classroom, in-real-time instructional support from university STEM faculty. To some extent, the partnership teachers were inoculated by the larger partnership whereby they were taught to recognize potential threats to their attempts and armed with an arsenal of resources to protect their beliefs, attitudes, and intentions for implementing new reform.

Given that many current efforts to affect educational change emphasize teachers having conversations and sharing their practice, there is a need to construct collaborative contexts in which teachers have a sense of relational trust (Bryk & Schneider, 2002; Jacques & Fletcher, 1997) and feel comfortable and confident to make their practice public. A school culture that is non-punitive but embraces inquiry (Timperley, 2008) and innovation (Rogan, 2007) as a model of professional learning might arguably reduce the degree of risk perceived in trying something new. Timperley (2008) suggests change involves risk, "but before teachers take that risk, they need to trust their honest efforts will be supported, not belittled" (p. 16). We speculate that the SLED Partnership fulfilled a need for a supportive school partnership wherein there is a shared understanding of this.

Conclusion and Implications

Risk involves uncertainty, and teaching, by its very nature, involves uncertainty (Jackson, 1968; McDonald, 1992). The risks characterized in this study are unique to teaching science through engineering design. Incorporating elementary engineering design-based science instruction requires additional instructional and planning time and learning to leverage students' prior knowledge and reasoning with science and engineering ideas to providing diverse solutions to authentic design problems.

The experience of learning to teach science through engineering design in the SLED Partnership provided an opportunity for both pre- and in-service teachers to take risks that they otherwise may not have taken given the pressures they felt as teachers in an era of high accountability. Moreover, the partnership promoted ongoing, collaborative support, making it safe for teachers to act on this opportunity. This targeted professional development initiative did not just provide an opportunity to try out an alternative approach to teaching science; rather, it *required* it. Teachers who joined the partnership made the commitment early on to develop, implement, and reflect on their efforts, while simultaneously receiving limitless instructional assistance. Given the changes teachers made to their science instruction, this infrastructure was the necessary support that inspired positive risk-taking in an environment that, in many respects, was averse to such risks.

The risks described in this study demonstrate the important role risk-taking plays in elementary science teachers' adoption of new reform, specifically engineering design. Rather than eliminate a sense of risk, the results of this study suggest that creating an environment that both reduces perceptions of risk and supports risk-taking as productive and positive. By situating risk-taking in a positive light, professional developers and curriculum consultants creating high-quality, engineering education professional development can debunk and reduce teachers' perceptions of engineering and associated pedagogies, thus laying the foundation for changing practices to improve science teaching and learning. We contend that increasing elementary teachers' willingness to take risks when learning engineering design-based science teaching is necessary to bring about effective educational change.

There are some limitations to the study to consider. First, the size of the study sample may be characterized as small or possibly marginalized. In an effort to explore the phenomenon of risk-taking, researchers in this study found it both interesting and exciting to interact with three generations of teachers located in the same school setting. Hence, we felt that this distinct sample, though small in number, provided rich insight into how risk-taking manifests itself among teachers with varying years of experience and involvement in the targeted professional development. A larger sample size could certainly help make our results more generalizable. A second limitation of this study was time. Researchers in this study examined the teachers' implementation efforts over the course of one school year. In order to further substantiate our claims about teachers' risk-taking behaviors and associated benefits, prolonged time in the field is clearly warranted.

Implications from this study suggest that creating an environment that both reduces perceptions of risk and supports risk-taking as both positive and practical is critical to supporting innovation and transformation in the science classroom. Increasing teachers' willingness to risk-take when changing teaching practices is necessary to bring about effective educational change. This can be achieved by establishing strong relational trust among all members of the partnership; most importantly, among the teachers and university collaborators. Those in favor of new teacher learning must think of ways to support teachers presented with opportunities to take risks, providing an environment that supports and values such risks.

Researchers, policy makers, educational leaders, teacher educators, professional developers, and others involved in implementing educational change need to understand that risk is a socially constructed phenomenon. As such, different educators will have different perceptions of what is or is not a risk, and how risky it is. While the current study presented four main types of risks among three generations of elementary science teachers, these types of risks could be further explored among teachers with more extensive teaching experience and expertise. Likewise, risks may differ across institutional contexts (schools and classrooms). Given the facilitative nature of engineering design-based science instruction, risk-taking may yield different outcomes with more diverse student populations. This study provided an initial exploration into theorizing risk-taking in relation to innovation and change in science teaching practice. Future research might examine a school that had less success with introducing and implementing change, wherein it might be hypothesized that teachers were unwilling to take risks. This might provide a context in which to further theorize what conditions encourage or discourage teacher risk-taking. Investigations into perceptions of risk for prospective teachers during teacher-preparation courses is also important given the findings of this research. While beyond the scope of this study, there are likely to be important ramifications for pre-service teacher education.

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