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Teachers' Beliefs in Enacting an Interdisciplinary Engineering Project in Inclusive and General Classroom Contexts (Fundamental, Diversity)

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Abstract

In this study, we examine the reported beliefs of two elementary science teachers who co-taught a four-week engineering project in which students used a computational model to design engineering solutions to reduce water runoff at their school (Lilly et al., 2020). Specifically, we explore the beliefs that elementary science teachers report while enacting an engineering project in two different classroom contexts and how they report that their beliefs may have affected instructional decisions.

Classroom contexts included one general class with a larger proportion of students in advanced mathematics and one inclusive class with a larger proportion of students with individualized educational programs. During project implementation, we collected daily surveys and weekly interviews to consider teachers' beliefs of the class sections, classroom activities, and curriculum. Two researchers performed a thematic analysis of the surveys and interviews to code reflections on teachers' perceived differences between students in the class sections and their experiences teaching engineering in the class sections.

Results suggest that teachers' beliefs about students in these two different classroom contexts may have influenced opportunities that students had to understand and engage in disciplinary practices. The teachers reported making changes to activities based on their perceptions of student understanding and engagement and to save time which led to different experiences for students in each class section, specifically a more teacher-centered implementation for the inclusive class. Teachers also suggested specific professional development and educative supports to help teachers to support all students to engage in engineering tasks. Thus, it is important to understand teachers' beliefs to build support for teachers in their implementation of engineering projects that meet the needs of their students and ensure that students have access and support to engage in engineering practices.

Introduction

In this study, we examine the reported beliefs of two elementary science teachers who co-taught a four-week engineering project in which students used a computational model to design engineering solutions to reduce water runoff at their school (Lilly et al., 2020). In particular, we investigate how these teachers' beliefs may have affected their implementation of the engineering project in two different classroom contexts. Teachers' beliefs include their own ways of thinking, attitudes, and self-efficacy about teaching as well as the disciplines and students that they teach (Gess-Newsome, 2015; Muijs & Reynolds, 2002). Particularly for elementary teachers who may not have formal training in engineering, science, mathematics, or computing disciplines, these beliefs may affect their instructional decisions in implementation of engineering projects (e.g., Estapa et al., 2017; Nathan et al., 2010; Stohlmann et al., 2011).

Relatively little research examines how teachers' beliefs may differentially affect students' opportunities to engage in engineering practices (e.g., Watkins et al., 2018) especially for students with individualized educational programs (IEPs; Lilly, McAlister, et al., 2021). Our study then seeks to explore the following research question: In what ways did elementary science teachers report that their beliefs about two different classroom contexts may have affected their implementation of an engineering project?

Background

Integrating engineering projects in elementary classrooms

Integrating engineering-based instruction in elementary settings has the potential to provide unique educational opportunities to students through project-based approaches grounded in real-world, relevant problems for students (Cunningham & Kelly, 2017; Dare et al., 2014). Engineering-based instruction can foster asset-based approaches that draw upon student resources. By basing design problems in real-world settings and having multiple solutions to a design project, engineering projects can value and sustain the individual knowledge and skills students bring to classrooms (e.g., Meija et al., 2014). For example, a student with a learning disability can become a valued expert in a project around environmental justice (e.g., Roth & Lee, 2007), and Latina/o students can use funds of knowledge from families and communities to solve design problems (Wilson-Lopez et al., 2016).

Engineering projects also provide novel opportunities for teachers to provide instruction that is differentiated and tailored to students (e.g., Gravel et al., 2021). Engineering design projects offer multiple ways that different students can solve the same challenge. Thus, just as students can bring in their own assets and resources to bear on solving a design problem, teachers can build upon students' design performance to provide tailored feedback. For example, teachers can provide additional criteria and constraints to make challenges more complex, or use students' design artifacts to notice places where students may need more conceptual or skill-based support (Qadir et al., 2020). The activity-based and material nature of engineering design projects can also help teachers provide differentiated instruction suitable for students with individualized needs. For example, Cunningham & Lachapelle (2014) note how Engineering is Elementary projects kept elementary students with IEPs engaged and on-task in different ways than traditional elementary instruction.

Given the potential of engineering design in preK-12 classrooms, a growing number of high-quality pre-college engineering curricular materials have been developed (e.g., EiE, Project Lead the way, Capobianco et al., 2016; Moore, etc.; Tank et al., 2018). High-quality pre-college engineering curricula include explicit processes of design, help students use science, mathematics, and computation, and encourage engineering ways of thinking and collaboration as well as teamwork and ethics (American Society for Engineering Education, 2020; Moore et al., 2014). Engineering curricula that involve these indicators may then benefit learners more than traditional teacher-centered approaches (Cunningham et al., 2020).

Such engineering curricular materials are being implemented in a growing number of inclusive classrooms that involve students with IEPs together with students without IEPs. Yet, despite the importance of engaging all students in high-quality engineering curricula, relatively little research explores engineering projects in inclusive settings. Research that has occurred includes large studies that explore relationships among engineering projects and learning outcomes for students with disabilities. For example, Guzey et al. (2017), as part of a large study with 59 teachers and 4450 students across 4-8th grades, found that classrooms with higher populations of students with IEPs scored, on average, lower on engineering posttests (however with a small effect). Similarly, Cunningham et al. (2020), in a study with 239 teachers and 14,015 students, found that having an IEP negatively predicted engineering and science learning outcomes. Thus, findings highlight the need to investigate how to support students with IEPs in engineering projects.

Teacher enactment of engineering design

Although high-quality engineering curricula have the potential to engage students, teachers play a critical role in the kinds of opportunities that are afforded to students. Teachers may use engineering curricular materials as planned by the designers or make customizations to fit the specific contexts of their students (e.g., Guzey et al., 2017; Van Haneghan et al., 2015). For example, teachers can make instructional decisions to bring in and value their students' cultures and ideas within engineering projects (Wilson-Lopez & Garlick, 2017). In this way, teachers necessarily filter the ways that engineering curricular materials are implemented in their classrooms (e.g., Lilly, Chiu, et al., 2021; Remillard, 1999).

However, teachers, and specifically elementary teachers, can face specific challenges when trying to implement engineering-based instruction in their classrooms. Elementary teachers often do not come to the classroom with disciplinary knowledge of mathematics, science, or engineering (e.g., Plumley, 2019) and may need support to develop self-efficacy as well as pedagogical strategies to teach these subjects (e.g, Hammock & Ivey, 2017). Considering teachers' self-efficacy in engineering in particular is important (Yoon et al., 2014) as engineering is not typically a core subject that is taught in teacher preparatory programs or emphasized in state standards, so teachers may have less exposure and access to high-quality engineering instruction.

Notably, we explicitly take an asset-based stance to teachers in our work. We believe teachers balance and work within an incredibly complex educational system with multiple, competing demands. Teachers bring their own experiences, cultures, and beliefs to classrooms that should be valued, leveraged, and sustained in schools through professional development and other learning experiences. Thus, we acknowledge that when teachers make instructional decisions they are in the context of potentially competing demands such as time, school, or district expectations, and teachers' beliefs and self-efficacy can be a product of limited opportunities within teacher education programs and professional development experiences (e.g., Yoon et al., 2013).

In particular, when elementary teachers try to implement engineering projects in inclusive settings, teachers may need more support to help students engage in high-quality, student-centered, engineering design practices. For instance, high-leverage practices for students with IEPs involve explicit instruction for students learning new concepts or skills as well as setting clear learning goals and designing instruction and feedback towards those goals (Maheady et al., 2018). In practice, high-leverage practices for students with IEPs can seem very teacher-centered and somewhat at odds with high-quality engineering design. However, explicit support for students with IEPs does not necessarily translate to only teacher-centered instruction, but rather that goals, skills, and practices are explicitly articulated to students (Therrien et al., 2017).

Teachers' beliefs in enacting engineering projects

Research demonstrates how teachers' self-efficacy and beliefs can affect classroom enactment of curricular materials (e.g., Askew et al., 1997; Gess-Newsome, 2015; Prescott et al., 2019). Teachers' beliefs involve their attitudes about teaching in general, their own ways of thinking about disciplines, and their perceptions of their students (Muijs & Reynolds, 2002). Teachers' self-efficacy includes the confidence teachers bring to their teaching practice or disciplinary knowledge (e.g., Kaya et al., 2019; King & Wiseman, 2001; Margot & Kettler, 2019; Menon & Sadler, 2016). Based on their beliefs and self-efficacy, teachers may make instructional decisions that can affect student engagement (e.g., Dare et al., 2014; Van Haneghan et al., 2015) and opportunities within engineering projects (Nathan et al., 2010; Yoon et al., 2014).

Disciplinary beliefs. Teachers may hold varied beliefs about engineering that can in turn affect the way teachers implement engineering projects in their classrooms (e.g., Lachapelle et al., 2014), particularly elementary teachers who may not be familiar with engineering concepts and practices (Plumley, 2019; Purzer et al., 2014). For example, a teacher who is unfamiliar with engineering and is not confident in their ability to support students in engineering content practices may allocate less time or fewer opportunities for student-centered engagement in engineering activities than is recommended by curricular materials. For example, a teacher may decide to support students to engage in an engineering activity through whole-class discussion where they can lead student ideas rather than enable students to work in small groups or pairs where teachers may struggle to anticipate, respond to, or evaluate alternative student ideas (Brophy et al., 2008; Lilly, McAlister, et al., 2021).

Considering the interdisciplinary nature of engineering projects, teachers may also have different beliefs and self-efficacy for the different integrated disciplines or their ability to teach concepts that support students to engage in different disciplinary-focused practices (Hammock & Ivey, 2017; Johnson et al., 2021; Muijs & Reynolds, 2002; Plumley, 2019). For example, teachers may feel more comfortable supporting students in science or mathematics-focused activities within an engineering project than computer science-focused activities based on their familiarity with these disciplines. This may lead teachers to offer students different opportunities to engage in different disciplinary practices, such as teachers providing more epistemic support within disciplines that they are more familiar with or allot less time to disciplines that do not have state-mandated standards (Lilly et al., 2022).

Interdisciplinary beliefs. Further, teachers may struggle to support students when the interdisciplinary nature of an engineering project means that activities use concepts or terminology from one discipline in another disciplinary context. This study investigates an engineering project where students engage in engineering design using scientific investigation, mathematics, and computational modeling through activities that build connections between engineering, science, mathematics, and computer science concepts, practices, and real-world problems (Stohlmann et al., 2012). As such, teachers in this study or teachers enacting similarly-aligned engineering projects may find challenges in the ways in which the engineering project curricula utilizes disciplinary practices in support of other disciplines and includes ideas or strategies that are atypical in elementary science teaching (e.g., Davis et al., 2019). This may lead teachers to struggle to support students to engage in disciplinary-focused practices when these practices are used in conjunction with a different discipline. For example, prior research shows that a mathematics teacher enacting an engineering project may struggle to support all students to use the mathematics concept of *ratio* with the science phenomena of absorption and run-off despite being comfortable with teaching this concept in mathematics-based activities (Lilly, McAlister, et al., 2021).

Beliefs about students. Teachers may also hold different beliefs and self-efficacy about teaching in inclusive settings that may affect what and how they choose to implement engineering projects in their classrooms (Lilly, McAlister, et al., 2021) based on their beliefs of students' abilities to engage in engineering practices in different classroom contexts (Lilly, McAlister, et al., 2021; Nathan et al., 2010). Specifically, teachers may hold beliefs about both the capabilities of specific students with disabilities and the pedagogical strategies for special education (Therrien et al., 2017) that they feel are necessary to support students with disabilities to engage in certain disciplinary practices. Attending to their beliefs about using high-leverage practices to support students with disabilities may be particularly difficult in engineering projects as these pedagogical strategies may not be in agreement with the more inquiry-based nature of engineering (Therrien et al., 2017). For example, teachers in inclusive classrooms may not believe that students would be able to work through the iterative process of engineering design or the challenges of coding individually as they are supported to do in general classrooms. Teachers may then choose to use direct instruction to support students in these practices even if such an instructional decision may not be in agreement with a more student-centered approach intended by the project's curricular materials (Lilly, McAlister, et al., 2021). Particularly when such instructional decisions are made based on the teachers' understanding of student ability in other disciplines (i.e., prior mathematics achievement) rather than to address actual student needs in the moment, teacher beliefs could then limit the opportunities that students have to engage in engineering practices. This is important to consider, as an elementary student with difficulties in mathematics may have success with engineering practices if given the opportunity and support.

However, despite the importance of supporting all students to engage in engineering concepts and practices, little research explores the beliefs of elementary teachers as they work to support elementary students to engage in engineering projects in inclusive settings (e.g., Hsu et al., 2011). Thus, in this study, we focus particularly on teachers' beliefs about students in general and inclusive classrooms and explore how their beliefs about students may influence their disciplinary and interdisciplinary beliefs as well as the ways in which the teachers enact the engineering project.

Supporting teachers' self-efficacy

Professional development experiences can support teachers' self-efficacy in enacting engineering projects by increasing their confidence in their teaching (e.g., Hammock & Ivey, 2017; Margot & Kettler, 2019; Stohlmann et al., 2011) and their beliefs about the importance of offering students opportunities to engage in engineering practices (e.g., Berland 2014; Estapa et al., 2017; National Research Council 2014; Roehrig et al., 2012). Considering what professional development to offer teachers who enact engineering projects is an important implication of exploring teachers' beliefs. For example, research may overlook challenges with more familiar disciplines in which teachers may be expected to be able to utilize their prior experiences and knowledge in lieu of challenges in focusing on unfamiliar disciplines. Yet, giving teachers a voice by considering teachers' beliefs about their challenges enacting engineering projects may then indicate that teachers need support across integrating both familiar disciplines (i.e., science and mathematics) and unfamiliar disciplines (ie., computer science; Lilly et al., 2022) in conjunction with engineering. For example, teachers in a prior study reported that they need additional support with helping all students to understand the mathematics concept of *ratio*, computer pedagogical strategies (i.e., debugging student program), and concepts that span across disciplines (i.e., using prior knowledge of how variables are used in mathematics and science to create a new understanding of variables in computational modeling) in enacting this project (e.g., Lilly, McAlister, et al., 2021). In this study, we consider the classroom contexts in which teachers are enacting the engineering project and propose that teachers' beliefs about students in different classroom contexts may influence their enactment of the engineering project. Thus, teachers may suggest additional supports to feel comfortable enacting the project across general and inclusive classroom contexts.

In this study, it is not our goal to evaluate teachers' beliefs or assess the success of the enactment of the project. Rather, the purpose of this qualitative study is to focus on teachers' reported beliefs about their enactment of this engineering design project. Thus, this case study explores how elementary teachers reflect on implementing an engineering project that integrated science, engineering, and computational modeling in two different classroom contexts. By doing so, this paper aims to expand our understanding of how teachers' beliefs may amplify certain opportunities for students within curricular materials or potentially filter opportunities within engineering design projects.

Methods

We consider teachers' reflections on implementing the engineering curriculum in order to give these elementary teachers a voice, and we report their beliefs in their own words when possible to preserve their perspective. Specifically, we use an embedded, single case study (Yin, 2018) in order to describe and understand the teachers' beliefs within a single, bounded context (Miles et al., 2020) of one implementation of this engineering project. We define the case as two fifth-grade teachers (pseudonyms, Mr. Skelton and Ms. Banet) who implemented the engineering project in two sections of their co-taught classroom.

Participants

We believe that this study presents a unique case (Yin, 2018) of teachers implementing an engineering project. Particularly, the elementary teachers in this study have undergraduate degrees in science, have over five years of teaching experience at the elementary level, engaged in co-developing this engineering project, and had prior experience in implementing and revising a pilot version of this engineering project the year prior (Lilly et al., 2020). Both teachers had also participated in four monthly meetings and a week of professional development prior to the implementation. When the project was implemented, Ms. Banet was a fifth-grade science and mathematics teacher. Mr. Skelton was the science, technology, engineering, and mathematics (STEM) coordinator for the elementary school, working to support teachers who were implementing design-based science and engineering activities.

Unrelated to this curricular unit, fifth-grade students in this study were placed in tracked classrooms based on their previous achievement in mathematics and/or additional support needed through an IEP. Together, the teachers enacted the engineering project in one general class with a larger proportion of students in advanced mathematics (General Class) and one inclusive class with a larger proportion of students with IEPs (Inclusive Class). There were approximately 25 students in each fifth-grade class, and these two class sections were representative of their public elementary school in the southeastern United States, which included: 6% Asian, 8% Black, 13% Hispanic, 38% White, and 5% Multiple Races; 17% Emerging Bilinguals and 53% qualifying for free or reduced-price lunch. Across classes, students had little experience with engineering design projects.

Engineering design project

The goal of the four-week engineering project was for fifth-grade students to redesign their school grounds to reduce water runoff, using engineering, science, and computational modeling (Lilly, Chiu, et al., 2021) as they met daily in their fifty-minute science class. In order to solve this authentic engineering problem of water runoff at their school, students investigated water runoff and absorption using various surface materials, created multiple design solutions according to the project constraints (i.e., providing different surface types for parking, play, and accessibility, and working within a budget), and then tested and evaluated their designs using a computational model that the students created in a block-based programming environment (Lilly et al., 2020).

As part of the engineering design project, students created scientific conceptual models of water runoff, followed by mathematical models of water runoff, which then connected to the development of computational models of water runoff at their school. The curricular materials motivated the creation of a computational model given the infeasibility of creating multiple prototypes and testing solutions on the scale of their school grounds. Thus, the project emphasized the development of computational models as part of engineering design with the purpose of testing design solutions (e.g., Lilly, Chiu, et al., 2021), aligned with current standards for PK-12 science and engineering education (ASEE, 2021; NGSS, 2013).

Finally, students were asked to communicate their final designs in a presentation to their principal about the design goals and how their designs did or did not meet project criteria. The engineering project was created to be inclusive of students with IEPs broadly, with opportunities for differentiation, self-pacing, and small group collaboration, while not targeting any single learning disability (Fujii et al., 2020).

Data sources

During the implementation of the four-week project, daily surveys and weekly interviews provided insight into each of the teachers' beliefs and views of the students in the two class sections and the implementation of classroom activities in each section. In the weekly interviews, the teachers were asked the same open-ended questions as in the survey but about an entire week of activities (Appendix). This allowed for expansion on ideas expressed in the survey. Audio recordings of the interviews were then transcribed.

Data analysis

Two researchers performed a thematic analysis of the surveys and interview transcripts to inductively code (Miles et al., 2020) the teachers' reflections on their perceived differences between students in the two different class sections and their experiences teaching engineering in these two class sections. The researchers engaged in team coding to read and discuss each of the teachers' reflections together and identify and code if a teacher's answer demonstrated (1) teachers' beliefs about each class section and any differences between the class sections and (2) how the teachers reported that their beliefs led to instructional decisions in each class section.

The researchers then looked across the statements that had been coded to extract themes concerning teachers' beliefs about the classroom contexts (including teachers' expectations of students' skills and prior knowledge), changes they made to the engineering project (adaptation of verbal support and classroom activities to differentiate based on their perception of student needs), and different ways they supported students in the different classrooms (based on recognized levels of student engagement in engineering activities; Miles et al., 2020). Based on these discussions, the researchers wrote analytic memos that became the basis for the findings section below. In the findings, we include representative quotations from the teachers to demonstrate the larger themes and consider teachers' beliefs broadly across the interdisciplinary nature of the engineering project. We address teachers' specific disciplinary beliefs in a separate paper.

Validity

In this study, we used several strategies to address validity. First, multiple data collection methods were used (e.g., daily interviews and weekly surveys) to triangulate evidence of teachers' beliefs. Additionally, we also interviewed and surveyed both teachers multiple times, allowing us to check our understandings of emergent themes regarding teachers' beliefs (Miles et al., 2020). Finally, peer review of the research design and initial findings came from external feedback during conference presentations from experts in science education (National Association for Research in Science; NARST), engineering education (American Society for

Engineering Education; ASEE), and STEM+CS education (International Society of the Learning Sciences; ISLS) as well as the curriculum developers of the project which shaped our final analysis methods and consideration of emerging themes.

Findings

In this section, we consider how teachers' responses to the surveys and interviews reflected different expectations for students in the Inclusive Class than students in the General Class. Teachers reflected on how their beliefs about students' skills and prior knowledge in the two classroom contexts may have affected the opportunities that they gave students to engage in the engineering project in different ways. Particularly, the teachers reported making changes to activities based on their perceptions of student understanding and engagement and to save time which led to different experiences for students in each class section, specifically a less student-centered implementation for students in the Inclusive Class. Teachers also suggested additional support and changes to the engineering project that they felt are necessary to help them to support all students to engage in engineering activities.

Different student expectations based on classroom context

The teachers' responses to the surveys and interviews reflected different expectations for students in the Inclusive Class than students in the General Class. Their beliefs about the students' abilities may have amplified and filtered the opportunities they gave students to engage in the engineering project. For example, Mr. Skelton wrote that the Inclusive Class was "successful in carrying out the first experiment after watching me do it" but the General Class was "successful in designing the experiment and carrying out the experiment." So while students in the Inclusive Class completed the science experiment by simply copying what the teacher modeled, the students in the General Class had the opportunity to understand the design of the experiment before engaging in the experiment.

Student engagement in engineering activities

Teachers also reflected on struggling to encourage students to engage in the whole-class discussion, either student-to-teacher or student-to-student. Ms. Banet, for example, felt that it was extremely difficult to support students to respond in engineering-based discussions because the content was "too high level" based on her understanding of students' prior knowledge in each class section. Ms. Banet also said that there needed to be "more of a buildup throughout the year" to encourage student talk. Teachers reported that they felt that facilitating student-to-student discourse during whole-class discussions was particularly challenging in the Inclusive Class, due to perceived differences in student ability level. For example, Ms. Banet commented that she struggled to facilitate student-to-student discussions with "two students who are on two different levels and can't have an equitable relationship." Teachers reported that these difficulties may have related to a majority of whole-class discussions in the Inclusive Class consisting mostly of teacher talk. Additionally, teachers also reported that they struggled to support student engagement in the Inclusive Class. Ms. Banet stated that she thought that the students were "kind of shutting down from the rigor of [the engineering project]."

Teachers' modifications to the engineering project

To address the teachers' belief that students in the Inclusive Class needed more support to engage in the engineering project, teachers reported that they began to test out activities in the General Class and then modify them for the Inclusive Class by choosing to intentionally put the Inclusive Class a day behind the General Class. Doing this then allowed time for the teachers to customize their support before implementing the engineering project with the Inclusive Class. According to the teachers, these modifications took the form of skipping questions that they would have asked in whole-class discussion, truncating or removing specific activities, and leading students through other activities in whole-class discussion rather than having students complete activities individually as suggested in the Teacher's Guide. For example, Ms. Banet reflected, "A couple of the slides I didn't think kids would understand. So we cut those slides." Similarly, Mr. Skelton wrote in his survey that,

> We used direct instruction more than suggested with [the Inclusive Class], leading them through the initial values and change rules and we guided students in [the Inclusive Class] through the engineering design more so than the [Teacher's Guide] suggested. We also skipped over the remainder of the activity with [the Inclusive Class] for the sake of time.

Thus, the teachers reported implementing the activities differently in the two class sections. Pacing concerns may also have contributed to this dilemma, which then affected how students in the Inclusive Class were supported to engage in activities.

Teachers' verbal support

The teachers also reported ways in which they made substantial changes to their verbal support for the Inclusive Class. In the Teacher's Guide, students were supposed to create their own computational model to test their engineering designs. Instead, in implementation, the teachers modified the activity to try to support the Inclusive Class by verbally leading them step-by-step through programming the computational model in a whole-class discussion. Even with this additional verbal support, the teachers felt that the Inclusive Class struggled to understand how to program their computational models and were running out of time. Mr. Skelton explained, "I felt the class wasn't making enough progress," and the teachers made the decision to move more quickly through the computational modeling activities. So, the teachers verbally gave students in the Inclusive Class the final computational model to use so that they did not have to create it for themselves. The teachers attributed the students' struggle with vocabulary. Ms. Banet stated,

> I think [students in the Inclusive Class] really struggled with the actual coding. So providing them with the working model alleviated a lot of stress. But the kids, I asked them, they said they had a lot of trouble just understanding the actual code. And I think it goes back to perhaps the vocabulary and then us not doing enough of talking about the variables inside the code and how we have to change them and why we have to change them. I think if they had a better understanding of the vocabulary and the variables it would have been easier for them to change them on their own.

Thus, the teachers made changes to their verbal support based on their perceptions of student understanding and to save time which also led to different experiences for students in each class section. Ms. Banet acknowledged that she believed that the Inclusive Class was “short-changed” by these modifications.

Teachers’ struggles to differentiate

In addition to teachers recognizing that the students needed more support with vocabulary, which was not addressed in the Teacher’s Guide, the teachers also reported that they struggled to differentiate between the class sections. For example, Mr. Skelton stated “differentiating for ability level was a struggle for me” and suggested that he could have used additional professional development to prepare for “differentiating this for varied learners.” Additionally, Ms. Banet reflected, “I could use more help in scaffolding for students.” Thus, the teachers felt that they needed additional help in order to be able to offer support that would help all students to engage in the activities intended by the Teacher’s Guide and to provide equitable engineering experiences for all of their students.

Discussion

This case study reveals that teachers’ reported beliefs, emerging from reflective interviews and surveys of implementation of an engineering project, may have related to the teachers having different expectations of student needs which then resulted in teachers modifying activities and supporting students differently to engage in the engineering project. Findings resonate with literature that underscores the importance of teacher beliefs on classroom enactment of curricular materials (e.g., Askew et al., 1997; Gess-Newsome, 2015; Prescott et al., 2019) and extends to engineering projects in inclusive settings.

Reported differences among teachers’ beliefs across the two class settings may have created different experiences with the engineering activities than was intended by the Teacher’s Guide. As a result, the Inclusive Class may not have had as many student-centered opportunities to engage in the activities as planned. For example, teachers reflected on making changes to support student learning in the Inclusive Class for additional support with vocabulary that resulted in whole-class, teacher-led instruction. The teachers also reported that changes to the implementation of the computational modeling activities may have resulted in fewer opportunities for students to engage as the Teacher’s Guide intended. Although students with IEPs are shown to be capable of engaging in inquiry-based, student-centered STEM activities (Therrian et al., 2017), current pedagogical practices for students with IEPs tend to be direct, explicit, and more teacher-centered (Maheady et al., 2018).

Results highlight the tensions that teachers may face when trying to implement student-centered engineering design projects in inclusive settings. Specifically, in line with prior research (e.g., Lachapelle et al., 2014), results show that teachers’ reported beliefs and knowledge from prior learning experiences working with students with IEPs may affect their instructional decisions with engineering curricular materials. Implications include more research into the kinds of beliefs and assets that teachers may bring into classroom implementations of engineering projects for both general and inclusive settings, and potential relationships to instructional decisions and opportunities afforded to students.

Similarly, it is also important to consider the experiences and self-efficacy of pre-service teachers (e.g., Menon & Sadler, 2016; Park et al., 2017) and the supports that they may need to enact engineering design projects in different classroom contexts (Van Haneghan et al., 2015), including inclusive classrooms. For example, pre-service elementary teachers in teacher education programs may need opportunities to engage in engineering design activities themselves in addition to learning pedagogical strategies for enacting engineering projects in both general and inclusive classrooms. This could be particularly important as pre-service teachers build beliefs about teaching, their own self-efficacy in different domains, and pedagogical strategies for supporting all students (e.g., Hammock & Ivey, 2017).

Further, while the teachers in this study did differentiate the project for the two class contexts, they reported not always feeling capable of, or supported in, making modifications to meet the different needs of their students across the two classroom contexts. An implication of these findings is that teachers may need additional support with engineering projects through targeted professional development and educative supports for self-efficacy and pedagogical strategies (Hammock & Ivey, 2017; Park et al., 2017; Yoon et al., 2013), specifically for inclusive settings. Although the Teacher's Guide provided general differentiation suggestions, it did not specifically address how to provide explicit support for students to engage in student-centered engineering practices.

Moreover, other implications include that professional development and curriculum designers may need to consider ways to leverage high-leverage practices for students with IEPs to support all students to engage in engineering activities. For example, Doabler et al. (2021) report on an inquiry-based science curriculum that was designed using principles of explicit instruction that resulted in students outperforming peers with more traditional science instruction. Given that teachers are faced with providing instruction to students with and without IEPs in inclusive classrooms, finding ways to bring together research from these two separate fields is imperative to help support teachers to engage all students in engineering regardless of prior academic achievement and to ensure that individualized student needs do not affect the opportunities given to students to engage in engineering.

Limitations

This is a case study of two elementary teachers with science degrees with deep involvement in the design of the engineering unit. Although we purposefully selected this case based on the teachers' backgrounds, findings may not generalize to other teachers in different settings with different backgrounds. Additionally, we did not have specific information as to the nature of students' IEPs in the Inclusive class. Given the wide variety of IEPs that students may have held, results may not generalize to other settings where students have different kinds of IEPs.

Moreover, teachers' reported beliefs and instructional decisions do not necessarily relate to student learning. For example, while teachers may have reported feeling like they may have been "short-changing" students by changing the way that the project was implemented in the Inclusive class, these more direct and teacher-led supports may have been necessary for students to be able to engage in the activities or access engineering practices. Also, the more explicit supports given to the Inclusive Class may have been helpful for students in the General Class. Future research can explore links from teacher beliefs to customizations to curricular materials to student learning as well as student perceptions of engaging in engineering design projects in elementary settings.

Lastly, this paper does not provide evidence of what actually happened during classroom implementation, but only focused on teacher reflections upon enactment. By doing so, this paper hopes to elevate teachers' voice and beliefs about engineering curricular enactment, highlight how teachers' beliefs can affect students' opportunities to engage in engineering projects, and provide insight into how to support teachers implementing engineering projects in inclusive settings.

Conclusion

In this study, results suggest that teachers' beliefs about students and enacting an engineering project in these two different classroom contexts may have influenced opportunities that students had to understand and engage in engineering practices. Teachers reported making changes to activities based on their perceptions of student understanding and engagement (e.g., Dare et al., 2014; Van Haneghan et al., 2015) and to save time which led to different experiences for students in each class section, specifically a more teacher-centered implementation for the inclusive class. These reports suggest that teachers may need professional development throughout a project rather than just in preparation for a project as well as support from curricular designers and school and district administrators (e.g., Hsu et al., 2011; Margot & Kettler, 2019). For example, close partnerships with curriculum developers may be important such that teachers can ask questions and receive support as questions and challenges arise on a daily basis. Further, school districts can support teachers implementing engineering design through instructional coaches or by pairing teachers who are enacting engineering projects based on their backgrounds and experiences with engineering as well as their self-efficacy. For example, it might be beneficial to pair a teacher with no prior experience in engineering with a teacher who has a higher self-efficacy for supporting students to engage in engineering practices.

While this study focused on two teachers with unique science backgrounds and experience enacting engineering projects, future research should consider a range of teachers with different domain and engineering teaching experiences as well as overall teaching experience (i.e., early career teachers) across K-12 grades. Further, while it is important to enact engineering-focused curricula in formal classroom settings to ensure that all students have opportunities to engage in engineering design, future research could also consider the experiences that students may have with engineering design in informal (i.e., makerspace) settings. Curriculum designers can also consider how to help teachers to offer students a range of experiences in engineering design over time rather than just in specific projects and include smaller activities focused on introducing students to specific skills needed in application of larger projects.

Teachers are engaging in the challenging task of enacting engineering design projects in elementary science classrooms to provide all students opportunities to engage in engineering practices (e.g., Nathan et al., 2010). It is then critical to understand teachers' beliefs to build support for teachers in their implementation of engineering projects, help teachers to meet the needs of their students, and ensure that students have access and support to equitably engage in engineering practices.

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Appendix

Daily Survey and Interview Questions

(1) What do you feel like students were successful with today?
(2) What do you feel like students struggled with today?
(3) What did you feel confident about in your teaching today?
(4) What did you struggle with in your teaching today?
(5) What changes did you make to today's lesson to support students' learning?
(6) Was there anything that came up in today's lesson that you felt like you could have used some additional Professional Development to prepare for?