Student Interest in Engineering Design-Based Science

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Current reform efforts in science education around the world call on teachers to use integrated approaches to teach science. As a part of such reform efforts in the United States, engineering practices and engineering design have been identified in K–12 science education standards. However, there is relatively little is known about effective ways of teaching science through engineering design. The study explores the approaches or strategies used by a sixth grade science teacher to teach science and engineering in an integrative manner. Classroom observations, teacher interview, and student surveys were used to study the features of engineering integration implemented by the teacher and the changes in student interest in science and engineering by participating in an engineering design-based science unit. Findings suggest that the teacher explicitly included practices and core ideas from engineering and science; used an engaging, motivating engineering challenge; and provided students with opportunities to be autonomous. Students engaged in the activities in the engineering unit and their interest level slightly increased. The results suggest that the three strategies that the teacher used to teach engineering and science are important foundations of integrated science and engineering education.

Introduction

The recent educational reports on science, technology, engineering, and mathematics (STEM) education emphasize the need to increase student interest and engagement in STEM subjects so that students develop STEM literacy and pursue STEM related degrees (e.g., National Academy of Engineering [NAE] & National Research Council [NRC], 2014). Previous studies demonstrate that students who show interest in STEM in the middle or high school are likely to complete a degree in STEM fields (Maltese, Melki, & Wiebke, 2014). Yet, several studies also demonstrate that student interest in STEM subjects, particularly, science, declines in fifth and eighth grade (e.g., Osborne, Simon, & Collins, 2003). Thus, providing quality-learning opportunities for students is necessary to help students develop and maintain interest in STEM fields.

Interest has long been a part of science education research. Over the years, various theories of interest have been developed and studied (Krapp & Prenzel, 2011). Gardner and Tamir (1989) suggested that interest is multidimensional and it can be conceptualized based on three components: topics, activities, and motives (e.g., environmental issues, moral issues). Similarly, Haussler and Hoffmann (2002) proposed that topic, context, and activity are three main elements of interest. The literature contains numerous suggestions concerning the curricular features and pedagogical strategies to be adopted by the teachers to increase student interest in science. Ainley and Ainley (2011), for example, showed the importance of science education programs that students find engaging and personally meaningful in developing strong interest in science. In their review of the interest research, Krapp and Prenzel (2011) indicated that student interest level and also interest development in science strongly related to "the perceived attractiveness" of the curriculum content and how it is presented and taught (p. 43).

The importance of developing and maintaining interest in science has been emphasized in the recently published *Next Generation Science Standards* in the United States (NGSS Lead States, 2013). Engineering when used as a context to teach science has potential to increase student interest in science and engineering, as well as learning (NAE & NRC, 2014). To date, a growing number of K–12 students are being exposed to engineering design activities in science classes. There is not a single approach to integrate engineering design into science instruction (Bybee, 2013). However, science teachers, in general, use project-based approaches to develop and implement engineering design activities in which students follow iterative problem-solving method known as engineering design to solve an open-ended engineering challenge (Guzey, Tank, Wang, Roehrig, & Moore, 2014). For example, students design rubber band or balloon powered vehicles following an iterative engineering design process in which they first design a prototype, experiment with the variables to discover ways to design a better prototype and redesign for the fastest vehicle possible (Guzey et al., 2014).

Studies have been conducted to measure student interest in engineering design-based projects and the results are mixed (Guzey, Harwell, Moreno, & Moore, 2016; High, Thomas, & Redmond, 2010; Lachapelle & Cunningham, 2014; Wendell & Rogers, 2013). For example, in Wendell and Rogers' (2013) study, students who engaged in an engineering unit did not have statistically significant favorable attitudes toward science than did students who did not engaged in a project constructed engineering unit. Conversely, students in the intervention group in Lachapelle and Cunnigham (2014) had highly positive attitudes toward engineering after the completion of engineering instruction. The measure of interest in these studies occurred before and after the engineering project; however, no information about delivery of the engineering project, strategies, or techniques used by the teachers is provided in detail. In other words, classroom instruction has been less clear in these studies. As Vedder-Weiss and Fortus (2012) argue, the interest research should focus on teacher practices since they have strong influence on student interest and motivation. Since relatively little is known about pedagogical approaches or strategies used in engineering-based science teaching and how they might influence student interest in science and engineering, the study was designed to address these areas. The following research questions guided the study:

- What strategies of engineering integration are present in a sixth grade science classroom?
- Do these strategies of engineering integration impact student interest in science and engineering?

Literature Review

Engineering Integration

Engineering integration in science education can take many forms. A general principle of engineering integration is the design process in which students identify and solve problems (Brophy, Kelin, Portsmore, & Rogers, 2008; NRC, 2009; NAE & NRC, 2014). The design process supports the idea that there may be many possible solutions to a problem, and it promotes systems thinking and creativity. In addition, the design process is iterative, which allows students to engage in practices such as defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematical thinking; designing solutions, engaging in argument from evidence; and obtaining, evaluating, and communicating information (NGSS Lead States, 2013). Various design curriculum materials have been designed and used in science classrooms (e.g., Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naam, 2004; Guzey et al., 2014; Kolodner et al., 2003). For example, recently, Wendell and Rogers (2013) developed several design focused curricular units called *Science through LEGO Engineering*. Students use LEGO materials to prototype their design solution. Students learn about how to use LEGO construction materials and complete scientific investigations that help them solve the design challenge. Afterwards, students are introduced to the design challenge such as designing energy efficient model houses or musical instruments. Wendell and Rogers (2013) found positive impact of the LEGO units on student learning. LEGO engineering students demonstrated greater science content knowledge when compared to students who did not participate in the LEGO units. This study and others (e.g., Fortus et al., 2004; Guzey et al., 2014) support the idea that design provides a meaningful and motivating context for learning science.

Student Interest

The development of interest in STEM related fields has been well documented in cognitive science literature (Hidi, 1990, 2006). While psychologists have offered various definitions of interest and conceptualizations of interest development, they all acknowledge the critical role of interest in learning and achievement (e.g., Dweck, 2000; Hidi, 1990; Hidi & Renninger, 2006; Renninger, 1992; Schiefele, 1991). According to Dewey (1913), interest "is a name for the fact that a course of action, an occupation, or pursuit absorbs the powers of an individual thorough going way" (p. 65). He proposed that interest has three characteristics: (a) it is dynamic, (b) it has personal meaning, and (c) it is object related. Dewey identified interest with concerns or affairs and argued that being interested in an object requires a person to actively be concerned with it. An interest in an object is a result of its recognized value or worth. Dewey's book *Interest and Effort in Education* (1913) influenced many researchers; his ideas about interest as a phenomenon that is based on person-environment or person-object relationship are generally accepted by many interest researchers (Hidi, 1990; Hidi & Renninger, 2006; Krapp, Hidi, & Renninger, 1992).

Several researchers have explored ways to increase interest in the classrooms (e.g., Mitchell, 1993; Rotgans & Schmidt, 2011; Schraw, Flowerday, & Lehman, 2001). In his model of interest, Mitchell (1993) focused on classroom activities that influence *catching* and *holding* interest. He proposed that "catching lies in finding various ways to stimulate students, whereas the essence of holding lies in finding variable that empower students" (p. 426). He identified group-work, computers, and puzzles (magic puzzles, mind-teasers, etc.) as catching facets and meaningfulness and involvement as hold facets. In the context of science education, few studies have been conducted on student interest developed by classroom activities (e.g., Hoffmann, 2002; Palmer, 2009). Palmer investigated student interest and its sources in inquiry lessons and found that student interest varied throughout a single 40-minutes inquiry lesson included mini activities (note taking, demonstration, proposal, experiment, and report). Classroom demonstrations that the teacher performed and the experiments that students completed highly increased situational interest while student interest was decreased when note taking. Swarat, Ortony, and Revelle (2012) took a more holistic approach to study student interest in science classrooms. In their study with a large group of middle school students, the authors focused on the influence of content topic, activity, and learning goal on student interest. Not surprisingly, findings show that hands-on activities and technology-based activities are the types of activities that influence student interest in science. Finally, Bolte, Streller, and Hofstein (2013) suggested three strategies in order to foster student interest to learn chemistry. First, teachers should connect content to contexts or socio-scientific issues which are interesting to the student. Second, it is important to use a variety of pedagogical strategies to provide differentiated learning opportunities to students. Third, teachers should take students' individuality into account since interest in any concept or activity change from student to student. Taken together, these studies show that student interest is tied to the classroom activities and instructional strategies.

Methods

The study was descriptive in nature and used an embedded, single case study design since one unit of analysis included practices of the science teacher and the second unit of analysis focused on students (Yin, 2009). This case study approach was chosen because it allows for an in-depth exploration of the engineering and science integration at a specific time period. Further, the case study approach particularly suits this study since student interest is uniquely tied to the engineering-based science unit and classroom context, which demonstrates that the phenomenon under study cannot be separated from the bounded context.

Participants

The study was conducted in three science classrooms of one science teacher who attended a professional development project. Convenient sampling technique was used to identify the teacher–participant, Emilie (pseudonym). Emilie developed a curriculum unit through collaboration with another teacher in the professional development program. While the majority of the teachers developed curriculum units that were mostly modification of the materials presented at the professional development program, these two teachers developed a unique curriculum unit thus identified for the study. The unit was designed to teach science and engineering in an integrated manner while motivating students to learn engineering and science. We aimed to include both teachers in the current study; however, we were not able to collect the complete set of data from the second teacher's classrooms. The second teacher could not teach several lessons of the unit due to health problems. A substitute teacher covered those days. Since teacher practices are a critical part of the study, we decided to eliminate the second teacher from the study.

Emilie and 75 students (37 females and 38 males) in her three sixth-grade science classrooms had agreed to participate in the study. Emilie had a middle school science teaching certificate and had taught science a little over five years in her current school. The school's population was highly diverse. During the time of the study, 65% of the students qualified for free-reduced lunch and 65% of the students came from minority groups in Emilie's classrooms. The three classrooms had the similar student profile. According to Emilie, students did not engage in any engineering design–based science activities prior to the study.

Professional Development Program

The professional development program that Emilie participated in aimed to help grades 4–8 science teachers incorporate engineering into their science teaching. The project offered teachers a three-week-long summer institute and support in the form of coaching and mentoring throughout the academic school year to successfully use engineering design and practices in science instruction. In the first week of the summer institute, teachers explored engineering design and engineering practices through completing a variety of activities. An engineering education faculty member and an engineering faculty member led this first week. The second week of the summer institute focused on learning science through engineering activities. Three science content area sessions were offered and teachers chose one area to focus on: physical science, life sciences, and earth science. In week three, teachers learned about designing engineering design based science units. Teachers in teams of two to three developed their own curriculum units that integrated science and engineering. Science and engineering education faculty members assisted teachers during the curriculum design process.

Table 1
Unit Overview

Lesson	Objective
Lesson 1: Fisherman of Ecuador	To introduce the engineering challenge and set up the context
Lesson 2: Density and insulators	To conduct experiments to study how the density of water affect melting rate of ice and to explore insulators
Lesson 3: Testing materials and building a prototype	To study what type of freezer materials are best for slowing heat transfer, to sketch and brainstorm ideas for the solution, and to build freezers considering heat transfer, price, and mass constraints
Lesson 4: Testing prototypes	To test products (freezers) underneath a heat lamp, using the class recommended solution of ice
Lesson 5: Redesign and report	To improve design and write a report to the client

Teachers also had an opportunity to pilot their curriculum units with small groups of university summer camp students, which helped them revise their unit. When teachers went back to their own classrooms, they implemented their revised unit with their students. The project provided extensive cognitive and content coaching throughout the academic year. Monthly meetings were held to discuss areas of teaching that teachers wanted to improve.

Data Collection

As Yin (2009) points out, case study data can include both qualitative and quantitative data to capture rich information. The qualitative data sources for this case study were video recordings of classroom instruction and a semistructured interview with Emilie. The quantitative data source included a student interest survey. Classroom observations occurred during the implementation of the science unit and the observer recorded the instruction. Extensive field notes were taken during the observations. The science unit included five lessons and implementation took twelve 50-minutes class periods. Several state science standards were addressed in the unit: Physical science (energy and matter) and engineering (understandings about engineering and engineering design). We observed and videotaped one of Emilie's three classrooms throughout the whole unit. As a requirement of the professional development program, Emilie rigorously followed the detailed lesson plans in every single classroom where the unit was implemented (see Table 1 for the overview of the unit). An electronic teaching log file was also filled out each day to document what was implemented and how much time spent on a subject to make sure what we observed in one class represented what went on also in other classrooms.

We interviewed Emilie after the completion of the unit. The interview data was used as a secondary data source to support the classroom observations. The interview focused on Emilie's experiences of designing and delivering an engineering focused science unit, engineering and science instruction, student interest and motivation, and possible modifications that need to be made to make the unit more effective.

We administered a presurvey and postsurvey to the student-participants at the beginning and immediately after the completion of the unit. From 75 students, 62 of them completed both presurveys and postsurveys. The survey was developed by the authors for the larger study of the project to measure student attitudes toward STEM and interest in STEM (Guzey, Moore, & Harwell, 2014). The survey was administered over 600 students for the validation study. The Cronbach's alpha for the survey was .91. The survey includes 28 items. There are four items that specifically aim to measure student interest in science and engineering. These items focused on positive affect and willingness to learn: *I enjoy learning science, I enjoy learning engineering, I am interested in taking more classes that involve science, I am interested in taking more classes that involve engineering.*

Student participants completed the whole survey but for the purposes of the present study, we focused on only the above four items in the survey. Students were asked to think about specifically the engineering based-science unit and the activities that they completed in the unit as they respond to the post survey questions. Thus, their responses to the post-survey were based on their experiences in the unit.

Data Analysis

We used an inductive-deductive approach to analyze the video data. We viewed the video recordings several times and then transcribed them. We read the transcripts and field notes from observations and then summarized each lesson by defining what Emilie and her students did.

Three researchers were involved in this process and researchers met regularly to share and discuss the summaries of classroom implementation. This process enabled the researchers to document when and how students engaged in the engineering design and science practices throughout the whole unit. We mapped out the instructional path by documenting when the engineering, science, or mathematics instruction occurred in each class period and how much it took. In few cases, the science and engineering instruction merged or blended, we then chose the major focus of the lesson or activity to document.

Afterward, we identified and created descriptive codes (Saldana, 2013). The descriptive codes largely focused on engineering design process (e.g., constraints, plan). The codes were clustered together to develop major categories (e.g., understanding the engineering challenge, building science knowledge). We met several times to discuss the codes and wrote short description for each. Next, two coders individually coded a video from lesson five (Re-design, lesson 5, day 10) and agreement reached 74% on the coded data. Differences were resolved through discussion. Based on the first cycle coding, some codes were eliminated (e.g., communication) or rearranged. We then coded another video individually and reached 85% agreement. The remaining ten videos were coded by the first author by using the coding scheme. Finally, categories were grouped into themes. Interview data was analyzed using an inductive-deductive approach as well (Saldana, 2013). We coded the interview data after coding the video data and used the coding scheme that developed to analyze the video data.

We analyzed the student survey data using Wilcoxon signed ranked test (Marascuilo & McSweeney, 1977). Wilcoxon signed ranked test is a nonparametric paired t test. The data met all the requirements to run the test: The data was measured on an ordinal scale, meaning that responses scaled from Strongly Disagree = 1 to Strongly Agree = 5. and included match pairs, and the distribution of the differences between the predata and postdata was approximately symmetrical in shape.

Results

The study explored the engineering integration strategies present in a science classroom and influences of those in student interest in engineering and science. The sections that follow first discuss the results from the video analysis of classroom instruction and the interview, which were organized in three major themes. Second, the findings from the survey used to measure the change in students' interest as a result of participating in the engineering design-based science unit will be presented.

Using an Engaging and Realistic Engineering Design Context, Criteria, and Constraints

Context. Emilie expressed that she wanted to find a "background story" or context for the engineering challenge that is realistic and meaningful for the students. While Emilie was searching for information on the Internet about real world engineering challenges, she found information about Lighthouse Foundation sponsoring projects that aim to solve problems in the marine locations. One of the projects that the foundation has supported since 2005 is for the Ecuadorian fishermen. Briefly, the project's goal is to develop better fishing methods and working processes for the fishermen in Ecuador. Fishing is highly significant in the area since there are not many other opportunities for earning an income. In the context adopted from this real-world problem, students in Emilie's class were asked to help fishermen who take their small boats over to the islands in long distances, which have many unusual and tasty fish. The fishermen need to bring ice with them in a cooler that can stay cold long enough to bring the fish back unspoiled. Thus, students were asked to determine the best type of ice to use and to design a cheap, nonelectric freezer or cooler.

Emilie created a design brief that explains the engineering challenge and what the client asks students as engineers to do to help solving the problem. This fictional letter was sent to students from the Lighthouse Foundation. The letter states the need as a clearly defined challenge in the form of a statement with criteria. As Emilie read the letter to the students in lesson 1, she elaborated certain pieces such as the realistic feature of the problem and the need to work within the clients' needs. To push the motivation even further, during the class discussion about the letter mentioned above, Emilie emphasized the need or want by stating that the fishermen in the area need help because fishing is the *only* way that they can make money to support living. The following class discussion demonstrated how Emilie emphasized the importance of helping fishermen and drew out the connection between lives of fishermen in Ecuador and the engineering challenge.

> Emilie: How does this project help the area?
> Student A: More fish equals more money.
> Emilie: Yes, so more fish equals more money. They are able to sell more obviously if they are able to keep more fresh. . .Why is fishing important in this area? If it is not working out for them why can't they go somewhere else?

Student B: 90% of the people are fishermen.
Emilie: Yes, it is almost the biggest occupation in the area. 90% of the people are fishermen. That is huge. . . You cannot just say, hey it is not working out, move to something else. There is not really much in the area.

The point was very well articulated; the fishermen really need students' help to survive.

Criteria and constraints. To share the *criteria and constraints*, which are the requirements and restrictions of a successful freezer, Emilie created a letter that explains the engineering challenge and what the client asks students as engineers to do to help solving the problem. Emilie stated that "[Cost] is a constraint that you're working under. . . In the real world, you can't just use whatever materials you feel like using. Things cost money. . .Engineers have to meet certain budgets. They can't just go spend whatever they feel." Emilie shared the cost of each material that students can use to build their prototypes and then she explained that students' design must cost less than or equal to $215 in order for them to build and test it.

Students in groups brainstormed ideas for their first design and chose materials (e.g., cotton ball, felt, aluminum foil) to use and they determined the cost of their design. Emilie also gave students a refund option. If students purchased a material but ended up not using it as they build their prototype, they could get a refund. According to Emilie, students "love" the constraints, particularly the constraints on cost. She stated that "I'm thinking about getting paper money for them next year because they were so excited about [budget]. And the refund, they were so funny about it."

Applying Science to the Engineering Challenge

Emilie stated that she wanted students to learn science through engineering design and apply science to solve the engineering challenge. She expressed that the science activities should be "so lab based and hands-on" to "engage students more" and help students to solve the engineering challenge. Emilie aimed to help students to understand that engineering and science are connected early in the unit. Thus, she started the first lesson, introduction to the engineering challenge, by asking students what engineering is and what engineers do at work. Students came up with responses such as "solving problems" and "analyzing data." After a short discussion about engineering, Emilie introduced an engineering design process that includes six steps: identifying the problem, conducting research, making a plan, implementing the plan, testing, and redesigning. Emilie explained what each step means and emphasized that the design process is iterative. Emilie strategically connected engineering design and science by telling students the research phase of the engineering design is the scientific investigation part. Students completed several inquiry investigations to learn about density and insulating properties of materials. Students test their freezers underneath a heat lamp, using the class recommended solution of ice. They record initial mass and final mass of ice to share with the class along with cost. The class discussed the results of the different materials and designs before redesign.

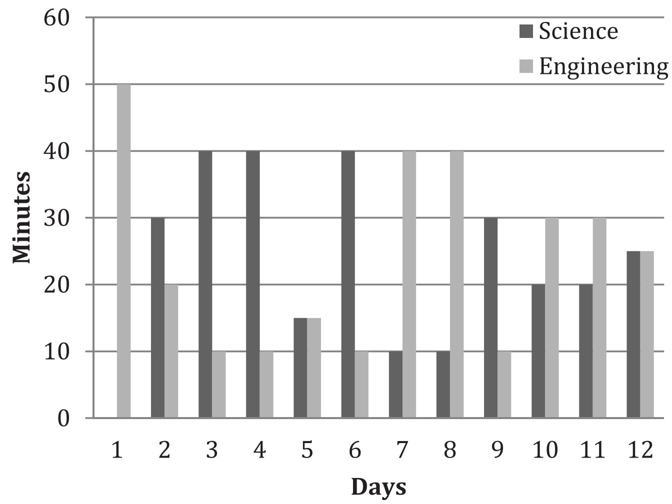

Figure 1. Time spent on science and engineering in the unit.

Figure 1 shows how much time Emily spent on engineering and science in this unit. Emilie introduced the engineering design challenge at the very first day of the unit, days 2–6 of the unit were mainly dedicated to science lessons while the engineering challenge was reminded to the students every single lesson, days 7 and 8 focused on engineering design and last three days (days 9–11) of the unit focused on both the engineering design challenge and targeted science concepts. In day 12, students wrote a letter to the client. The place of engineering in this unit shows the approach to integration of science and engineering that Emilie applied.

Providing Options and Choice for Engineering Solutions

As students design, build, and test their engineering solutions Emilie provided students with opportunities to be autonomous. Students were allowed to make choices for their prototypes, thus they had control or ownership over their engineering design. The students were able to make choices over freezer design. They were encouraged with their groups to select different materials within the budget constraint and to choose the shape and design of the freezer. Emilie limited the amount of leading language she used to influence the students to choose any one material, design, or price. Instead, she taught the scientific information behind the materials and the implications of the potential choices the students could make.

> Here's the materials that you need to choose from. Now listen, there's a few things to think about, there's no restriction on your size, right now, there's no restriction on your weight, but remember, we're trying to build this for a fisherman's boat, light weight is good. But also, if your group loses the same amount of mass as this group, but your option is cheaper, we're going to want to go with that idea. So keep that in mind, spending \$215, which is your budget, doesn't necessarily mean that yours is the best freezer.

Emilie ensured that the students had all the information that they needed to make informed decisions about their freezers, but she never led them in one concrete direction.

Emilie also asked students to write a letter or report to the client when they completed their redesign and final test. Students were asked to write a one-page letter providing information about the mass of the final design, cost of the design, materials used and why they used them, the type of ice used, and total mass lost of the ice. Emilie also asked students to justify their choice of the type of ice and freezer design using their data. Emilie used the letter as an end of unit assessment to evaluate student learning of engineering design, density, and heat transfer. Writing a letter to the client, Lighthouse Foundation and fishermen, also promoted student ownership. Students wanted the fishermen to use their "own" recommended design. Thus, writing a letter was a way for them to share all their work with the fishermen. Students found the idea of a letter to the client so realistic that they asked Emilie several times if and when she will send the letters to the Lighthouse Foundation and fishermen.

Student Interest

Wilcoxon Signed Rank Test for matched pairs was used to assess whether $N = 62$ sixth grade students' interest were modified by participation in this engineering design-based science unit based on the ranked order magnitude of the change between their before and after responses. Students in Emilie's class scored an average of 16.17 ($SD = 2.84$) on the pre-survey and 17.08 points on the postsurvey ($SD = 2.17$). Interest levels after participating in the engineering-based science unit were statistically higher (Mdn = 17.00) than the interest levels prior to participating in the unit (Mdn = 16.5). Results revealed a significant difference in interest after the students participated in the engineering design-based science curriculum, $z = -1.99$, $p < .05$, with a small effect size ($r = .17$) (Cohen, 1988). The sum of the positive ranks (722. 00) were larger than the sum of the negative ranks (359.00), showing that the unit provides opportunities increasing student interest in science and engineering.

Discussion

The study aimed at identifying strategies of engineering integration in a sixth-grade science classroom (RQ1) and if these strategies influence student interest in science and engineering (RQ2). Examining the teacher's strategies in this way is critical in providing insight to classroom instruction that would lead students to develop and maintain interest. The analysis revealed Emilie's integration of engineering into her science teaching and the positive effects of it on student interest in science and engineering.

Engineering Integration Strategies

The examination of the strategies for the integration of engineering showed that Emilie used three distinct strategies. First, she used a realistic engineering design context, criteria, and constraints. The meaningful context and clearly defined criteria and constraints made the engineering design challenge engaging. Other researchers have shown the impact of using engaging context on student interest (Bolte et al., 2013; Hoffmann 2002; Schraw et al., 2001). Ainley and Ainley (2011) indicated the importance of making science more engaging and meaningful for students to increase their interest in science. In the case of engineering, the engineering context should be "accessible to the learners, difficult enough to be interesting and rich enough to provide links to the breadth of content knowledge to be learned" (Brophy et al., 2008, p. 372). The context of Ecuadorian fishermen who really in need of help in finding ways to keep fish fresh is realistic and the freezer design is complex enough for the students to solve. Second, Emilie explicitly integrated engineering into science instruction. Instead of the engineering just being an add-on to the science, the two subjects were necessary to each other for this activity. Emilie did not use engineering to "make things interesting" in her classroom instead she planned to arouse student interest in science and engineering by explicitly including engineering in the science unit. As Dewey (1913) suggested simply adding interesting details or materials to instruction can make learning materials more interesting but it may decrease attention from content being taught. In Emilie's classroom, the connections of the science activities and the engineering challenge were purposefully mentioned and presented in almost every single class during the implementation of the unit. Explicit integration of engineering is critical in supporting students building knowledge, skills, and interest within science and engineering (NAE & NRC, 2014). To help students to make connections across science and engineering, the scientific investigation part of the unit was posed as the research phase of the engineering design process, and this layering of engineering and science made the activity more engaging for the students. Previous research also suggests that providing students opportunities to involve in student-centered activities positively affect student interest and motivation (Mitchell, 1993; Rotgans & Schmidt, 2011; Swarat et al., 2012).

Third, Emilie provided students with opportunities to take ownership of their engineering design. Students engaged in an engineering task involving in intellectual creativity. The design task was challenging but it was not overwhelming in a way that caused students to give up or feel incompetence. The students were given all the information they needed to create their freezers but were not told that there was one right answer for designing a freezer. The idea that there were multiple solutions for the problem deflected feelings of failure. Emilie reminded the students of the constraints they had to work with and that real engineers have constraints as well, but she avoided leading the students in one specific direction for the design of their freezers. Students experienced freedom to make choices for their design. For example, Emilie encouraged and supported students to use and test different materials to successfully build a freezer. Choice helps increase the feeling of autonomy and leads to increased interest and motivation (Schraw et al., 2001) and in this unit, students had control of what and how to solve the engineering problem.

Student Interest in Science and Engineering

The quantitative findings showed the difference between the pre- and post-interest survey results of the students. Students became more interested in science and engineering after participating in the engineering design-based science unit. This is in line with Lachapelle and Cunningham's (2014) observation that students who completed engineering curriculum improved interest in engineering. A similar finding was reported by Guzey et al. (2016), who investigated the relationship between the engineering curriculum and students' science content learning, attitudes, and interest. The authors found that students who had participated in the engineering curriculum rated the engineering experience very highly. In our study, we found a statistical difference between pre- and post-student interest. However, it is important to interpret the findings of increased student interest with caution. The level of change in student interest was not large. Our findings revealed that students enjoyed learning science through engineering design and responded positively to the integration of engineering into their science curriculum. In general, findings from studies of interest suggest that interest impacts learning, goal setting, and attention (Dweck, 2000; Hidi & Renninger, 2006). Teachers can help students develop and sustain interest by providing quality-learning opportunities for students (Hidi, 1990, 2006) and promoting a sense of autonomy (Hidi & Renninger, 2006).

Conclusion

The study provided insight into strategies for implementing engineering in science classrooms in an effort to help science teachers more effectively structure engineering instruction in K–12 classrooms. Engineering design is inherent in engineering integration. Using engaging and motivating context, criteria, and constraints; having students apply science to solve engineering challenges; and promoting autonomy during engineering design instruction can help students increase their interest in science and engineering. There are various approaches to engineering integration and effective strategies have to be documented to support other teachers in their efforts to infuse engineering into science instruction (NAE & NRC, 2014). Engineering is new to many science teachers and developing and implementing engineering design-based science units requires exposure to engineering design and practices. Effective use of the design-based pedagogy has beneficial effects on the development of student interest in science and engineering.

Future Research

Many questions have yet to be answered about engineering integration in K–12 classrooms. A variety of engineering integration strategies should be evaluated to find the impact of engineering on student interest in STEM fields. Future research should also include longitudinal studies to understand the long-term effects of engineering integration in science classrooms on student interest in STEM disciplines. Longitudinal studies could shed new light on how to better support students to develop and maintain attitudes favorable to STEM fields and enhance student achievement in STEM.

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