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Manifestation of Integration into Practice: A Single Case Study of an Elementary Science Teacher in Action (Research to Practice)

Farah Faruqi

Farah Faruqi is a Ph.D. Candidate in the STEM Education program at the University of Minnesota. She earned her bachelor's and master's degree in biological sciences from Pakistan. Her research focuses on integrated STEM learning, teacher practices, and online learning. She is interested in integrated STEM curriculum development, teacher practices, and teacher professional development to support STEM learning.

Khomson Keratithamkul (PhD candidate)

Gillian Roehrig (Professor)

Benny Mart Hiwatig

Benny Mart Hiwatig is a PhD candidate in the STEM Education program at the University of Minnesota. He earned his bachelor's degree in Secondary Education and took master's coursework in Chemistry Education in the Philippines, where he also taught high school chemistry. He is currently involved in a research project that aims to develop an observation protocol for STEM lessons and relevant training materials that are directed at improving the quality of STEM instruction in K-12 spaces. His primary research interests include assessment of student learning in STEM contexts, exploration of how integrated STEM is enacted in the secondary level (especially in chemistry classes), and assessment and promotion of students' conceptual understanding of chemical concepts.

Elizabeth Forde

Nilay Ozturk

University of Minnesota

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Introduction

The inclusion of engineering in K-12 science education is growing increasingly common in the United States through *A Framework for K-12 Science Education* [1] and the *Next Generation Science Standards* (NGSS) [2]. The framework articulates the role of engineering as a vehicle for students to learn scientific concepts and to engage them in meaningful learning [1]. With the adoption of recent science standards (i.e., NGSS); teachers are faced with the task of integrating engineering design into their science instructions and making connections between Science, Technology, Engineering, and Mathematics (STEM) disciplines in their instructions. This is partly daunting for elementary teachers, given their minimal preparation in engineering [3].

While STEM education is recognized by educators and research communities as important, there is no common understanding or agreement on the nature of STEM education as an integrated endeavor. Consequently, K-12 teachers have limited guidelines and teaching models to follow regarding how to teach integrated STEM [4].Without clear guidelines, the implementation of integrated STEM education comprises a broad range of approaches [5]. Because of this, it is essential to understand the ways teachers use integrated STEM approaches in their instructions. Such teaching experiences will provide valuable perspectives on how STEM integration is represented in practice. Thus, the goal of this study is to examine how an elementary school teacher enacted STEM integration in her science classroom. Specifically, this study aims to answer the following research questions: a) In what ways does an elementary teacher make connections between different STEM disciplines?, b) How did contextual integration manifest in her integrated STEM implementation?, c) How did content integration manifest in her integrated STEM implementation?

Conceptual Framework

Integrated STEM education can be modeled and defined in a number of ways; some features are common and exist across different models. This work is driven by Roehrig and colleagues' framework [4]. This framework includes seven key characteristics of integrated STEM: focus on real-world problems, centrality of engineering, context integration, content integration, STEM practices, twenty-first century skills development, and STEM careers awareness. This framework views integrated STEM as contextualizing learning in real-world problems, using engineering design challenges to contextualize student learning of science, and providing students with a realistic representation of how STEM knowledge is used beyond K-12 education.

Engineering is considered a central element of integrated STEM [10], [11]. The teacher frames the activity from a real-world problem perspective, which helps situate students' learning in STEM in an authentic context to make learning relevant to students. As students engage in an engineering design challenge to develop solutions to an overarching real-world problem, they draw upon the knowledge, skills, and content from multiple disciplines [12], [13]. Research shows that using real-world or authentic problems as a context for learning in integrated STEM spaces motivates students to learn STEM content [6]. Furthermore, engaging students in learning through authentic engineering design problems improves student interest in science and engineering [14], [15].

Literature review

The problems we face in this society are complex in nature and require the integration of multiple disciplines, concepts, and skills to solve. Therefore, educational reforms advocate for a change in how these disciplines are taught in schools, with an emphasis on the integration between STEM disciplines to teach students problem-solving skills and to model real-world problems [1], [8]. Researchers agree that integrated STEM instruction should use real-world contexts to engage students in authentic and meaningful learning [6], [9] that reflects the interconnectedness of the four STEM disciplines.

Despite the pedagogical drive for more integrated STEM in K-12 grade levels, research on STEM integration shows that there is no single definition or conceptualization of what STEM integration should look like [5], [8]. Various broad definitions of integrated STEM education exist in the literature and policy documents. For example, Moore, Stohlmann, and colleagues [10] broadly defined integrated STEM education as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38). Similarly, Kelley and Knowles [6] defined integrated STEM education as "the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (p. 3).

Since there is no universal definition of integrated STEM out there, it makes implementation even more challenging; however, there is an emerging sense of agreement around several features that are indicative of quality integrated STEM instruction (see Table 1).

Table 1 Key Features of Integrated STEM and Supporting Research

Feature of Integrated STEM	**Supporting Research**
Learning situated within a real-world context	[6], [9-10], [16], [19-20]
Student-centered pedagogies	[6], [9-10], [16], [19-21]
21st century skills: Teamwork, communication, and critical thinking	[10], [17-19]
Connections between STEM Disciplines	[6], [17-19], [21-23]

The inclusion of engineering into K-12 science classrooms is the way to integrate multiple STEM disciplines, given the interdisciplinary nature of the problems we currently face in this world, and the need to engage students in authentic learning to solve real-world problems. STEM policy documents [1], [2], [24] highlights the importance of engineering. Some scholars (e.g., [7], [10]) suggested that infusing engineering context or problems in an integrated STEM curriculum can be central for integration. Additionally, Kelley and Knowles [6] emphasize that engineering design can "provide the ideal STEM content integrator" (p. 5). Engineering can be viewed as a critical link to develop integrative STEM curricula and linked to several efforts to teach STEM subjects in an integrated manner [8].

The primary rationale to include engineering in science instruction is to enhance students' science learning [8], [25]. Furthermore, science learning can be enhanced by giving students an opportunity to apply science knowledge and also provide an authentic context for learning through an engineering design approach [6]. From this perspective, engineering is introduced as an "iterative process that starts with identifying the problem and takes into account the identified constraints and meets the criteria for desired outcomes and ends with the solution" (p. 6-7) [26]. Typically, engineering-focused curricula incorporate design challenge to situate student learning. An engineering design challenge (EDC) involves a fictitious client with defined criteria and constraints to engage students in problem-solving. Students work in teams to build a prototype, test, evaluate, and communicate the solutions to the client. This process allows students to use scientific knowledge, employ computational thinking skills, and collaborate with others to co-construct knowledge related to design solutions.

Within K-12 classrooms in the United States, engineering is most commonly integrated in science classrooms through the *NGSS*, with the most common approaches to integrated STEM generally taking two forms: content and context integration [10]. In content integration, a single unit or lesson includes learning objectives from multiple STEM disciplines. Research highlights that content integration can be achieved through multidisciplinary, interdisciplinary, or transdisciplinary approaches [27] despite having multiple approaches presented in research, there is an agreement that one approach is not superior to another [28]. On another hand, context integration involves contextualizing learning objectives from one discipline in context from another discipline to provide a context that creates meaning, provides relevance, and serves as a motivator for students to learn the primary content [10]. By contextualizing learning through real-world engineering problems, these integrative STEM approaches have been shown to help students better learn and apply science knowledge [10], [29].

The crosscutting concepts and core ideas presented in the framework of K-12 science education stress the importance of argumentation; one of the essential practices is on engaging students in arguments from evidence. The *argument* practice is described differently in science and engineering contexts. For example, in science, the argument is used to make and support claims about natural phenomena; in engineering, it is used to develop the best possible solutions to engineering problems [1]. Reaching conclusions in science is independent of context, but in engineering, the conclusions are based on the needs and demands of a particular client. In the real world, scientists and engineers engage in the argument practice by using evidence, but the underlying reasons are different [30]. Engineering allows the use of science and mathematics, but it requires consideration of design criteria (e.g., performance, safety) and constraints (e.g., budget, client's needs, materials) [1].

Additionally, many scholars (e.g., [10], [30-32]), agree that engineering experiences can develop students' understanding of the various roles of engineering in shaping the world around them, and how mathematics and science knowledge can be contextualized through engineering to enhance students' motivation and achievement. Teachers play a critical role in contextualizing students' learning and making connections amongst the STEM disciplines visible to students. Since research on the nature of STEM integration is limited, we seek to expand upon this literature base to better understand how elementary teachers incorporate and implement engineering design in their science classrooms to integrate content and context.

Methods

Research Design

A single case study design was employed in this study to examine how an elementary teacher used engineering design-based activities to engage and to teach science content in an integrated STEM unit to students. According to Yin [33], a single case study is best used if the goal is to examine a complex phenomenon, with the focus of the study on a single person, thing, or group. The boundary of this single case study is one integrated STEM unit taught by Ms. Ashley. This qualitative research design was selected because it allowed for an in-depth exploration of an integrated STEM unit implementation [33].

Context

The data in this study came from classroom observations of Ms. Ashley's elementary science classroom where she implemented an integrated STEM unit. Classroom videos were collected during the third year of a 5-year NSF-funded research project; teachers were videotaped during the implementation of their STEM units with each video corresponding to one class period (approximately 45 minutes).

Participant Context. Ms. A, a white female teacher in this study, had less than five years of teaching experience. She worked at an urban Midwestern elementary school with a diverse student population. More than 90% of the students at this school were students of color. Furthermore, more than half of the students at this school were English language learners and over 70% had access to free and reduced lunch.

Curriculum Context. Ms. A implemented an integrated STEM unit called *Claw Game*, which she co-developed with a team of teachers and educational researchers as part of a large NSF-funded project. Within the unit, students designed and tested an electromagnetic claw for an arcade game, given a set of criteria and constraints provided by the client. Students learned and applied scientific concepts surrounding magnetism and electromagnetism to their design solutions. Client letters and memos were provided to students throughout the unit. This unit comprised seven distinct lessons (see Table 2), each of which was intended to take at least one 50-minute class period. In this study, the unit was implemented for 15 class periods, but only 14 days were observed and recorded.

Table 2: Lesson summary of the claw game

Lesson	Lesson focus	Lesson summary	Connections to the NGSS Unit Standard
1	Engineering	**Problem-Scoping:** At the beginning of the lesson, students are introduced to the client and the engineering design challenge (EDC) via a client letter. They review the engineering design process and engage in problem-scoping and learn the criteria and constraints from the client letter.	3-5-ETS1-1
2	Science	**Science Investigation:** In this lesson, students learn background information on magnets and magnetic materials. Students investigate different aspects of electromagnets that affect the	5-PS1-3

		strength of the electromagnet. They identify and select a variable to test in the following lesson.	
3	Science	**Science Investigation:** In this lesson, students investigate different aspects of electromagnets that impact the way magnets work. Students work in their small groups to carry out an experiment, testing how the number of coils affects electromagnet strength. They graph their data and write claims supported by evidence about the effect of coils on electromagnets.	3-5-ETS1-1 3-5-ETS1-3 MS-PS2-3 MS-ETS1-1 MS-ETS1-2
4	Science	**Science Investigation:** In this lesson, students carry out experiments to test variables that affect the strength of an electromagnet. They identify patterns in their data and create a poster to share their experimental results with the class.	3-5-ETS1-2 3-5-ETS1-3 MS-PS2-3 MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4
5	Engineering	**Plan and Design:** In this lesson, each team of students chooses another variable to test. They then collect data and create visual displays to look for patterns in their data. Using the information they have learned about electromagnets, students design and build a prototype electromagnet for the client. They then test their design to see how many washers it can pick up, learn about other groups' designs, and reflect on ways to improve.	5-PS1-3 3-5-ETS1-3 MS-ETS1-3 MS-ETS1-4
6	Science	**Science Investigation:** In this lesson, students are introduced to a new client's need for a "tag" material to be placed on the toys in the game. They investigate which materials are magnetic and make a recommendation to the client about the "tag" material.	3-5-ETS1-3 MS-ETS1-1 MS-ETS1-3 MS-ETS1-4
7	Engineering	**Redesign and Communication with the Client**: In this lesson, students	3-5-ETS1-2 3-5- ETS1-3

		redesign and retest their new designs based on a new set of criteria and constraints introduced by the client in the previous lesson. They then make a presentation to share their best design with the client, describing the results of their tests and the reasoning behind their design choices.	MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4

Table 3: NGSS Unit Standards with description

NGSS Unit Standards	Description
5-PS1-3	Making observations and measurements to identify materials based on their properties.
3-5-ETS1-1	Defining a problem that includes specified criteria and constraints (i.e., materials, time, or cost).
3-5-ETS1-2	Create multiple possible solutions to solve the problem based on how well each is likely to meet the criteria and constraints.
3-5-ETS1-3	Testing includes plan and carrying out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
MS-PS2-3	Asking questions about data to determine the factors that affect the strength of electric and magnetic forces.
MS-ETS1-1	Taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions while defining the criteria and constraints of a design problem with sufficient precision to ensure a solution that meets the criteria.
MS-ETS1-2	Using a systematic process to evaluate design solutions to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3	Data analysis from tests to determine similarities and differences among several design solutions to identify the best fit to better meet the criteria for a successful solution.
MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Data Collection

During the school year, the participant implemented her integrated STEM curriculum in her own classrooms. For each day of the unit's implementation, the teacher was observed by the researcher who took detailed field notes and collected videotaped recordings (implementation videos) of both whole-class and small-group instruction; memos were created by the researchers as a result of watching these recordings. The detailed field notes were carefully noted down by the researcher on what happened in each lesson including what was said by the teacher or how this teacher made connections between science and engineering explicit to students as a part of the note-taking process.

Fourteen days of the integrated STEM unit implementation were observed and recorded. Data sources included video and transcripts available for analysis. This dataset included approximately an equal representation of science-focused and engineering-focused activities (100 minutes of science and 107 minutes of engineering). Additional data sources included daily field notes, taken by the researcher during the unit implementation and memos written by researchers while watching implementation videos.

Data Analysis

Data sources were analyzed in multiple phases. During the first phase of the analysis, the authors first reviewed the field notes and video-recorded instruction several times, specifically looking at how science and engineering content were represented and integrated and noting instances where the teacher made connections between the disciplines in her instruction. The researchers observed each unit as a whole by identifying and labeling its major parts (e.g. identifying the problem, engaging in science investigation, planning, and designing). This process aided the researchers in identifying the sequence of the science and engineering lessons. The episodes of interest were then identified and transcribed, paying careful attention to the teacher's instruction. For the second phase of the analysis, the researchers selected and discussed one transcript as a group to build a codebook. Once the codebook was constructed (see Table 4), all the researchers then independently coded it. The last step involved coming to a consensus as a group after individual coding sessions.

Using deductive analysis based on Roehrig and colleagues' [4] integrated STEM framework, the initial set of codes were developed, and codes were consistently applied to the data [34]. To answer the research questions we focused on the specific tenets of the frameworks (i.e, context integration and content integration). After reading and coding each transcript individually, then individual codes were discussed to check for places of agreement and disagreement between coders before moving on to reading the next transcript. Codes were repeated across multiple days of implementation.

Table 4: Codes

Codes	**Description**
Context Integration [CXI]	When teachers situate students learning in real-world scenarios through engineering design challenge
Content Integration [CNI]	When a teacher connects content from two or more STEM disciplines (S, E, and/or M)

	Explicit [Ex]	When the teacher makes a direct connection between two or more STEM disciplines
	Implicit [Im]	When the connections between two or more STEM disciplines have to be inferred.

Findings

Our findings revealed that Ms. Ashley integrated STEM disciplines in her lessons in two different ways: context integration and content integration.

Context Integration

Context integration happened throughout the integrated STEM unit, with the client letters being used by the teacher as an integrator. In order to situate student learning, Ms. Ashley utilized the client letters in three ways: to introduce the problems at the beginning of the lesson, to remind students of the client's needs throughout the unit, and as an avenue for students to communicate their ideas and learning to the client.

Client Letter was Used to Contextualize Learning during Problem-Scoping Phase

The client's letter guided her instructions and provided context for students to learn during the problem-scoping phase. During this phase, students were introduced to the engineering design challenge (EDC). They engaged in problem-scoping by discussing and identifying specifics about the design challenge, described by the client in the first letter:

> Our company *Arcade Inc.* has a problem. We design and build arcade games. For some reason, people are losing interest in the game and not playing it as much. We need a new "claw" in hopes that customers will play more. We would like to give you a contract to develop an electromagnetic arm to replace a claw in the game.

This problem-scoping phase took place on Day 1 where she introduced her students to the fictitious client company "*Arcade Inc.*," who tasked students with addressing the design challenge. This introduction was done through a letter from the client and included as part of the teacher's instruction to situate students' learning in an authentic design context. The client letter contained background context and information relevant to the design challenge, including the design criteria and constraints.

Similarly, on Day 2 she stated that they would get further instruction from the company to start the electromagnet investigation. Specifically, she mentioned "in order to figure out how electromagnet works, we're gonna find out what we need to do. This is a memo from *Arcade Inc.*" Furthermore, on Day 3, Ms. Ashley shared the client memo and the instructions the class received from the company, asking this class to come up with a list of things they could change about the electromagnet. She informed the students that they would be:

> creating a new attachment electromagnet arm for the claw game … [and] investigate electromagnet to find out how you [students] can make one [by] doing some experiments to figure out and make decisions on how you want to make your electromagnetic arms.

Not only were the students informed about the design challenge, they were also asked to test the coils to optimize the electromagnet. As shown in the examples above, client letters were used to situate student learning throughout this problem-scoping phase.

Client Needs were Addressed Through Reminders

Another way that the teacher used the client letter in her instruction was to remind students of the context for learning. On Day 2, the client memo stated, "today, we would like you [students] to begin to investigate electromagnets. You need to know how they work before designing it. We would like to know what variables in an electromagnet can be changed to change the way it works." Similarly on Day 4, the teacher again reminded students about the client letter they previously received, which asked them to "complete the first control experiment and to test the number of coils in [their] team" to find out which one would work best for their design solution.

For Day 5 and Day 6, context integration was either momentarily present or lacking. While there was no context integration on Day 5, the context integration was brief on Day 6, as students were simply told "to make the conclusions … [and] report back to *Arcade Inc.* about what you [students] found out because they [client] want to know what your results are." Similarly on Day 9 and Day 10, context integration was also brief. During both of these days, she revisited the client letter by asking students, "does *Arcade Inc.* want their game to be won every single time?"

On Day 11, she revisited the client letter and informed students that the client's company wanted another round of tests to determine the best material for their electromagnet. Unlike Day 11, she revisited the design challenge on Day 12 by asking her students to remind the class about what they had to do. In particular, she asked, "can anyone remind us what *Arcade Inc.* asked us to do?" She then transitioned back into sharing what materials worked best for their electromagnet claw machine and connected them to the client letter by asking "why did they [client] ask you [students] to test that?"

Communicating Back to the Client

Occasionally throughout the unit, students had to communicate back to the client. This communication was most prominent at the end of the unit, as they had to make a video describing their design, justifying why they chose to build it that way, sharing the results of the test, and mentioning the strengths and weaknesses of the design. They were also asked to engage in evidence-based reasoning (EBR) by including the data from the experiment they conducted. As shown on Day 13, the teacher used the client letter to remind her students about the steps of the design process and the design constraints (i.e., budget). Later on, she asked the students to communicate with the client by creating a video, where they had to describe and justify their design choices. Specifically, she told her students to prepare a filled-out cost sheet, "a total cost …, a chart that shows reasons, [and] the data on what you [students] found" all included in the presentations to the client. This video was presented to the client and shared with others on Day 14, the last day of the integrated STEM unit implementation.

Furthermore, students were asked to collect data and report to the client, describing what they found. On Day 7, she mentioned the client letter again to contextualize and justify why they would engage in variable testing. Students were asked to test certain variables, such as the materials used for wire wrapping, the wire thickness, the number of batteries, the battery voltage, the number of alligator clips, and the length and thickness of the core materials. She asked her students to do their experiments, draw experimental conclusions and report them to the client. In particular, she informed the students that they would be "responsible for making a data table, you [students] w[ould] need to make a graph and you w[ould] need to make some conclusions about what you find."

Content Integration

Content integration happened when Ms. Ashley made connections between different STEM disciplines within the integrated STEM unit. These connections among disciplinary STEM content were either explicit or implicit in nature. Throughout the unit, the teacher made connections between science and engineering; they were often brief and used to inform them about the science content that they had to draw from. She made inferred connections between mathematics and other STEM disciplines, and it was not clear in her instruction why students were learning mathematics to find design solutions.

Explicit Connections between Science and Engineering

Ms. Ashley explicitly connected science and engineering through evidence-based reasoning activities, which took place multiple times throughout the integrated STEM unit. For example, on Day 1, she connected science to engineering by foreshadowing to students that they would need to explain how to make an electromagnet and to justify their design. On Day 2, she layered more details into how students would use science content to inform their engineering design decisions by telling the students "to investigate electromagnetism and begin to think about experiments …[which would] help you [students] think about your final design."

When students were in the planning phase, they were explicitly asked to include an explanation and justification of their designs by drawing on the science data that they produced throughout the unit. For example, on Day 10, the teacher said, "you [students] can use the data from a previous science experiment." On the last day of the *Claw Game* unit, Ms. Ashley redirected her students back into the EBR activities by asking them to create a video and share their final designs with the client. Her employment of EBR activities enabled her students to see and understand the connections between science and engineering - mainly how science was utilized for the purpose of engineering. In particular, Ms. Ashley asked her students to use data that they obtained from their scientific investigations as evidence to support their design decisions. This design justification involved asking why they selected certain materials over another during the design planning stage.

Implicit Connections between Mathematics and other STEM disciplines

Implicit connections between mathematics and other STEM disciplines were observed. Mathematics was present in only four lessons from Ms. Ashley's integrated STEM unit implementation. Its presence was mainly for the purpose of data analysis. For example, students were tasked with calculating and displaying averages of their data. Specifically, on Day 5, she told her students that "we're just going to graph the average. Okay so here is what we need in a graph." Students were engaged in graphing as an important tool when working with data collected from their science experiments. On Day 6, she instructed, "you [students] now have data and the graph. Now we need to make the conclusions." Here, students were expected to use data and information from averaging and graphing as evidence when making claims about their designs. She did not make it clear to students why students need to learn calculating averages and graphing practice would help inform design decisions.

Discussion

In this study, two different ways of STEM integration happened through Ms. Ashley's teaching instructions: context integration and content integration. Context integration occurred throughout the unit through the use of client letters to situate students' learning, to help them better understand the EDC, and to provide a more detailed contextualization of the problem. The teacher occasionally used the client memos and letters throughout the unit to contextualize students' learning, either as reminders or as the main lesson content itself. These documents from the client provided a means for Ms. Ashley to remind her students about the client's needs and how they could apply the science and mathematics content they learned to address the EDC. The client letter was used at the beginning of the lesson (problem-scoping phase) to situate students' learning by addressing the client's needs and also later in the lesson while students were communicating with the client. Moreover, the letters were used as part of the main lesson content itself during the problem-scoping and the communicating to the client phases.

Content integration occurred through explicit and implicit connections made between different STEM disciplines. Connections between science and engineering were explicit in Ms. Ashley's instructions. EBR provided an avenue for students to connect science content with the EDC. She asked students to draw on the data they collected and to justify their reasoning by using what they learned from their science lessons. Students were engaged in argumentative practices in an engineering context where they had to use the data they collected through science experiments to make design decisions.

The connections between mathematics and other STEM disciplines seem weakly connected, meaning they were not made clear to students when it came to the purpose of using mathematics within the unit. Throughout the unit, mathematics was used as a tool for data analysis. For example, students were asked to keep track of budgets for their design solutions, construct graphs of science and/or engineering data, and calculate averages of multiple trials. The implicit integration of mathematics as a tool becomes the norm of STEM classrooms [35], [36]. It becomes challenging for teachers to engage students in science and/or engineering learning without using mathematical practices, as connections are often not transparent to students. For more desirable learning outcomes, these connections involving mathematics should be made more explicit to students [18].

Making connections between STEM disciplines are essential to prepare students for the real world to solve complex problems. When connections are not made transparent to students, then it becomes a problem because students are potentially left to tinker rather than apply science and math knowledge to design solutions. Researchers have found that integrating science, mathematics, and engineering can be challenging for teachers [10], [37], especially elementary teachers who have limited background knowledge of other STEM disciplines besides science.

In addition to contextualizing learning in real-world problems and/or engineering design challenges, it is important to make connections between the disciplines and make them explicit to students [22], [8]. Although teachers may understand the connections within an integrated STEM lesson, students often struggle to make connections between STEM disciplines on their own [38]. It is critical that teachers must help students recognize and identify these connections or explicitly make these connections visible for students within integrated STEM lessons.

Limitation

While this study provides important information about the ways Ms. Ashley made connections between different STEM disciplines and fills a gap in the literature, there are a few limitations to this study. First, findings are not generalizable to other contexts, given its single case study nature. Furthermore, only transcripts for whole class instruction were available as our primary data source. Because of this, there may have been other instances where teachers made connections between different disciplines during small group discussions, which were not captured by the video camera during recording.

Conclusion and Implications

This case study advances pedagogical understanding of how to teach STEM content in an interdisciplinary manner in K-12 science classrooms. It posits theoretical models of context and content integration across STEM disciplines, and models student learning in a context-rich manner. In this study, a real-world problem is presented as an EDC. The use of an EDC, presented from the client's perspective, provides a context for students to learn and engage in learning science and mathematics content. Furthermore, as shown in this study, the use of an EDC engages students in engineering practices and serves as a contextual integrator within a STEM unit. Integration through engineering practices engages students in authentic STEM practices that are important to developing a conceptual understanding of STEM [6]. Science and mathematics knowledge and application are central to the discipline of engineering and integrated STEM [10]. Since students learn best when they see how STEM disciplines are connected to one another, elementary science teachers should make these connections explicit and visible to students to help them develop a conceptual understanding of STEM concepts. The findings from this study provide some preliminary guidance on content and context integration.

To address the STEM initiatives and policies on a national level, it is important to understand STEM integration at the practice level. This single case study allows several meaningful implications for integrated STEM education to emerge. First, having an understanding of integration at the practice level will allow curriculum developers to better understand how integrated STEM curricula can be implemented in classrooms. Second, by researching the implementation of K-12 engineering standards through STEM integration, this paper adds to the theoretical basis for integrated STEM curriculum development, where engineering is the key to integration. This case study could be used as an exemplar to show how STEM integration can be implemented in elementary science classrooms and can be important for teacher educators, district administrators, and those involved in creating and facilitating professional development surrounding STEM integration; thus, breaking down the barrier between research and practices. Further large-scale studies related to science teaching practices used in integrated STEM education are needed. As schools are adapting to STEM-focused learning, elementary science teachers need more guidance in integrating STEM disciplines. As such, professional development opportunities should be grounded in integrated STEM models and should provide an example of what integrated STEM instruction looks like in practice.

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