Is this a Science Lesson? Is this an Engineering Lesson?: Understanding how Elementary Teachers Characterize Science and Engineering and its Connection to Practice

Abstract (2100 characters)

Many professional learning (PL) opportunities with inservice teachers often focus on enhancing their understanding of the nature of engineering and the work of engineers. However, few studies connect inservice teachers' conceptualizations of science and engineering and how these inform their classroom practice. Therefore, this study explores inservice elementary teachers' conceptions of teaching science and engineering and how they connect their understandings of these disciplines to classroom practice. We examined the breakout discussions of 11 inservice elementary teachers regarding five vignettes of science and engineering classroom activities in a completely online PL experience. We employed the Attending-Interpreting-Responding (AIR) Teacher Noticing Framework and followed a six-step thematic analysis process by Braun and Clark (2012). These steps included collaborative sense-making sessions to discuss the descriptive coding (Saldaña, 2021) generated during independent coding sessions. Our analysis revealed several consistent key (mis)conceptions about teaching science and engineering. Teachers often characterized engineering classroom activities as tasks where students should be *building* and *solving a problem*, while they characterized science as involving *observation* and *learning content knowledge* about a topic. When describing a vignette as engineering, teachers often used the words *goal, problem,* and *purpose* interchangeably. Additionally, we uncovered teachers' misconceptions about science that do not align with the nature of science or science and engineering practices. This gap in how teachers make sense of classroom science and engineering tasks versus how they conceptualize science and engineering disciplines highlights a significant need to address in teacher education.

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Clear Focus/Problem

Supporting inservice teachers' abilities to include high quality science and engineering instruction in elementary classrooms has been recognized as a challenging responsibility for science teacher educators. Prior research has suggested that much of the challenge in teaching science and engineering is personal to inservice teachers, including their beliefs and perceptions of the science and engineering disciplines (Author, 2017; Author, 2019; Hsu et al., 2011); lack of science and engineering content knowledge (Firat, 2020; Pleasants et al., 2021); and low self-efficacy (Author, 2017; Crawford et al., 2021) for teaching these subjects. Additional studies also demonstrated that when inservice elementary teachers lack science and engineering content knowledge, this frequently translates to them exhibiting less science and engineering pedagogical content knowledge (PCK) (Kang et al., 2018; Love & Hughes, 2022). This is important as the concept of PCK has been identified to contribute to high quality science and engineering teaching and improved student learning (Love, 2013; Love & Hughes, 2022).

Further, inservice elementary teachers' low engineering self-efficacy, coupled with a lack of meaningful professional learning (PL) in engineering education often perpetuates misconceptions about the nature of engineering and how to teach it (Antink-Meyer & Meyer, 2017). Much of the PL opportunities developed and implemented with inservice teachers focused on the nature of engineering (Pleasants, 2021) and the work of engineers (Pleasants & Olson, 2019; Pleasants et al., 2020). However, missing from these PL experiences are connections between inservice teachers' conceptualizations of science and engineering and how this informs their classroom practice. Consequently, if we aspire to support inservice elementary teachers in implementing high quality engineering teaching practices, we must begin by providing them with PL experiences where they can reason through their conceptions of science and engineering and connect these ideas to their classroom practice.

Therefore, the purpose of this study was two-fold: 1) to explore inservice elementary teachers' conceptions about teaching science and engineering following their engagement in one year of professional learning that was aligned with the *Next Generation Science Standards* (NGSS); and 2) to examine how elementary teachers justified their reasoning and made connections between their understandings of the disciplines and their practice. In particular, we sought to address the following research question:

- How do teachers conceptualize what characterizes a science learning activity and an engineering learning activity in the classroom, and what evidence do they use to justify/explain their reasoning?

Conceptual Frameworks: Teachers' Pedagogical Reasoning and Attending-Interpreting-Responding (AIR) Teacher Noticing Framework

Teachers' pedagogical reasoning has been conceptualized as a framework that focuses on the interpretations, explanations, and justifications that underpin teachers' decision-making in the classroom (DeLucca et al., 2024; Horn, 2019; Krist & Shim, 2024). Pedagogical reasoning is a fundamental process that allows teachers to learn from their own teaching (Horn, 2005; Horn & Little, 2010). Researchers have measured progress in teachers' pedagogical reasoning in science and engineering by how their reasoning integrates their understandings of the science and engineering disciplines; responsiveness to others' (e.g., colleagues; students) thinking about the nature of these disciplines; and consideration of the impact of this disciplinary knowledge on their pedagogical actions within their classroom practice (Watkins et al., 2021). Understanding teachers' pedagogical reasoning is significant because it not only allows teachers to make connections between their conceptual understandings of science and engineering and its impact on their instructional moves, but also allows researchers to better understand teachers' learning and development over time and across contexts (Watkins et al., 2019; Watkins et al., 2021).

Within the context of this study, we sought to examine elementary teachers' science and engineering pedagogical reasoning to explore how they are making connections between their conceptions of these disciplines and their classroom practice. To do so, we utilized the attending-interpreting-responding (AIR) teacher noticing framework (Sherin et al., 2011). Although the AIR framework was originally developed to conceptualize processes that are important in teacher noticing and responding to student thinking, the framework has recently been used to examine teachers' pedagogical reasoning. Because we sought to explore how teachers reason about what characterizes science and engineering lessons, we adapted this framework to explore how elementary teachers: (1) *attend to* their own and other teachers' ideas surrounding the disciplines of science and engineering; (2) *interpret* the nature of science and engineering within classroom contexts; and (3) *respond* to their own and others' conceptual understandings of these disciplines by making connections between their conceptual understandings of science and engineering and the pedagogical actions they take within their classroom practice. Ultimately, what elementary teachers choose to *attend to* and how they *interpret* and/or justify it is significant to how they *respond* or make pedagogical decisions in teaching science and engineering. Table 1 summarizes our adaptation of the AIR framework.

Methods

Participants

Participants (n=11) included a purposefully selected subgroup of inservice teachers who were part of a larger grant focused on providing NGSS-aligned professional learning opportunities for rural teachers. Participants were teaching in rural schools located across four western states and were responsible for the instruction of at least one of the following grade levels: 3rd, 4th, or 5th grade. Some participants taught multiple grade levels in combined classrooms (e.g., combined 3rd-5th classroom).

Professional Learning

Participants completed 5 days of intensive online professional learning during the summer, followed by monthly online professional learning community meetings (approximately 90 minutes each) focused on providing follow-up supports connected to designing and implementing NGSS-aligned science and engineering instruction. Participants were introduced to the Culturally Relevant Engineering Design (CRED) Framework and used the CRED to develop engineering lessons connected to severe weather in their local communities. Participants video recorded themselves teaching the lessons and shared clips with each other and the research team.

Data Collection and Analysis

This proposal focuses on one of the culminating professional learning community activities during which participants were provided short, descriptive vignettes of classroom activities (i.e., building a solar system model, observing growth rates of plants with different amounts of light, participating in a cookie assembly line, creating and exploring materials in a maker space, and building the tallest toothpick and marshmallow structure) and asked to discuss, in breakout rooms of 3-4, if the activities were science or engineering. In addition to the vignettes, each room was provided with a Jamboard space to place the activities along a science-engineering spectrum and provide evidence of their reasoning for its placement (see Figure 1). Each breakout room discussion was recorded and transcribed, and images of the Jamboards were downloaded. Transcript data from the participants' discussions in breakout rooms and Jamboards were carefully examined and coded using the six-step thematic analysis process described by Braun and Clark (2012), with a specific focus on identifying how teachers discussed their reasons for where to place activities along the continuum. Two authors independently coded the data and then met for a collaborative sense-making session to discuss the descriptive coding (Saldaña, 2021) generated during their independent coding sessions and to compare results and establish agreement on the final codes and themes that emerged from the data. The authors wrote analytic memos and kept an audit trail to document the details of the process. In making sense of the analysis, the authors interpreted the findings using our adapted version of the AIR framework. In doing so, they looked for examples of how the participants were *attending* to their conceptions of science and engineering classroom activities based on the characteristics teachers identified as being associated with teaching science and engineering. Next, the authors identified examples of participants' *interpreting*, or how they justified their conceptions. Finally, due to not having observations of classroom practice, the authors chose to apply the *responding* process to instances where teachers talked about how they might modify or implement vignette activities within their classrooms, as these were instances where they were thinking specifically about their pedagogical practices.

Findings

There were similarities across all three teacher groups with how they positioned the different vignettes along the science/engineering continuum. Figure 1 shows a Jamboard from one of the breakout rooms. There was uniform agreement that observing growth of plants with different amounts of light was science because it was observation based and did not involve solving problems. There was also uniform agreement that building the tallest toothpick tower was engineering with different groups offering slightly different reasons but all connected to associating engineering with building, having a problem or goal, and using creativity.

The conversations around the other three vignettes varied across all groups, though all three groups placed them in similar locations on the continuum, with the solar system model being closer to the science side, working in a maker space being in the middle, and the cookie assembly line being closer to the engineering side. With the solar system model vignette, for example, teachers grappled with the scientific practice of modeling versus an engineering design task in which students are building or developing the mechanics of making the planets rotate. Teachers also discussed the differences between an engineering design task and an art project or playing, which was a common point addressed when deciding where to place the make space vignette. Most teachers decided that there needed to be a problem posed or identified constraints for the task to be considered engineering, and no one connected this task to science or properties of materials. The cookie assembly line was a particularly complex vignette for teachers to place along the science and engineering continuum. Two of the three groups felt that this task was more engineering than science, with teachers identifying a connection to quality assurance, product development, and a clearly identified challenge. One of the three groups, however, decided to not even place the vignette on the continuum at all, indicating that it was neither science nor engineering but rather an arts and crafts activity, unless students were building the mechanism by which the cookies would be decorated.

Discussion and Conclusion

Upon review of the findings to answer the research question, several key themes were consistent across teachers' explanations and reasoning for why a vignette was science and/or engineering. The common reasoning for what made a lesson more aligned to engineering was that students should be *building* and *solving a problem*, while characteristics of science were identified by teachers as *observation* and *learning content knowledge* about a topic.

Due to their focus on *building* as a requirement for engineering, some teachers struggled to identify certain tasks because they were looking for the building opportunity for students. For example, with the cookie assembly line vignette, one group indicated that if the students built a mechanism to decorate the cookies using a specific process, then it would be an engineering lesson, but if they were decorating the cookies by hand using the process, then it was not engineering. For these teachers, there was a fixation on the need to build something and they completely looked over the process of engineering. Not all groups did this though. In one group, the teachers noted that while the solar system model vignette had students engaged in building, they were "making a model for something you observed, hence it's more science," while another group justified it as science rather than engineering because if you are just decorating foam balls, there is "no real building involved there."

When describing a vignette as engineering, teachers often used the words *goal, problem,* and *purpose* interchangeably. For example, teachers unanimously agreed that building the tallest marshmallow toothpick tower was engineering because students were solving a problem. They also described how the solar system model could become engineering if students were challenged to design a system to make the planets rotate. However, with both of these vignettes, there was no problem or client associated with the activity. Instead there was a *goal* of creating the tallest tower or creating an interactive model. In these cases, teachers were conflating solving a problem with meeting a goal, when arguably, lessons in any discipline should have a goal.

Teachers focused on *observations* and the *development of knowledge* as characteristics that made a vignette science. For example, one group described the solar system model as both science and engineering; science because they had to learn about the planets and engineering because they had to build. Others referred to the plant growth vignette as purely science because "you're just observing mother nature." Interestingly, one group reasoned that part of what made the toothpick tower strictly engineering was that "you don't have to learn anything, but you learn about teamwork." For these teachers, science required an explicit connection to either learning disciplinary content knowledge or observing phenomena.

An unexpected finding when reviewing teachers' explanations was that some of the words and phrases used to describe why something was an engineering lesson could just have easily been used to describe science and pointed to misconceptions about the nature of science and engineering. For example, one teacher described a vignette as engineering because "you're manipulating things and discovering." Another teacher held misconceptions about science that surfaced when discussing multiple vignettes. This teacher claimed that the plant observation vignette must be science because "there wasn't the opportunity for exploration of what [students] thought" and that the solar system model vignette was not science because it "limits children…you have to stick to what we've learned and it can only be the stuff that we've covered…that makes it science verses if it's any sort of exploration…or if they're just genuinely curious about something else is what leads that to the engineering side." Curiosity and discovery are at the heart of science and students should be manipulating variables to discover outcomes as part of inquiry-based instruction. The view of science as being limited to the facts that have already been covered in class does not align with the nature of science or science and engineering practices.

Multiple participants across all three groups provided examples from their own teaching to help situate their reasoning for why a vignette was science or engineering. This was most commonly seen for the vignettes that closely resembled activities the teachers had previously taught in their classrooms. Additionally, participants in one group spend considerable time reasoning around how each of the vignettes could be modified to become more engineering-like. One teacher shared,

> I think that's ultimately what we have to do as teachers to be able to bring engineering into our room is to take these things that we typically do and turn them into some sort of engineering task. But it takes a lot of creativity, and I don't necessarily always have that, unfortunately.

For each vignette that followed, the participants talked about how they could adjust the vignette to create space for engineering. Later, when talking about the plant growth vignette, one participant described an engineering task they had completed with their students to address the lack of a window in their classroom. The students were tasked with using mirrors to reflect light from the window across the hallway so their plants would grow. After hearing this classroom example, another participant in the group responded that they have a single small window in their classroom and many plants and had not previously considered the idea of having students reflect the light from different sources and expressed interest in looking into this over the next few weeks. The conversations that played out within this breakout group demonstrated how the participants were reasoning through their understanding of science and engineering and thinking about how this knowledge could inform their classroom practice.

Relevance to Science Teacher Education

This study is relevant to science teacher education in that it fills a current gap in the literature related to how teachers make sense of classroom science and engineering tasks versus how they conceptualize the disciplines of science and engineering. Considerable work has focused on how teachers perceive science and engineering. This study builds upon that work by connecting these perceptions to teacher PCK. We share examples of teacher reasoning about how science and engineering are represented through classroom activities, which help highlight misconceptions that can influence pedagogical choices and lesson design. These misconceptions underscore the need for purposefully designed professional development that allows teachers to build their PCK and explicitly compare the characteristics of science and engineering classroom-based instruction and how they can be taught in an integrated manner.

Interest to the ASTE membership

Within ASTE membership, we think this research will particularly support preservice elementary methods teachers, professional learning providers for inservice teachers, researchers focused on engineering education, and curriculum/policy individuals focused on improving the STEM pipeline. This session will specifically point out the ways teachers are reasoning about what science and engineering look like within classroom settings, which will offer implications, additional insights, and potential avenues for future investigation for supporting engineering education.

Table 1
Adapted AIR Teacher Noticing Framework (Krist & Shim, 2024; Sherin et al., 2011)

Processes	Initial Explanation	Adapted Explanation
Attending	Represents what teachers select to pay attention to in the classroom, amidst many foci within interactions in the classroom	Demonstrates how elementary teachers attend to their own and other teachers' conceptions surrounding the disciplines of science and engineering
Interpreting	Represents how teachers make sense of what is holding their attention; often involves various reasoning practices	Refers to how elementary teachers interpret their own and others' ideas about the nature of science and engineering; Also refers to how elementary teachers justify their conceptions and looks at what evidence they draw from to support their ideas
Responding	Represents the actions that teachers take in response to what they attend to and interpret in the moment or for future teaching	Represents the connections that elementary teachers make between their conceptual understandings of science and engineering and how this knowledge informs their classroom practice (e.g., instructional moves; pedagogical actions) in teaching science and engineering

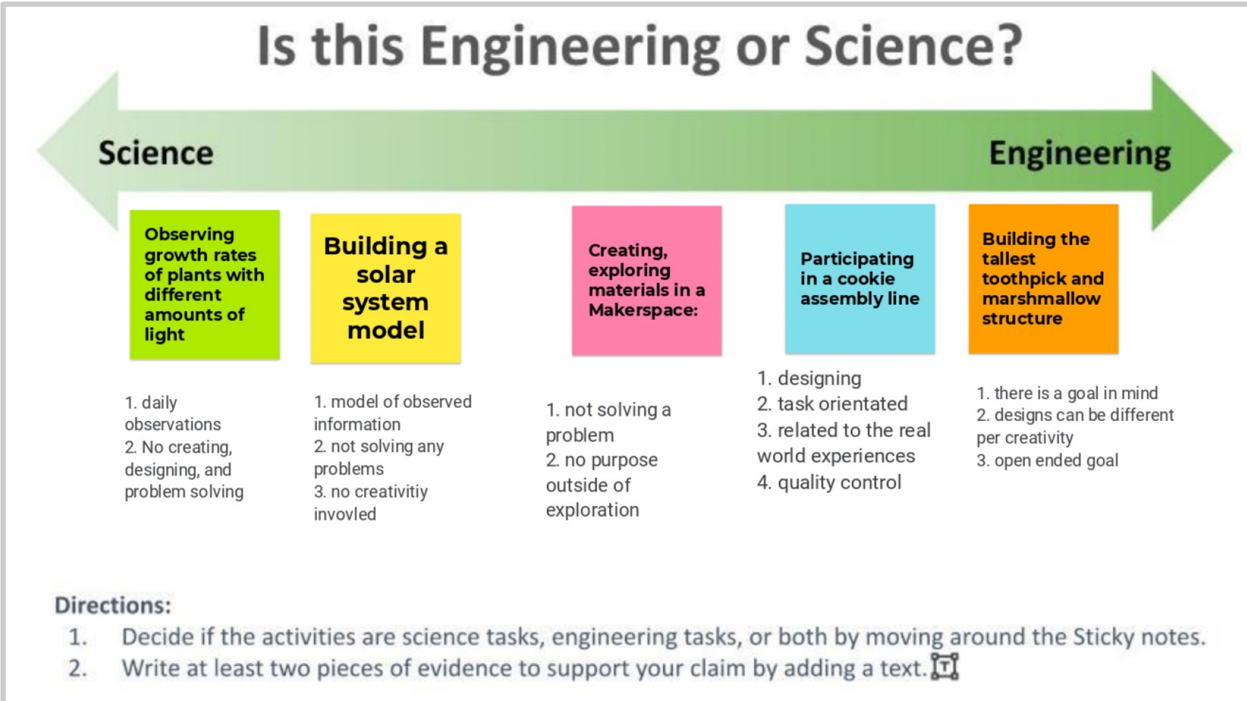

Figure 1. *Breakout Room 1 Jamboard Activity*

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