



# TEACHERS' CURIOSITY ABOUT ENGINEERING, ENGINEERED OBJECTS AND PHENOMENA AND THEIR CONFIDENCE FOR TEACHING ELEMENTARY ENGINEERING (FUNDAMENTAL)

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## Abstract

This study explored whether, and how, preservice elementary teachers' (PSTs) curiosity about engineering, engineered objects and phenomena related to their confidence for teaching elementary engineering and integrated STEM. We focus on *engineering curiosity* in this study and frame it using Jirout and Klahr's (2012) conception of scientific curiosity which is "desired uncertainty in an environment which leads to exploratory behavior" (p.26). Based on the operationalized distinction between self-efficacy and confidence proposed by Stankov and colleagues, we examined the engineering confidence and curiosity of a group of 29 preservice, elementary teachers across a semester of a scientific inquiry and engineering design course where they engaged in curiosity journaling. We use the term *curiosity journaling* to describe the strategy for writing reflections on natural and technological phenomena that an observer notices and finds interesting. This study also expands upon the Luce and Hsi scientific curiosity framework and reflects the findings of Turner (2012) who observed that the relationship between reflection on content and the development of content knowledge is not direct. In addition to examining journaling strategies that sustain connectedness to inquiry and engineering design experiences, future studies are needed that examine whether disciplinary domains imbue associations between types of curiosity and types of epistemic engagement.

## Curiosity and Engineering

Luce and Hsi (2015) found students' curiosity about science and engineering as a more product means of gauging and promoting interest in STEM. Their study of middle grades learners' curiosity outlined specific types of curiosity about science and engineering and this study extended that work by investigating the curiosity of teachers. Curiosity among future engineers has been a focus within entrepreneurship (e.g. Gorlewicz & Jayaram, 2020) and engineering coursework (e.g. Pusca & Northwood, 2018). In addition, although curiosity in engineering is not often an explicit focus of research on K-12 settings, it arises as important within studies of elementary students' conceptions of engineering (Lampley et al., 2022). This study explored whether, and how, preservice elementary teachers' (PSTs) curiosity about engineering, engineered objects and phenomena related to their confidence for teaching elementary engineering. We focus on *engineering curiosity* in this study and frame it, in part, using Jirout and Klahr's (2012) conception of scientific curiosity, which is "desired uncertainty in an environment which leads to exploratory behavior" (p.26). Many decades ago, Berlyne (1954) distinguished between perceptual and epistemic curiosities. The latter describing curiosity that stimulates noticing and the former that motivates knowledge generation. While intimately connected in engineering, this study sought to understand the nature of teachers' perceptual curiosity only. In what ways did they notice, find interest, and express curiosity about engineering knowledge, processes, and cultural connections. Understanding the nature of this study's group of participants' perceptual curiosity, as a group of non-engineers but future engineering educators, has implications for finding teacher education supports that better engage them.

Curiosity can serve as a motivator to teaching and learning. In Cunningham and Carlsen's 2014 review of pre-college engineering education, they describe engineering engagement as a motivator of student learning in pre-college settings. Blumenfeld et al. (2006) described engagement as a motivator of learning because students' experience a sense of agency, competence, and responsibility. While curiosity is never made explicit in the 2014 research review, perceptual and epistemic curiosities are implicit in the descriptions of the importance of including engineering in pre-college learning like "[e]ngineering engagement takes advantage of children's natural interest in goal-oriented activity" (p. 756). While other studies of teachers' curiosity about engineering are lacking, Belecina and Ocampo (2016) found that among a group of pre-service mathematics teachers' their curiosity and epistemological beliefs not only related, but influenced their mathematics performance.

In addition to relatedness between teachers' curiosity and disciplinary performance, studies also suggest that teachers' classroom practice and pedagogical orientations can influence learners' curiosity. Orcutt and Dringus (2017) observed that even in online learning environments teachers can influence learners' intellectual curiosity. In their study of early childhood teachers' perceptions about curiosity in science and curious learners in early childhood classrooms, Spektor-Levy (2013) found that teachers did not feel confident in their abilities to promote curiosity in science learning. Nor, were there any consistent findings around their beliefs about the nature of curiosity in general. That is potentially consequential because Inayat and Ali (2020) found that students' (in their case university-level) perceptions of their teachers' teaching style contributed to their curiosity. How a student perceived whether their teacher is supportive or controlling influenced the curiosity that the students expressed. Although not specific to pre-college engineering education, studies of teachers' roles, perceptions, and attitudes about students' curiosity are extant in the literature.

### **Confidence for Teaching Engineering**

This study focuses on confidence instead of self-efficacy. Stankov et al. (2012) defines confidence as "a state of being certain about the success of a particular behavioral act" (p. 747). In their work, they observed that in comparison to self-efficacy, confidence was a better predictor of achievement (2012). Confidence was also found to better explain variance in their 2014 study. Confidence and self-efficacy are also highly correlated and for these reasons, in this study, confidence was the focus of the work.

Dubey and Griffiths (2020) found that the relationship between curiosity and confidence is one in which confidence affects curiosity, where an inverted u-shape is observed. Having *some* confidence in an area influences the likelihood that an individual will express curiosity. This implies that teachers' who have some confidence around engineering, engineered objects, and phenomena may influence their own curiosity related to engineering. According to Dubey and Griffiths that curiosity is also mediated by how novel the concept or object is, as well as whether they perceive a moderate challenge in terms of understanding. The Dubey and Griffith work implies that teachers may be more curious themselves about engineering when they have enough confidence to engage with it, where they perceive novelty, and when they sense some challenge in understanding. However, none of any of these factors can be present to so great an extent as to make it either lacking in interest or of limited accessibility.

The nature of these relationships has not been investigated in an engineering education context, and studies of teachers' own curiosity and its relationship to their teaching are generally lacking. We were interested in the other direction of a relationship between confidence and

curiosity. Could expressions of curiosity influence the development of confidence for teaching engineering? In a related study, Antink-Meyer et al. (in review) examined the relationship between teachers' scientific curiosity and their confidence for teaching related content. For example, if they had demonstrated curiosity about the nature of microorganisms and the transmittance of disease, did they later report improved confidence around teaching about microorganisms? In that study, no statistically significant relationship between confidence for teaching and curiosity was found.

### **Purpose**

The purpose of this study included a more general exploration of confidence for teaching engineering by a group of preservice elementary teachers and their expressions of engineering curiosity. The other purpose of this study was to understand the nature of their engineering curiosity more specifically as prior work in this area was not found at the time of this writing.

### **Methodology**

We explored the engineering confidence and curiosity of a group of 29 preservice, elementary teachers across a semester of a scientific inquiry and engineering design course. Participants wrote reflections on natural and technological phenomena that they noticed and found interesting and these reflections comprised the curiosity data that was analyzed in this study. Two research questions framed this study.

- 1) How do changes in pre-service elementary teachers' confidence for teaching elementary engineering, and the engineering curiosity they express when journaling, relate to one another?
- 2) What is the nature of the engineering curiosity expressed among a group of pre-service elementary teachers?

This two-phase study employed an embedded mixed methods design, the intent of which, according to Creswell and Plano-Clark (2011) is "not to converge two different data sets collected to answer the same question" (p. 70) but in this case, to inform an understanding of both whether, and how, the extent and nature of a teachers' engineering curiosity related to their confidence for teaching the topics they were curious about. The first research question was explored in terms of the frequency of journaling about engineering, engineered objects, and phenomena as journal entry topics. The course was the first in which engineering concepts and epistemology was taught. The second research question focused on the nature of their engineering curiosity itself.

To address the first research question the Horizon Science Teacher Survey, Preparedness to Teach (BaniLower et al., 2018) was used in this study at the beginning and end of the course. The survey is Likert scale (not adequately prepared, somewhat prepared, fairly well prepared, and very well prepared) and asked survey takers reflect on their confidence to teach specific concepts and topics. Only a portion of the full survey was used in this study therefore it was necessary to re-establish internal consistency. A satisfactory Cronbach alpha value of .961 was found. The survey includes questions like "how well prepared do you feel to teach engineering" and "how well prepared do you feel to teach forces and motion". Only one survey item was used in the present study, "how well prepared do you feel to teach engineering" as our interest was on their self-perceptions of their confidence.

The other data source in this study was a curiosity journal which was kept as part of the class across a 16-week semester. Students were required to make at least eight entries that were explicitly about engineering, engineered objects, or engineering phenomena or science that they encountered and were curious about. Entries could also focus on science but at least two entries explicitly focused on engineering were required. In journal entries, participants were asked to notice, observe, and wonder about engineering-relevant aspects of their worlds. Their entries were coded by each author in iterative cycles where the unit of analysis was each utterance (e.g. questions, observations, explanations). Codes were inductively generated first by the creation of broad themes which were refined in coding iterations separately by each author independently in two-to three cycles until codes were reflective of 100% intra-rater agreement. Initial codes were then discussed by both authors with examples from the journals five thematic codes were agreed upon. Given that utterances, and not journal entries, were the unit of analysis in some cases more than one code was applied to a single entry. The codes generated were used to address the second research question.

### **Participants**

Study participants were 29 pre-service teachers in their final STEM content course of their elementary education program. The course focused on scientific inquiry and engineering design and included epistemic practices, the nature of science and of engineering knowledge, inquiry, and engineering design projects. Eighty-three percent of participants identified as both female and White, 10 percent identified as White and male, one teacher identified as a Black woman, one teacher identified as an Asian-American woman, and two teachers identified as Latina teachers. All participants had completed all previous science course requirements but no participants reported any post-secondary engineering courses nor any engineering classes in high school. Most participants reported some engineering experiences in middle or high school which included projects like the egg-drop and bridge experiences traditionally included in physics settings in middle and high schools in the U.S.

### **Findings**

The findings associated with each of the research questions are described separately.

#### **RQ1 How do changes in pre-service elementary teachers' confidence for teaching elementary engineering, and the engineering curiosity they express when journaling, relate to one another?**

Our interest was centered on the change in confidence across a curiosity journaling experience. Initially, the frequencies of each Likert scale category illustrate that no participants felt well prepared to teach engineering and the majority felt that they were not adequately prepared. The number of participants reporting confidence falling within each Likert rating is shown in the parentheses: not adequately prepared (n=14), somewhat prepared (n=12), fairly well prepared (n=3), and very well prepared (n=0). At the end of the study the mean change across the 29 participants was an improvement of one to two categories (mean of 1.71), and the most common category was *very well prepared*. Frequencies for each rating are shown in the parentheses: not adequately prepared (n=1), somewhat prepared (n=1), fairly well prepared (n=13), and very well prepared (n=14).

In order to address the first research question we first used the four categories of self-reported confidence collected at the beginning and end of the study and categorized each participant according to whether they had gained confidence, lost confidence, or not reported any difference in confidence for teaching engineering. The number of entries they made in the journal that included engineering were also categorized as (0 entries, 1 entry, >1 entry) were also categorized and a Chi-Square test of independence was conducted. The mean number of entries that were engineering related was four entries.

Although there was positive growth around engineering confidence and some engineering curiosity, Chi-square tests of independence suggested that improving confidence for teaching engineering was independent of expressions of curiosity about this topic in journals ( $\chi^2 = 3.593$ ,  $df = 4$ ,  $p = 0.464$ , Contingency Coefficient = 0.332). The contingency table is shown in Table 1 where 0 indicates either no journal entries related to engineering or no change in confidence to teach engineering. A 1 in the contingency table indicates either 1 journal entry related to engineering or an improvement of one or two confidence ratings. A 2 in the contingency table indicates either 2 or more journal entries related to engineering or a change in confidence of three ratings.

**Table 1**  
**Contingency Table**

Engineering Journal Entry Category	Change in Confidence to Teach Engineering			Total
	0	1	2	
0	0	8	0	8
1	1	9	0	10
2	0	10	1	11
Total	1	27	1	29

The findings suggests that the extent of reflection on a topic that a PST was curious about did not meaningfully relate to any changes in their teaching confidence. This is similar to the findings from Antink-Meyer et al.'s study wherein science curiosity and change in confidence was not observed. Reflection on content and the development of content knowledge was not direct. In addition to examining journaling strategies that sustain connectedness to inquiry and engineering design experiences, future studies are needed that examine whether disciplinary domains imbue associations between types of curiosity and types of epistemic engagement.

**RQ2 What is the nature of the engineering curiosity expressed among a group of pre-service elementary teachers?**

This study also expands upon the Luce and Hsi framework and developed themes of engineering curiosity that were more specific than their framework included. Using the entries from the PSTs, five specific themes of engineering curiosity were generated. These are curiosity about: (1) the interaction of science phenomena and engineering design or function of engineered technologies, (2) technologies as engineering products (big picture “how” and “wow” thoughts),

(3) implications of engineering appreciation (what-if type wonderings), (4) design and design outcome relationships including specific design attributes and their role in overall function (e.g. materials), and (5) engineers creativity (“how did people create this” type wonderings). Each of these codes were developed as described in the methodology section and derived inductively across both authors using the journal entries.

Each code is reflective to some degree of extant literature around the teaching of the nature of engineering and engineering design in K-12 settings. For example, code (1) the interaction of science phenomena and engineering design or function of engineered technologies is reflective of work that has examined the inclusion of engineering design in science classrooms and curriculum where design work has manifested students’ conceptions of science (see Chao et al., 2017 and Schnittka & Bell, 2011 for examples). Technologies as engineered products (code 2) is reflective of both research and the ITEE Standards of Technological and Engineering Literacy (STEL). Code (3) the implications of engineering appreciation, while not directly reflected in research literature, is indicated in work on appreciation of engineering as an outcome of learning about, and engaging in, engineering design (for example, English & King, 2015). The fourth code, design and design outcome relationships including specific design attributes and their role in overall function, is reflective of research on engaging in engineering design broadly. The last code related to creativity of engineers and engineering also related, limitedly, to literature on the creativity of engineers (see Cropley & Cropley, 2005) but also to research on the nature of engineering and the nature of engineering knowledge (see Antink-Meyer & Brown, 2020, Kaya et al., 2017 for examples)

Table 2  
**Engineering curiosity codes and examples**

<b>Code</b>	<b>Description of Code</b>	<b>Proportion of entries with code</b>	<b>Exemplar</b>
(1) the interaction of science phenomena and engineering design	specific reference to science phenomena	.29	This makes me wonder if somehow the molecule makeup of these different materials impacts the absorbency?
(2) technologies as engineering products	big picture "how" and "wow" thoughts	.23	How do the poles of bridges hold such a heavy bridge up when they are just in the water?
(3) implications of engineering	what if type wonderings	.04	How much food would go to waste or not even be able to be stored in the first place without it?
(4) design and design-outcome	specific design attributes and their	.38	What goes on inside the light to make it change to the next color? Why are

	role in the function or overall design		some lights longer (time) than others?
(5) engineers' creativity	how did "people" create "this" type wonderings	.06	How can an engineer put together electrical things, air flow sensors, bakes, tires, transmission and full body throttle to make something move at a possible 120+ mph?

### Discussion and Conclusions

The most common type of engineering curiosity expressed in their journals we refer to as *design and design outcome* type curiosity. This type of curiosity was characterized by reflections on specific design attributes and their role in the function or overall design but was also exclusively focused on physical objects that were physically present and observable. The example in Table 2 was characteristic of journal entries where the teachers were noticing and wondering about something they perceived as engineered that was commonplace in either their lived space or in spaces where they typically found themselves (e.g. vending machines). The next most common type of engineering curiosity focused on the interaction of science phenomena and engineering design. Given the nature of the course as one developed to focus on both science and engineering concepts and experiences, this code was expected to be common. Entries coded this way were focused on wonderings about engineering and the influence of science phenomena within the ways that engineering products worked and why. These entries were reflections on the necessity of science understanding within understanding of engineered products. The third most common code emerged in more than 20% of entries and were reflections on technologies as engineering products that expressed wonder about how such products were possible given their scope, place, or size. The final two codes, *engineers' creativity* and the *implications of engineering* were the two least common types of curiosity expressed. Each of these codes reflected big picture or systems type thinking about how people were able to generate such solutions or what the consequences might be if one part of a system were changed or compromised.

This work does not suggest that any "type" or category of curiosity is more valuable or worthy of focus, but instead gives insight into ways that engineering educators-particularly engineering teacher educators-can purposefully frame engagement with engineering epistemology and practice in ways that are varied and that draw out reflections that may effectively engage teachers as engineering learners. Researchers, such as Weible and Zimmerman (2016), claim that the interest that drives individuals to attain expertise is indicative of high levels of curiosity. By situating learning within opportunities for curiosity more purposefully, driving self-regulated learning and engineering identities among teachers can create more opportunities to help them see themselves as teachers who can promote engineering interest and identity development among their students.

Whether confidence for teaching engineering and curiosity about engineering can be mutually reinforcing or meaningfully related is an area in need of future work. While curiosity journaling as a learning strategy can be viewed from within an empirically based instructional model like Keller's ARCS-V (attention, relevance, confidence, satisfaction, and volition) (Li &



Keller, 2018) motivational model, it likely represents an incomplete opportunity. If situated within Dubey and Griffiths (2020) claims about the relationship between confidence and curiosity, then purposeful selection of engineering experiences that pre-service teachers have at least some confidence around may influence deeper engagement and more sustained curiosity. Growth in their confidence for teaching engineering is an area in need of more study. The next step in our work is to explore how practicing teachers' curiosity about the engineering design activities in their classroom influences their confidence for teaching novel engineering design challenges or concepts. Similar investigations may also be informative of work with pre-service teachers and those may include the use of a journaling strategy but journaling alone may not be an effective means to promote confidence in teaching engineering among novice teachers and engineering educators.

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