

Exploring how Science Teachers' Views of the Nature and Pedagogy of Science are Affected by their Transition to Engineering (Fundamental)

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Shifts in Science: Exploring how Science Teachers' Views of the Nature and Pedagogy of Science are Affected by their Transition to Engineering (Fundamental)

Introduction

“When I taught science, it was a small classroom with little bitty tables with four chairs a piece, and I walked in and out of them, I taught at the board and we did a few pre-made experiments, we did projects that showed different things. It was very different, I couldn't, I would not teach engineer that way, but I could teach science the way that I teach [engineering] now.” – Steve

With the integration of engineering into the Next Generation Science Standards (NGSS), many science teachers are now being asked to understand both engineering and science at the level they will be teaching as well as how to navigate the complex nature of teaching the subjects in an integrated fashion. The addition of engineering to K-12 education has been shown to benefit students and provide teachers with a new mode for teaching science.^{1,2,3,4} However, like many new educational innovations, this amendment will require that teachers gain a new set of knowledge and resolve how it fits within their current conception of science and science education. This study examines how teaching engineering affects or shifts the way educators think about science and the ways it should be taught in K-12 schools.

While there has been much progress in K-12 science education over the past decade, research continues to show that many science teachers do not hold adequate views of Nature of Science (NOS) and struggle to teach in more inquiry or project-based ways.^{5,6,7} Specifically, Anderson⁵ found that many teachers have limited experience with scientific inquiry and hold naive conceptions of the process by which scientific knowledge is generated. This lack of knowledge and experience likely puts limitations on teachers' abilities to plan and implement more progressive lessons that will help their students develop an image of science that goes beyond the general, familiar body of knowledge.

The addition of engineering to NGSS has introduced many K-12 educators to new subject matter and approaches to teaching science. The purpose of adding engineering, as noted in the Framework^{2,8}, is to provide opportunities for students to deepen their understanding of science by applying their developing scientific knowledge to the solution of practical problems. The integration of engineering is based on research studies that have found engineering to act as a catalyst for enriching and improving science education, providing a space for the application of science and positively affecting student learning, motivation, and problem solving skills.^{1,2,3,9} Additionally, research has shown that engineering helps teachers transform their instruction to a more integrated, project-based, hands-on, and student-centered approach⁴. Therefore, engineering has the potential to provide an entry point for teaching science in new ways. This renewed emphasis on the application of science through engineering, as well as the new approach to teaching science will require science educators to adjust their thinking.

Along with new possibilities offered by engineering, it is important to remember that it adds the challenge of understanding a new, and often-unfamiliar, content area. Research has shown that many K-12 teachers are resistant and feel unprepared to teach engineering due to a self-described lack of understanding and confidence.^{10,11} Wendell et al.¹² and Lee and Strobel¹¹ also found that teachers face numerous pedagogical challenges when attempting to integrate and apply science within engineering activities. These challenges may affect how classroom instructors view and embrace teaching engineering, and consequently, the application of science. As science teachers grapple with the new subject and approach to teaching, it is important to examine how engineering affects their views of the nature of science, goals for teaching science, and science pedagogy.

Purpose. This study examines how three teachers' (two middle and one high school) interpretations of the Nature of Science (NOS) and goals for teaching science have 'shifted' after transitioning from teaching science to engineering. While there are countless studies that look at teachers' views of science, few studies have investigated how teachers understand and grapple with the NOS as they are learning about Nature of Engineering (NOE) and how it affects their views of teaching. I am also interested in how teachers view the two content areas in relation to each other and how they can be integrated within the classroom. The research method employed by this study is qualitative in nature. An exploratory case study design was utilized to develop an in-depth understanding of how these teachers view of NOE and its relationship to science and the pedagogical similarities, differences, and relationship between the two disciplines. Below are the guiding research questions for this study.

- 1) How does teaching engineering affect the way educators think about science and how it should be taught in K-12 schools?
- 2) How do teachers, who have transitioned from teachers of middle and high school science to engineering, view the nature of science and the nature of engineering?
- 3) How are teachers' views of the nature of science and science education shifting as they transition into engineering educators?

Nature of Science & Nature of Engineering

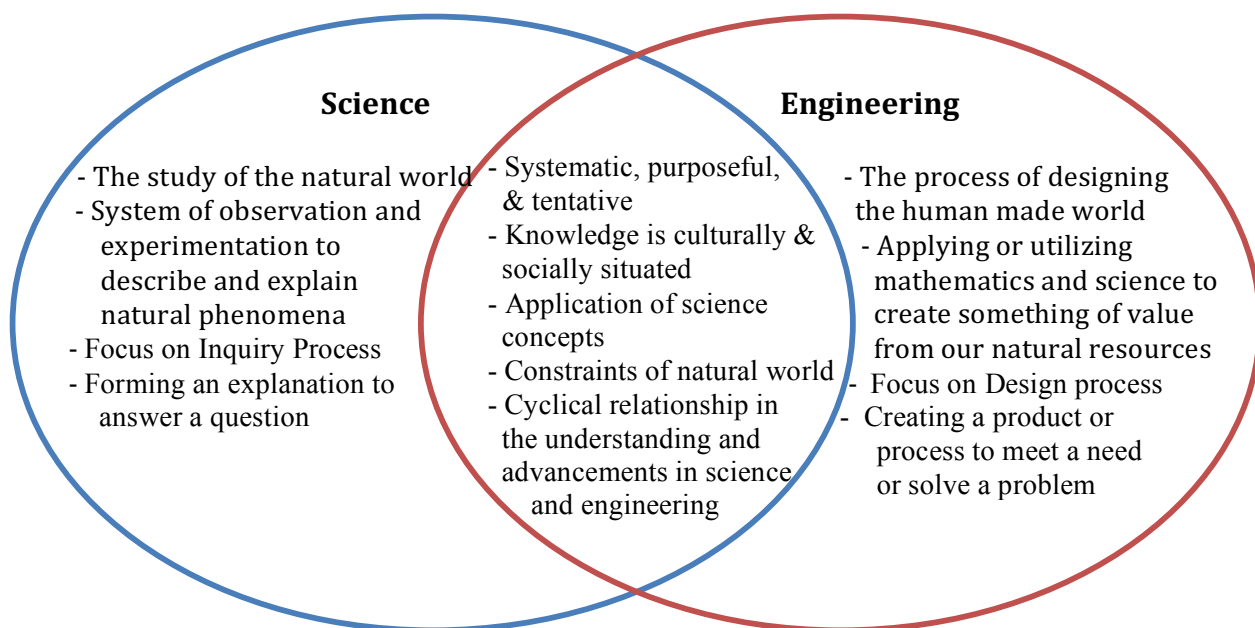
To examine teacher content knowledge, this paper looks at how teachers' conceptualize the nature of science (NOS) and the nature of engineering (NOE). The theoretical basis for the first part of this study is based on the work of Lederman's^{13,14} notion of the Nature of Science (NOS) and Karatas¹⁵ and Karatas, Bodner and Unal's¹⁶ notion of the Nature of Engineering (NOE). Through the lenses of NOS and NOE, this study aims to describe K-12 teachers' views of the Nature of Engineering and determine how it compares or relates to the teachers' views of science.

The nature of science (NOS), understood as part of the epistemology of science, is described as science as a way of knowing, or of values, beliefs and assumptions essential to the development of scientific knowledge.¹³ Lederman et al.¹⁴ further describe science knowledge as "... tentative; empirical; theory-laden; partly the product of human inference, imagination and creativity; and socially and culturally embedded" (p. 499). Based on the work of Lederman and his colleagues and other scholars, this study conceptualizes Nature of Science (NOS) as the (1) study of the

natural world, (2) an empirical, creative and social and culturally embedded endeavor, (3) a system of observation and experimentation to describe and explain natural, phenomena, (4) inquiry based process, (5) forming an explanation to answer a question, (6) science knowledge is a tentative, empirical, theory-laden and partly the product of human inference.

Like science, the Nature of Engineering (NOE) is understood as dynamic conception that has no fully agreed upon consensus within the engineering community. Karatas' notions the Nature of Engineering (NOE), which build on the work of Dym et al.¹⁷, Wulf¹⁸, Koen¹⁹ and Adams²⁰, includes the following tenets: (1) solutions are tentative and involve designing artifacts and systems; (2) depend on existing scientific and mathematical theories, as well as failures and successes in the field; (3) affected by cultural norms and the needs of society; (4) involve stepwise and iterative problem-solving activities; (5) require creativity, imagination, and the ability to integrate different scientific, mathematical, and social values and theories in novel ways; (6) is a complex human endeavor that require analytical thinking to make complex problems simpler; and (7) should involve an holistic, open-system approach that requires the consideration of all aspects and perspectives of not only artifacts and consumers, but also the potential impact on individuals, society, and the environment.

Figure 1. The Nature of Science and the Nature of Engineering



As shown in the Venn diagram above, the nature of science and engineering are distinct yet closely related. The overlap illustrates the interwoven and cyclical relationship between the nature of science and engineering. Through the lenses of both NOS and NOE, this study aims to describe K-12 teachers views of the Nature of Engineering and determining how it compares or relates to the teachers' views of science.

Pedagogical Content Knowledge

The second part of this study aims to determine how these middle and high school teachers view the pedagogical relationship of the science and engineering. To examine the pedagogical views of teaching science and engineering, this study employs the theoretical lens of teacher knowledge bases, specifically targeting teacher knowledge base related to pedagogy.^{21,22,23,24} Shulman²¹ argues that teachers must develop a general understanding of how to teach (general pedagogical knowledge) and how to specifically teach a subject or topic (pedagogical content knowledge). While the scope of a teacher's pedagogical content knowledge has remarkable depth and breadth, this study will specifically focus on pedagogical content knowledge related to the teachers' goals and instructional strategies as a means to compare and contrast the teachers' broader approach to teaching science and engineering. With this lens, this study aims to explore and further understand K-12 teachers' pedagogical knowledge of both science and engineering as well as a unique integrated pedagogy that bridges both content areas.

To better understand teachers' pedagogical views of the two subjects, it seems important to also examine how these views are influenced by their understanding of the subjects. Research has shown that a strong connection exists between a teacher's subject knowledge and effective science teaching.^{21,25,27} Abd-El-Khalick²⁵ and Rutherford²⁶ used coupling to relate the NOS to teaching with inquiry. As an example, Abd-El-Khlick²⁵ states that science teachers who have internalized robust understandings of key aspects of NOS are more likely to abandon "traditional" science teaching practices in favor of practices that would sustain more authentic science learning. While there is continued debate about how much or to what extent a teacher's knowledge of the subject matter positively influences their teaching, this study takes the opinion that it has some affect on a teachers pedagogical view. To understand how the development of knowledge of engineering affects the way teachers think about the NOS and how to teach science, this study aims to explore the connection between teacher's view of NOE and their views and goals of teaching the science.

Methods

Context. This research study was done in the context of a grant-funded program for secondary science, technology, engineering, and math (STEM) teachers. In this program, mid-career, middle and high school teachers in complete a master's degree in teaching and teacher education while also participating in summer industry work experiences in a variety of STEM industries. The purpose of the program is to provide teachers with experience in industry to learn how science, technology, engineering, and math are applied in the real world, so they can bring back meaningful experiences to their students. During the Master's program, teachers develop content and pedagogical knowledge by taking education and content courses over three years. All participants have completed three or four summers of industry experience and taken seven education courses and four STEM content courses during their three years in the program. While I have selected teachers from this program, I am more interested in their positions as science educators who have transitioned into teaching engineering.

Participants. Three mid-career, secondary science/engineering teachers were selected to take part in this exploratory case study. Purposeful sampling was used to select participants who are both varied and representative of a middle and high school teachers who have transitioned from teaching science to teaching engineering. This sample is representative of the many science

teachers who are now being asked to teach engineering without much formal education in engineering^{10,11}. While each teacher has been educated and certified as a science teacher, none were formally educated or trained in engineering education. The teachers are varied in the amount, degree, and level that they teach engineering. For example, one of the teachers includes engineering within a single unit of his science courses; another participant teaches a sequence of three high school engineering courses on top some science courses; the third participant teaches a full course load of engineering courses at the middle school level. While the teachers are representative in terms of formal education for teaching engineering, their work experience in industry, especially at engineering firms, makes them a unique cohort of educators. The three participants, whose experiences, coursework, or exposure to engineering is described in detail below, represent a spectrum of science teachers who are transitioning from teachers of science to teachers of engineering in a variety of ways and in varying degrees.

One participant, Steve, was a former middle school science teacher who now teaches a full load of engineering courses. Steve is certified as a K-8 in Math and Science educator. While in his sixth year of teaching, he spent two years as a first-grade teacher, another two years as a 6-8 math and science teacher and is currently in his third year of teaching a full load of engineering courses at the middle school level. While Steve has no official training to teach engineering, he spent four summers as an intern at two engineering firms and took a single engineering course as part of his master's degree.

The second participant, Eli, is a male middle school teacher in his sixth year of teaching. He currently teaches 7th grade advanced science course, an 8th grade general science course and 6-8th sustainability course. While Eli does not teach stand-alone engineering course, he integrates engineering into his science courses. In fact, he has integrated an engineering design unit on rocket cars into his physics unit this year. Eli, who was not formally trained to be an engineering educator, does hold a bachelor's of science in materials science & engineering. He was also an engineering intern for one summer at a local startup before deciding to teach and has spent the last two summers as a teacher intern at an engineering firm. Of the three participants, Eli has the most highly education in the field of engineering.

The third participant, Molly, is a female, mid-career educator in her 13th year of teaching. She currently teaches high school chemistry, physical science, and two engineering courses (engineering 1-2, an introductory level engineering course for 10-12 graders, and engineering 3-4, an upper level engineering course for juniors and seniors). While Molly began her teaching career as a science teacher, over the past three years, she has slowly been transitioning to engineering. She started by adding elements of engineering to her science course, then taught one elective engineering course and now teaches three sections of engineering. While Molly never formally studied engineering or engineering education, her education and experience with engineering comes from participating in a master's program where she spent four summers in a workplace internship program at several engineering companies. She also holds a career and technical education (CTE) certificate and has recently been certified in emerging technologies.

Data Collection and Analysis. Following in the tradition of case study research (Merriam, 2009; Creswell, 2014), interviews will be used to reveal the participants' interpretations of a lived experience. A two-part semi-structured interview series was used to first examine the

classroom instructors' views of the nature of engineering and how it relates to science interviews; and second, to examine teachers' pedagogical view about science, engineering, and the relationship between the two subjects. The interview questions (see below) were based on questions from Karatas, Bodner and Unal's "views of Nature of Engineering" survey¹⁶. The two-part interview was conducted during the spring semester.

Figure 2. Part 1 Interview question (based on Karatas, Bodner & Unal¹⁶).

PART 1: Interview Questions (NOS and NOE)
1. In your opinion, what is engineering?
2. What is the goal or purpose of engineering?
3. What image or images comes to mind when you think of engineers or engineering?
4. In your view, what is science? What is its purpose?
5. Do you agree with the statement "engineering is applied science? Why, or why not?"
6. In what way are science and engineering similar?
7. What are the differences between science and engineering?
8. If two engineering firms are given the same job (to design a new cell phone), would the product be more or less the same? Why, or why not?
9. Please answer the following three questions based on the statement here. Imagine that another bridge is going to be built over the Colorado River. <ul style="list-style-type: none"> a. What do engineers need to consider in the process in planning this? b. What component(s) of this task will be done by engineers? c. How do engineers achieve the tasks needed to be done?
10. What characteristics are needed to be a good engineer? Explain why they are important.

The second semi-structured interview focuses on teachers' pedagogical views about science, engineering and the relationship between the two. For the purposes of this study, the participants' pedagogical views are conceptualized as a subset of the teachers' PCK^{21,23,24}. This study uses in depth interviews to explore the specific elements of a inservice teachers PCK as it relates to their interpretation of: (1) the general view of teaching and learning for science and engineering, (2) pedagogical goals, (3) instructional strategies and learning activities, and (4) sequence for each subject separately and as integrated. While many studies on PCK included observations and artifacts to understand teachers' knowledge of a phenomenon such as inquiry teaching, many scholars understand that teachers' personal understanding and interpretation impact their teaching practice. This follows the research of Magnusson et al.²⁴, who argue that teachers' personal understanding and beliefs strongly influence their practice. Studies on teachers' conceptions of inquiry science²⁸ and design pedagogy³⁰ align with this perspective. This study accepts the limitation in inherent in exploring teachers' conceptions and personal understanding through their interpretations. Without looking at a teacher's actions and enactment, this study does not aim to fully conceptualize teachers' pedagogical content knowledge (PCK). Nevertheless, this study highlights the importance of exploring how inservice teachers interpret the pedagogical approaches of science, engineering and the relationship between the two, as these views can greatly impact their practice. The questions for part two of the interview are based on a combination of interviews developed by Kim³⁰ to measure middle school

mathematics teachers' pedagogical content knowledge and Hynes²⁹ who looked at middle school teachers understanding of design teaching.

Figure 3. Abridged interview question for the second part of the interview (based on Kim³⁰, 2004 & Hynes²⁹).

PART 2: Interview Questions (Pedagogical Views)
1. What is your goal for teaching engineering to your students?
2. How is the way you teach engineering different or similar to the way you teach science?
3. How would you teach both engineering and science together? (sequence, organization, goals)
4. Which simile best describes learning science? Why? -- Learning science is like... (examples: working on an assembly line, cooking with a recipe, working on a jigsaw puzzle, building a house...)
5. Which simile best describes science teaching? Why? -- A Science teacher is like a... (examples - news broadcaster, entertainer, doctor, orchestra conductor, gardener, coach...)
6. Describe a "good" science lesson or unit? (key components, describe classroom)
7. Which simile best describes learning engineering? Why? -- Learning engineering is like... (examples: working on an assembly line, cooking with a recipe, working on a jigsaw puzzle, building a house...)
8. Which simile best describes engineering teaching? Why? -- A engineering teacher is like... (examples - news broadcaster, entertainer, doctor, orchestra conductor, gardener, coach...)
9. How do you envision a "good" engineering lesson or project? (key components, describe the classroom would look like)
10. Is there a difference in the characteristics needed to be a good engineering teacher compared to science? Explain why.

Data collected during the interviews was coded using thematic analysis³⁰ of the teacher's interpretations of teaching an engineering unit. In this thematic analysis, data from the interviews were analyzed separately for each participant and then in parallel to look for similarities and differences and establish consistency. Through a process of open coding, key words or phrases were identified and then categorized into overarching themes. During this process, teacher responses were first coded by question and then coded across all questions. The initial categories include: parallel views of engineering and engineering education, parallel views of science and science education, shifting view of science, and science as a tool. Using these initial categories and the literature on NOS, NOE and PCK, the data was reexamined through a constant comparison method³¹ to look for alternative explanations and new themes until final, consistent themes were determined. The final themes were categorized into four groups that are explained in the findings section below.

Findings

Perception of Engineering. Overall, these three teachers understand engineering as a flexible, systematic process, in which engineers apply science and mathematics to design, build, make, or solve real world problems. In the following paragraphs, the teachers' perceptions of engineering will be expanded and explained in terms of the overarching themes; (1) engineering as a design process, (2) creativity and problem solving, (3) engineering as the application of knowledge, and (4) engineering as a complex endeavor.

Engineering, from all three participants' descriptions, is soundly centered on the design process. The design process, as Molly described, starts "off with a problem, you do research, you brainstorm and then prototype." Molly further described the iterative quality of this engineering design as different from science as it is non-sequential, with "different iterations" where you can make mistakes and keep going back in different ways when designing." Steve added that engineering design is a flexible process that can be manipulated but must stay within a set of "criteria and constraints."

In conjunction with engineering as a design process, the teachers further described engineering as a physical and imaginative process that promotes deep problem solving. As Molly states, engineering forces us to "think outside the box," and to problem solve. It is a "different way of thinking, "she [the student] had to put all these things together, it was much deeper problem solving than what she was doing in calculus." From this quote, Molly views engineering as pushing students to a deeper problem solving than students experience in their highest math courses. Eli further emphasized how engineering has a "creative side" and that "most successful engineers are both creative and analytical." Overall, these portrayals demonstrate an understanding of engineering as an iterative design process that is confined by criteria and constraints, but is flexible, non-sequential, creative, and allows for failure.

Participating teachers also commented on the capacity of engineering and the design process to tackle complex, authentic problems. Molly focused on the ability of engineers to test more than one variable, which, to her, "is the difference between science and engineering, how they go about testing in that world." She specifically stated that in engineering, "one of the things that I found interesting is that you can test more than one variable, you have to be able to identify that the variable will have a correlation, and if they don't you can't test them together, but if you know that they have a correlation, you can test them." She gave the example of solar ovens to make her point, stating, "we do a solar oven and here you are looking at multiple different controllable variables that the engineer has, and then there are a ton of uncontrollable variables that you can't control (...) yet we are taking this mathematical model (...) to accurately predict the temperature of the solar oven." Eli and Steve further discussed the capacity of engineering to tackle complex problems with the many unanticipated "problems that arise along the way." Steve stated that engineers are "never just doing one thing, they are doing multiple things at the same time, because they have to put all their pieces together, like a multitasking capability." For these teachers, engineering represents a process with the capability to deal with problems that are situated in the complexity of the "real world," where there may be multiple variables and unanticipated problems.

All three participants also explained engineering as a physical, hands-on application of knowledge. Eli, for example, stated that engineering is "making stuff based on knowledge from scientists." Steve described engineering as "the application of sciences to design and build products that are used by human beings." An important point is the teachers' explicit inclusion of mathematics as an essential part of engineering, not just the application of science. Eli stated that engineering is the physical, where ideas applied and "meaning making is real world." Steve further stated that engineering is "defining needs, understanding all the factors, seeking out

knowledge, applicable knowledge.” Steve provided an explanation of engineering as the application of knowledge, stating,

“Engineers say, okay..., you have proven what you need so I am going to take your theory and I am going to design everything and then I am going to test it. So it is like science in reverse, because it is taking what they said, building something with that knowledge and then testing it out to see if what they said was really true. They are not really testing out the idea, they are just testing out, did the rules work, so that is what it is applied sciences. Engineering is not just science.”

In this excerpt, Steve appears to be explaining that engineering is not about proving whether or not a science concept is true, but if the science concept improves a design or helps solve a problem. From this perspective, engineering applies scientific (and mathematical) knowledge for a tangible purpose, where concepts are tools that should be sought out, tested, and used for solving problems. In this view, scientific knowledge is purposeful and situated within the context of solving the given problem.

Perception of Teaching Engineering. The participants described teaching engineering as a project-based and student-centered way of teaching that promotes ownership and control. The teachers further described engineering activities as non-sequential, creative, hands-on and allowing for mistakes. Lastly, teaching engineering is a practice-oriented process that promotes problem solving and critical thinking.

For Eli, the goal of teaching engineering is adding components of engagement and creativity to his science class. When comparing engineering to science in schools, he explained engineering as project based learning (PBL) that is an engaging, hands-on type of learning. He specifically stated that he has “seen some example that are sciency” but it doesn’t have “the same hook with the kids who want to be mentally and physically engaged. He explained that “doing a poster or research does not physically engaged for my kids and all the science only PBLs “are all just really conceptual, mental, it doesn’t have the hands-on-ness.” Eli viewed teaching engineering as representing a new way of teaching that is possible with science, but not as feasible or likely. Engineering represents what he describes as a “sweet spot” for engaging students with physical, hands-on activities while still including science content.

For Molly, teaching engineering represents flexible, creative, hands-on activities that allow for mistakes and promote problem solving and perseverance. In comparing engineering to science, Molly emphasized the non-sequential aspect as helping her students “get out of the mode that everything has to happen in a sequential process, and it doesn’t, especially in engineering.” Molly described the rewards of engineering as forcing students “to think outside the box, to problem solve.” She added that engineering promotes a sense of “Independence, self-reliance, and perseverance.” She gave the example where her student “kind of looked at me like, you are supposed to help, nope, go back to research, go figure it out.” To Molly, engineering provides a means to promoting many of the 21st century practices, through more flexible process that more than what is seen in science.

Similar to Eli and Molly, Steve explain teaching engineering as creative, process oriented activities that allows students learn from their mistakes. He states that engineering “adds a

component of creativity, it's awesome with that, it is a good venue for that, whereas I think sometimes science isn't about that, especially with middle school kids." Steve states, "science kind of wants them to discover what the answer is, engineering has no answer, so you can't get what I am doing wrong, all you can do is not be doing it. Doing my grading, a lot of it is participation, because as long as you are involved, you can't really be messing it up."

From all three teachers' descriptions, two significant deductions seem to arise: (1) the purpose of engineering is not about discovering but creating, building and problems solving and (2) teaching engineering is not as much about finding an answer, as it is about learning the process and developing skills or practices, such as creativity, perseverance, and critical thinking.

The discipline and teaching of engineering are about the application of content, not the discovery of the content. From this view, teaching engineering is about taking what you know and applying it, it is about finding information (content) and applying it. When teaching engineering, these teachers perceive scientific (and mathematical) concepts, not as something to be discovered, but instead as a *tool* for designing, creating, and problem solving. These two themes represent the significant differences between the goals for and approaches to teaching science and teaching engineering.

Perception of Science and Teaching Science.

When asked, "In your view what is science? What is its purpose?" all three participants broadly view science as a systematic way of understanding the world. Specifically, they commented that science is "a way to understand the world around us" and understand "how things work." The participants further defined science as a systematic process or method of answering questions and understanding the universe through observation and inquiry. These broad views of science align with a fundamental and universal understanding of science that many people learn in school.

Beyond these overarching views, teachers described science as a more absolute, linear and conceptual endeavor when compared to engineering. The teachers described science in school as heavily content focused, less creative, focused on getting the answer, and a fixed process. To look closely at how these parallel views between science and teaching science, each participant will be discussed separately in the coming paragraphs. It is also important to remember that the teachers described science as much more than just absolute, linear and conceptual. However, in contrast to engineering, these descriptors were used frequently to describe the nature of science and even more frequently with regards to teaching science.

Steve explained science as rule-based system of absolutes and "right" answers. He stated that science "is really just telling us all the rule that exist, if you are talking evolution, what are the rules that have existed for the system to go the way that it does, what are the rules for why two chemicals bonds act the way they do, what are the rules that say that gravitational forces will pull in this way or that to create stars." Similar to this rule based perspective, Steve further explained that science is a way to prove if you are right. Steve specifically describes the scientific method as "I have an idea, I observe something in nature, I make a hypothesis, I run some tests, I prove if the tests are right." Science, from Steve's perspective, appears to be portrayed as having a system of absolutes or rules with a "right" answer that need to be proven.

Paralleling Steve's description of science, he explained science teaching or the science seen in school as less creative, focused on getting the answer, and a fixed, rule-based process that has to be right or the results will be invalid. He stated that science is "following the rules, if you are not following the rules because you are trying to do something different, that shouldn't be counted against you, because that is just a new way of thinking about it." He further states that in science "the process, every step of the way has to be right, otherwise they are not going to get the right answer, and they are not going to come close, and they just wasted their time." From this description, Steve's view of science parallels his views of teaching science, with his view of teaching science matching "traditional school science."

Beyond the descriptions above, Steve, like all the other participants, view of science in schools as exceedingly content focused. Steve stated "science has become mostly teaching content, what have other people discovered, but ideally is taught about skills. While Steve mentions the purpose of learning science in schools as "ideally" about skills, for him, the reality of science in schools seems to be a very fixed process, where there is one "right" answer and it is hard for students to think or do things differently or creatively. This theme of school science as lack of flexibility, creativity and ownership for the students, as compared to engineering, was echoed throughout the interviews.

Similar to Steve, Molly described science as a linear and protocol based process. She emphasized how you must have a control group, you must test one variable at a time and you cannot do things differently. Molly stated, "... an example in science, you go off the scientific method, it is very linear, you get a problem, test hypothesis, answer a question, you can go back through the process and do it all over, but essential it is still a very linear way." She stated that "at least in science, you know we have been told, well at least I have been told all my life, you have to test one variable at a time, you have an independent variable and a dependent variable." For Molly, science is a linear, fixed process this perspective seems to be imbedded in her experiences with science both in her own schooling and as a teacher.

In addition to the Molly's view science portrayed above, she seems to understand science in two ways and in sense, more than just linear process of discovery. To illustrate this point, Molly explains science as, pure science and applied science. Below is Molly's response in which she explains the two types of science.

Molly – "so, I think that science is a way to understand the world around us, from that knowledge, this is where you get between pure science and applied science."

Molly – "Pure science is like research - this is what I gravitate towards in what science really is, but then you have the applied sciences, where you take the research, like eyes and optics, and your applied science is building the lens for people who wear glasses so that you are able to see, so there is a part of science that is engineering like, because they are using the scientific knowledge to find out the how and why of the world and make it better, as well as what engineers do."

From this perspective, “pure” science seems to resemble a more traditional view of science and is what we see more in typical science classrooms. On the other hand, what Molly describes as “applied science,” is associated with engineering, but it is nonetheless considered part of science. By distinguishing science into these two categories, Molly provides an insightful depiction of how she may be processing and grappling with how engineering fit within her views of science.

When asked about teaching science, Molly stated that “science is really heavily content” and “vocabulary” driven. She further explained that school science as being hands-on yet dominated with premade labs and experiments and “a lot of direct instruction.” Molly, for instance, stated “there are still labs, there are still hands on activities, but there are less opportunities for making it project based. From this example, Molly feels that school science includes hands-on learning opportunities, yet many of these hand-on activities lack an open-endedness and have limited opportunities for student to be creative or have any control or ownership. Molly appears to see the confines of teaching science in a more traditional way of direct instruction and pre-made labs as she has transitioned into an engineering teacher. These descriptions of science also seem to parallel her views of “pure” science.

For Eli, science is about understanding how things work or how we know stuff. He explains that science as being able to predict, make predictions, and a method of answering questions. Beyond these overarching descriptions, Eli, views science as more conceptual than engineering. He stated that “science is almost conceptual, where engineering is the physical, applied, meaning making it real world.” He also stated that “science is the idea, the foundational knowledge, whereas the engineering is the applied subset.” From these descriptions of science, Eli appears to understand science as a set of ideas or concepts but not something that is applied or physical, that is engineering to him.

For Eli, teaching science is also about engaging students, working together and focusing on the idea. For example he stated, the kids are thinking, and are working together to understand something, to do something.” When discussing the similarities between teaching science and engineering, he stated “I do a lot, to me it is all very collaborative, a lot of idea sharing, even when I do science, I look for PBL stuff, I try to do hands-on activities or labs, some of which were maybe a little creative, a little hands on...” From these descriptions, Eli emphasizes the importance of collaboration, and while he seems to attempt hands-on, creative, physical activities in science, to him, they seem constrained when compared to engineering.

Discussion

Overall, the teachers view of science as a systematic, inquiry based process of observation and experimentation to understanding the natural world matches with the literature on the Nature of Science^{13,14}. However, the teachers’ description of science as more absolute, linear and conceptual endeavor differs from the literature on NOS and lines up with the traditional view of science in school. Absent from these teachers’ descriptions of science as tentative, the product of human inference, creative and social endeavor, and as culturally embedded. The teachers all seem to view science as more of what Molly describes as “Pure science.” This partial view of NOS matches other studies by Abd-El-Khalick²⁵ that have found science teachers to hold naïve or inadequate views of science. What this study adds to the literature is how the transition to

teaching engineering appears to have shifted or broadened the teachers' views of science to include the application of scientific ideas. These teachers not only seem to understand the application side of science, but they emphasize its importance for teaching and student understanding of the discipline.

The participants view of engineering is the application of mathematical and scientific knowledge to design, create, and solve problems. Overall, the participants' description of the engineering as a creative process that is systematic yet flexible, non-sequential, iterative and allow for failure and redesign closely matches the elements of NOE outlined in the literature¹⁵⁻¹⁹. It is interesting to note that the teachers' views of NOE match the fields view of NOE more closely than the teachers views of NOS. The reason these teachers may hold a more comprehensive view of NOE compared to science may be due to the fact that teachers hold views of science that have been deeply imbedded since they were students. A benefit of teaching engineering, which is a new to many teachers, may be that it does not come with the same deeply imbedded views as teaching science. Overall, the transition to teaching engineering appears to permit teacher to consider new ways of to think about the nature of science, its purpose and how it should be taught to students

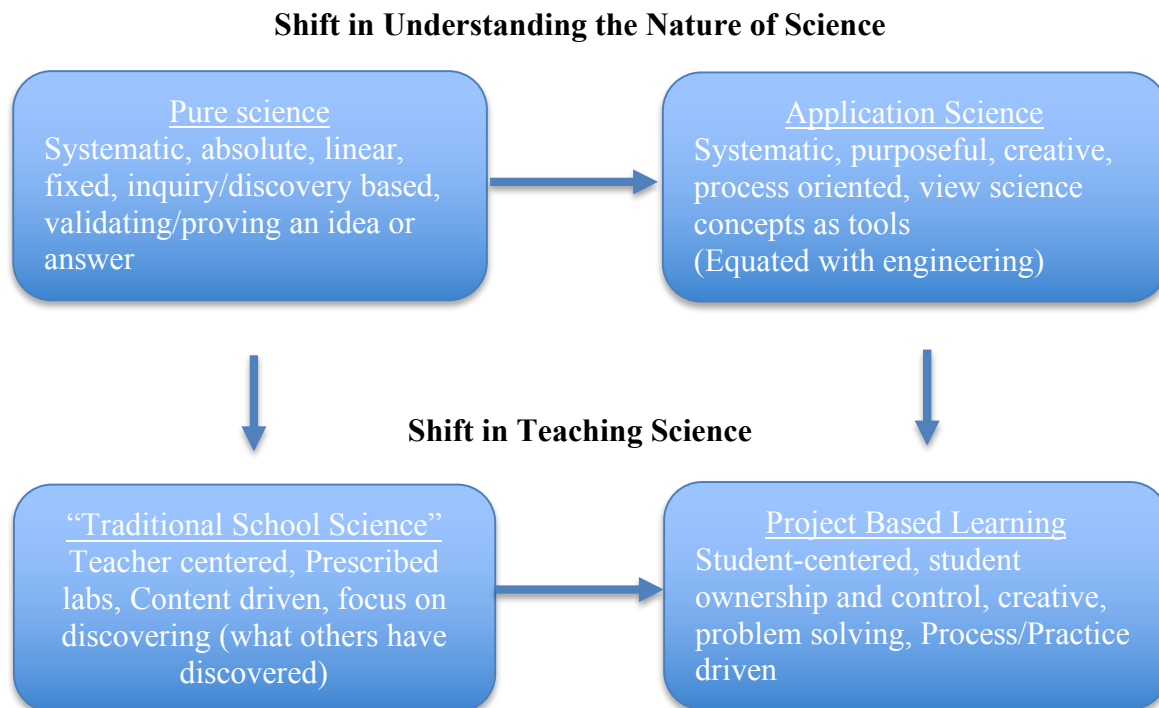
Engineering as a catalyst or bridge. The teachers' perception of science and engineering appear to guide or parallel their views of and goals for teaching science. Based on the findings, teaching engineering appears to act as a catalyst or bridge for teaching in new ways. This finding corroborates O'Brien and his colleagues,⁴ conclusion that engineering helps teachers transform their instruction to a more integrated, project-based, hands-on, and student-centered approach. What this study adds to the literature is that this transformation of instruction appears to parallel teachers shifts in understanding science in a more application based. Engineering from this perspective appears to compels teachers to look critically at what science is and how it should be taught in school.

Science as a tool. A part of the teachers' broadened views of science as more application based, and their teaching of science through engineering, teachers begin to see scientific knowledge as more of a tool. The findings show how teachers have begun to see scientific concepts as something to be understood not to be discovered. The participants view scientific knowledge as purposeful and situated within the context of the problem or situation. In this more practical view scientific knowledge, learning scientific concepts is not about discovering or proving a concept or about knowing for the sake of knowing. Scientific concepts are learned, instead, for the purpose of using and applying them to meet a specific need or solve a specific problem. While the benefit of this approach is generating a sense of relevancy, ownership and purpose for the learning, it also comes with trade-offs or consequences. A possible downside of this approach is that teachers may cut short or simplify their instruction of the science concepts. If the problem only calls for minimal understanding of a concept, teachers and students may adapt the teaching to the required depth that is needed for the design problem. Due to time constrains, teachers may also turn to direct instruction and shortcuts to quickly teach science concepts so there will be sufficient time for often lengthy process of designing and building. As more and more teachers, integrate engineering into their science instruction, it is important to watch out for the potential downsides of viewing science this way.

Parallel shifts. For these teachers, the nature of a subject and its purpose for education are closely related and seem to shift in parallel. As the teachers transitioned from teachers of science to teachers of engineering, findings suggest that their views of the nature of science and teaching science shift in parallel. While the teachers understand the importance and necessity of pure science as a foundation for engineering, they seem to understand the application of science as an important part of the discipline. Figure 4 illustrates these parallel shifts.

The shifting nature of science and changes in teaching science appear to go hand in hand. This could be an important for helping teachers change their teaching practice. The findings in this study show that a teachers’ view of the nature of a subject influences their goals and purpose for teaching the subject. It seems that the shifts may happen simultaneously and perhaps feed off of each other. This matches the purpose of the NGSS, which describes the integration of engineering as a means for including more application in science, which is overwhelmingly left out of in K-12 classrooms.^{2,8}

Figure 4. Parallel Shifts between teaching science teaching science



Significance of the Study

Due to the fact that K-12 engineering education is still a new and emerging field, the results of this study are informative for the both researchers and teacher educators in the areas of K-12 science and engineering education. To fill this gap in the literature and begin work to improve science teacher preparation and support for teaching engineering, this study offers an interpretation of how middle and high school science teachers view of the Nature of Engineering (NOE), how it relates to their views of science, how these teachers view the pedagogical

relationship of the two disciplines. By exploring in-service teachers' views of engineering and science, the results of this study help improve how science educators are prepared and supported to integrate engineering into their classroom. The results of this study may also be utilized to integrate the Nature of Engineering (NOE) into K-12 science and engineering preparation programs.

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