Learning to Engineer My Educational Experience

Michael G. Eastman
Randy K. Yerrick
University at Buffalo

A Paper Presentation at the NARST Annual International Conference
Baltimore, MD, April 16, 2016

DO NOT CITE WITHOUT WRITTEN PERMISSION
Abstract

This phenomenological study investigated a cohort of long-time engineering educators during the early stages of their participation in a STEM focused PhD program. Confident in our own discipline and teaching, we soon realized we had more to learn than we initially believed. We struggled with our own deeply rooted beliefs as we were introduced to numerous concepts in education theory including notions of how science is done, elitist attitudes in STEM, conceptions of privilege and inquiry-based teaching practices. This research analyzed the lived experiences of nine engineering educators early in their journey to becoming engineering education researchers and supports extant research calling for substantive change in the culture of engineering education.

*Keywords:* constructivist, privilege, equity, engineering, STEM, inquiry
Learning to Engineer My Educational Experience

What we want and need is education pure and simple, and we shall make sure and faster progress when we devote ourselves to finding out just what education is and what conditions have to be satisfied in order that education may be a reality and not a name or a slogan.

(Dewey, 1938, pp. 90, 91)

This research involves the story, and the history, of an engineering education culture quick to identify the have-nots and dismissive of those individuals “not cut out” to become engineers. Specifically, this investigation tells the story, through rigorous research methods, of a cohort of engineering educators (the cohort) who chose to enroll in a STEM Education PhD program and investigates initial challenges and learnings during the journey from engineering educator to engineering education researchers. Much of this research is told from the perspective of the first-person. When the terms “me” or “I” are used, it is because the perspective being shared is that of the first author.

Nearly 20 years ago, I embarked on a career in engineering education; young, energetic, and ready to take on the world. I believed the knowledge I gained in seven years as a design engineer would help me produce outstanding engineers to solve the world’s problems. I felt I could push students beyond what they believed they could accomplish. Full of confidence and content knowledge, but lacking any foundation in educational theory, I didn’t know what I didn’t know. It was several years before I came to the realization the students who were highly successful in my courses, those I accepted credit for “making”, would have been successful with or without me. I eventually recognized the students I should have been able to help were those who struggled; who worked hard, but failed; who did not engage because the material was abstract; disconnected; or did not hold an intrinsic value to the student.
The last three years of my journey as an engineering educator have been dedicated to pursuing an education-based PhD focused in Science, Technology, Engineering, and Math (STEM). Throughout my career, I continued to learn and adapt. I attempted to improve every aspect of my teaching. However, in many ways, I did not realize I was flying blind, unaware of a wealth of educational theory which could have aided my progress. These last three years have proven paramount in my professional development. In some ways, the pursuit of a PhD in STEM has served as an epiphany as the process has continually challenged my perspectives on teaching and learning. I am one of nine colleagues and engineering educators who entered a PhD program as a cohort, encouraged and supported by our Dean, to breathe new life into teaching and research, at our university. In this qualitative research study, I retell the stories of a cohort of engineers as we embark on a journey from long-time engineering educators to engineering education researchers through the common pursuit of a PhD in STEM Education at a large research institution in the northeast.

Despite each cohort member boasting between seven and 32 years of college teaching experience, all of us, in our writing, classroom discussions, and personal interactions, described surprise regarding unfamiliarity with educational history and theory uncovered through reading authors such as Dewey (1902), DeBoer (1991), Calabrese-Barton (2003), Rodriguez (2005; 2004), Latour & Woolgar (1986), Traweek (1988), Gay (2000), and Bransford (2000). While focused on the pursuit of a PhD, we began to understand our professional and academic experiences had provided little background related to the history and philosophy of science (HPS), equity and diversity in the classroom, and teaching and learning in general. Indeed, as engineering educators, we began to recognize how far we had to go in our quest to become
engineering education researchers, and how much our discipline needed to learn if there would ever be substantive and sustained reform in engineering education.

In my growth as an engineering educator, and through participation in the PhD program, I came to recognize a theme all too common in engineering education: capable students cast as outsiders in a privileged world, combined with well-intentioned faculty unprepared to meet the needs of students with cultural, socioeconomic, and academic backgrounds different from their own. This research investigates the first year, of what has become a suite of transformational experiences, for a cohort of engineering educators, the cohort, enrolled in a STEM Education PhD program. I focus on the culture of engineering education and the persistence of deeply rooted faculty beliefs long-influenced by that culture. The study describes how the shared and individual educational experiences of the cohort have shaped individual’s understandings of the culture of engineering education, classroom practices, and teacher beliefs. Ultimately, each faculty member resides somewhere along a continuum of quality teaching practices. As a community of engineering educators, recognition of where we reside on that continuum, recognition of our need for improvement, and an understanding of mechanisms to enact meaningful change to positively impact the culture of engineering education, are critical to the long-term success of engineering education.

Reconstructing the lived experiences

This research, therefore examines the individual, yet shared experiences of five tenured university faculty members during their first year participating as a cohort in a STEM Education PhD program. I report on the challenges, beliefs, and new learnings experienced by this cohort. For similar and unique reasons, each sought to transition from engineering educator to engineering education researcher. For some, this process is predominantly about earning a
terminal degree, for others it has become a transformational experience. The retelling of our stories and the investigation of our journeys is first supported by a literature search focused on the culture of engineering education, the traditional preparation of engineering educators, and the challenges of trying to educate a diverse population of potential engineers in light of that culture. I develop the theoretical framework of constructivist based teaching strategies within the literature review and highlight participants’ reactions to an introduction to constructivism in the findings. Following the literature review, I present the research questions and establish the qualitative research methodologies, selected to permit a rich retelling of the personal experiences of the participants. The findings are presented next, incorporating thick descriptions of the participants’ stories, which describe unique experiences and establish the invariant structure uncovered in the data analysis. Finally, I provide the conclusions and implications of the research.

**Literature and Theoretical Framework**

This review of the literature focuses on the culture of engineering education; the need for change in engineering education; and constructivism, which was introduced to the cohort early in their PhD journey. As engineering educators indoctrinated to the culture of engineering and reared in the United States, cohort members were comfortable with a positivist approach to science delivered with the expectation the teacher and the textbook were the known authorities in the classroom. We grew up envisioning science as an objective and noble quest for truth by subscribing to methodical process. We tended to teach in the manner we were taught, and we had much to learn about teaching and learning theory, and the culture of our own discipline. I will use relevant literature to show why this group of engineering educators, lacking an epistemological underpinning, is representative of our discipline at-large.
This research was undertaken through the lens of constructivist teaching practices. While constructivism is a term unfamiliar to the cohort prior to beginning the PhD program, it was introduced early in our first semester. Not only did teachers and coursework discuss and describe constructivism, additionally, several courses were structured using constructivist (Barrow, 2006; Dewey, 2013; von Glasersfeld, 1995) and social constructivist (Lave & Wenger, 1991) frameworks, which enabled and encouraged participants to build or construct their own knowledge.

The Need for Reform in Engineering Education

As an engineering educator accustomed to favorable job-growth (NSB, 2010) in my discipline I was originally insulated from underlying structural concerns pointing to a crisis in engineering education in the United States. During participation in this cohort, I came to understand opportunities have been constrained to a select few. This situation is predicated by (a) the United States rapidly losing ground to other countries according to established measures of innovation and educational quality; (b) a history of chronic underrepresentation of individuals outside the dominant culture (i.e. White males) in engineering careers; (c) a population dynamic that will soon result in Caucasians representing less than 50% of the national census; and (d) an engineering education culture biased in favor of the White males. These factors, combined with an engineering education culture resistant to change, have preceded numerous calls for improvement in engineering education (Augustine, 2005; Clough, 2004; Jamieson & Lohmann, 2012; NRC, 1996) and improvement in engineering education research (Borrego, 2007b). One prominent engineering education researcher recently explained:

“Chronic industry complaints about skill deficiencies in engineering graduates, high attrition rates of engineering students with good academic performance records, the
worldwide adoption of outcomes-based engineering program accreditation, and findings from both cognitive science and thousands of educational research studies showing serious deficiencies in traditional teaching methods have all provoked calls for changes in how engineering curricula are structured, delivered, and assessed” (Felder, 2012, p. 1).

Felder continued his argument by enumerating four issues central to debates between engineering education reformers and those believing the current system works fine: the structure of engineering curricula, how teachers are prepared, how courses are taught, and who should do the teaching. These items are central to the STEM focused PhD program in which the participants were enrolled.

While engineering education has experienced consistent improvement in the quality and quantity of educational research since the early 1990s (Froyd & Lohmann, 2014; Johri & Olds, 2014), when compared to research performed by colleagues in science education, engineering education research is considerably less established (Singer, Nielsen, & Schweingruber, 2012). In reviewing the history of engineering education research, Froyd & Lohmann (2014) described four conditions responsible for the slow progression of reform: (a) engineering education literature is focused on undergraduate students, though this is beginning to change; (b) engineering, until recently, has been absent in K-12 curricula; (c) most education research is focused on K-12 curricula, and therefore not attractive to engineering educators; and (d) engineering faculty “… receive little or no formal preparation for their instructional duties…” at any point in their careers (p. 4). The majority of engineering educators are bequeathed the title, absent any formal underpinnings in educational theory. Rather than a foundation in educational research, they rely on, as benchmarks, their own college teachers, themselves lacking education backgrounds. These engineering educators, therefore, do unto others as was done unto them, and
because of their own academic achievements and professional success, they wholeheartedly believe they are doing right by their profession. The result has been a persistent mentality of competition and weeding out the weak (Seymour & Hewitt, 1997), uninspiring curriculum lacking connection to the lives of the student (Prince & Felder, 2006), and consistent with criticisms of STEM in general, a focus on computation rather than conceptual understanding (Tobias, 1990). Moving the mindset of engineering educators to begin enacting pedagogical changes on research from engineering education and the learning sciences has been described as “… a major challenge for engineering education practice and research” (Froyd & Lohmann, 2014, p. 4).

The inadequate progress in pedagogical research demonstrated by the engineering education community is not due to lack of effort. Unfortunately, and perhaps predictably, those trained as engineers tend to approach educational problems with a post-positivist, practitioner’s mindset (Borrego, 2007b). It is unfortunate, as this approach is ultimately insufficient when addressing problems, such as pedagogical challenges, which necessitate a social science perspective (Borrego, 2007a). It is predictable because today’s engineering educators are those who have successfully navigated the perilous waters of and engineering education machine focused on weeding out, competition, and didactic teaching practices, and tend to teach as they were taught. While some positive changes in engineering education have occurred, faculty base most improvements in the classroom on hunches and their own experiences, rather than implementing research or evidence-based pedagogy (Jamieson & Lohmann, 2012). Researchers have also criticized lack of assessment of pedagogical changes as a shortcoming of engineering education research. A review of engineering education literature has led researchers to explain “[s]eldom are engineering education innovations sufficiently grounded in relevant learning
theories and pedagogical practices, and many innovations, once implemented, are not adequately assessed for their effectiveness in achieving their stated objectives” (Jamieson & Lohmann, 2009, p. 14). Clearly, a new strategy, for addressing longstanding problems in engineering education, is desperately needed if we are to alter the inertia maintaining the status quo of ineffective teaching and modifications unsubstantiated by theory.

Attempts to increase the number of graduating engineers and the diversity of the engineering workforce have been virtually unproductive. The culture of engineering education develops a sense of entitlement and near arrogance in those that succeed (Tonso, 2014) and favors middle-class, White males, while shunning outsiders who do not arrive with or quickly adopt an engineering identity.

Simply put, a student who comes from an economically disadvantaged background outside the dominant culture and who attended a resource-poor high school does not have the same odds of contributing to the gene pool in engineering as a student from a family within the dominant culture of median or above median means, and attended a resource rich school district (Foor, Walden, & Trytten, 2007, p. 103).

In propagating the system in which they themselves flourished, faculty insiders continue to fail to recognize within the system, constraints which disadvantage individuals from the non-dominant culture.

To address cultural shortcomings within engineering education, it is necessary to refocus the lens through which engineering faculty situate themselves in the educational process. First and foremost, today’s engineering faculty are exemplary products of the system they now guide. For most engineering faculty, enrolling in and achieving success in an undergraduate engineering program likely set the stage for pursuit of either a MS or PhD in engineering which in turn
fostered a desire to pursue a career as an engineering educator. Many engineering educators possess extensive engineering experience; many embarked on their professorships immediately following graduation. All enjoyed success in an academic environment steeped in competition and didactic teaching, and hailed as a gauntlet where only the strongest survive.

**Our Exposure to the History of Education Reform**

To provide a common backdrop for understanding future doctoral studies, members of the cohort were exposed to the long history of education reform in the United States during our first semester of study. This was one of many education-related topics introduced during the PhD program, never before experienced by this cohort of long-time engineering educators. It quickly became apparent to me, as a member of this cohort, our collective knowledge about teaching and learning was severely lacking in depth, breadth, and perspective. I became frustrated and dumbfounded that major reform efforts, geared toward making science education more engaging and more practical, had been unsuccessfully introduced repeatedly over the last 100-plus years. Equally concerning was the realization engineering education research lags well-behind our brethren in the sciences. Using DeBoer (1991) as a primary resource, but also reviewing documentation from major reform efforts such as the Biological Sciences Curriculum Study (BSCS), and Harvard Project Physics (HPP), members of the cohort became acutely aware reform efforts alone would not measurably improve engineering education.

The parallels between today’s goals and repeated calls for change seen throughout history are uncannily consistent. Some one hundred years ago, Charles Eliot (1898), in his inaugural address as the president of Harvard, described the importance of a practical education and one in which students would not simply read or be lectured to but would be “... taught in a rational way, objects and instruments in hand – not from books merely, not through the memory chiefly, but
by the seeing eye and the informing fingers” (p. 6). In 1902, John Dewey (2013) described the importance of making an organic connection to the life of the student to make the classroom valuable to students, and actively engage them in the learning process. Jerome Bruner, leader of the Woods Hole Conference of 1959, espoused the advantages of teaching the structure of disciplines and supported inductive learning environments. Bruner believed teaching the facts of science in a didactic fashion, without exposing students to “… the scientists’ spirit of discovery produced knowledge unrelated to the essence of the subject itself” (DeBoer, 1991, p. 160). Bruner felt, to truly learn science, students needed to understand the theories of science and the relationships between entities.

Similarly, Joseph Schwab (1962) focused on learning through enquiry as opposed to lecture and telling. His preference for enquiry learning was to engage students in discussions because participating in discussion requires active participation by the students, encourages groups of students in collaboration, and affords teachers the opportunity to develop deeper relationships with more students (DeBoer, 1991).

Donald Schon (1983), wrote about what he referred to as “reflection-in-action” whereby practitioners reflect on what they are doing as they are doing it. To explain his position, he too cited Dewey to support the process of “learning by doing” in which the learner is actively engaged in tasks associated with the concept being learned. To illustrate by example, Schon described a detailed account between of a teacher and student as the collaborated on an architecture design problem. The teacher, due to his expertise, was able to reflect on a variety of design decisions and engage the student with an inquiry based learning strategy. Schon, like others before him pushes for learning beyond fact, understanding that disciplines are “messy” and real problems not easily solved.
More recently, Barrows (2006), supported Dewey’s position on science curricula and explained the has been “… too much emphasis on facts without enough emphasis on science for thinking and an attitude of the mind” (pp. 265-266). In illustrating the evolution of inquiry-based education, Barrows included over one hundred years of philosophers and reformers who posited the advantages of an inquiry-based education. Interestingly, Barrows describes a century later, there is still remains the “… need for science teacher educators to reach consensus about what is inquiry.” (p. 265). In a country which believes it is, or at least believes it should be, a world leader in education, the lack of progress and continued quest for improved STEM education is alarming.

The paragraphs above highlight more than a century of calls for STEM education reform. In spite of these efforts to revamp educational strategies to include more constructivist teaching practices implementations continue to fall short of the mark. They have failed for a variety of reasons. For one, they tend to produce only hegemonic practices, and fail to accomplish stated goals of providing diversity. A recent solicitation from the National Science Foundation (NSF, 2014), aimed at improving undergraduate engineering education claimed “… the inclusion of persons from groups underrepresented in most disciplines of engineering and computer science has remained a stubborn, longstanding issue…” (p. 4). Similar to calls from Eliot (1898) and Dewey (2013), over one hundred years ago, this solicitation from NSF describes “… hands-on, do-it-yourself environments where community members gather to create, invent, and learn…” (NSF, 2014, p. 5). Save for the use of current English terminology, this solicitation might have been written 100 years ago as well. The juxtaposition of writings by yesteryear’s reform advocates with today’s calls for revolutionary change begs the question what have we accomplished in science and engineering education over the last century?
Most recently, the Next Generation Science Standards (NGSS, 2013) have included engineering as a component of science education: “Science and engineering are integrated into science education by raising engineering design to the same level as scientific inquiry in science classroom instruction at all levels, and by emphasizing the core ideas of engineering design and technology applications” (p. 1). This explicit inclusion of engineering into K-12 science standards is both promising and troubling. If successfully implemented, exposing more students to engineering principles should result in an increase of both awareness and understanding of engineering disciplines. This in turn should lead to more students entering engineering and potentially more students remaining in engineering majors. Unfortunately, the details of how K-12 teachers are to incorporate engineering principles into daily teaching practices have not been well articulated. In fact, researchers have pointed out, in spite of reform efforts such as No Child Left Behind (NCLB), a long litany of reform documents, and encouragement from educational philosophers and government programs, “…how science should be taught and specific strategies for teaching science effectively—have not been definitively addressed in recent years” (Schroeder, Scott, Tolson, Huang, & Lee, 2007, p. 1437). The lack of direction associated with these reforms, coupled with the fact engineering principles are foreign to most K-12 educators, the likelihood they will effectively weave engineering into their daily lessons is slim.

**Our Introduction to Constructivism**

Teaching strategies based on constructivist practices have been described to be more effective than didactic approaches to teaching and learning. Constructivist teaching strategies include an environment in which students create their own understanding through inquiry-based learning rather than being told information espoused to be factually correct. As constructivist researchers and philosophers have described, experience is the foundation of the construction of
knowledge, and that “…knowledge is not passively received but built up by the cognizing subject” (von Glasersfeld, 1995).

In our introduction to constructivism, we learned of a variety of definitions and perspectives. As researchers have described, without a functional understanding or framework, “… teachers cannot be expected to link constructivist objectives or to adapt constructivist principles to their particular classroom contexts” (Windschitl, 2002, p. 138). Therefore, to establish a common footing, I will adopt the structural organization offered by Windschitl (2003) to describe inquiry in science and engineering classrooms. Though Windschitl argued inquiry is still uncommon in most classrooms, he articulated a four-category structure developed by science education researchers captured in the following table:

<table>
<thead>
<tr>
<th>Inquiry Level</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirmation Experiences</td>
<td>Step-by-step procedure provided to students</td>
</tr>
<tr>
<td></td>
<td>Verification of known scientific principles</td>
</tr>
<tr>
<td>Structured inquiry</td>
<td>Teacher-presented question</td>
</tr>
<tr>
<td></td>
<td>Students do not know answer</td>
</tr>
<tr>
<td></td>
<td>Teacher provides procedures</td>
</tr>
<tr>
<td>Guided Inquiry</td>
<td>Teacher-presented problem</td>
</tr>
<tr>
<td></td>
<td>Students do not know answer</td>
</tr>
<tr>
<td></td>
<td>Students develop resolution strategy</td>
</tr>
<tr>
<td>Open Inquiry</td>
<td>Students develop their own questions</td>
</tr>
<tr>
<td></td>
<td>Students design their own investigation</td>
</tr>
</tbody>
</table>

Windschitl described confirmation experiences as the simplest to implement in a STEM classroom, with each level becoming progressively more complex for teachers to enact. When I read Windschitl’s reference to “cookbook” procedures in the continuum of constructivist teaching activities, I was reminded of Dewey’s (2013) description of the “third evil” as material “… presented in an external, ready-made fashion, by the time it gets to the student” (p. 26). Dewey argued, when material is delivered to the student in an over-organized fashion, “[t]he really thought-provoking character is obscured, and the organizing function disappears” (p. 26). I interpret Dewey’s writing to mean a constructivist teacher provides mechanisms to support the learner to construct his or her own understanding rather than situating the learner as a passive recipient of knowledge. The cohort quickly identified with initial conceptions of constructivist theory, and many embraced the ideas of student-centered, inquiry-based learning enough to call for a change in teaching practices within themselves, their own departments, and university. This early recognition was still filtered through a lens of traditional science and a culture of engineering education dismissive of those not cut out to succeed.

In an effort to support our cohort of engineering educators, in their introduction to educational theory, faculty members from Northern University regularly modeled constructivist and inquiry-based teaching strategies. Not only was constructivism a common discussion topic within the curriculum, teachers guided cohort members to experience for themselves the lessons being taught within the classroom. Members of the cohort read, discussed, and implemented commonly accepted research practices with real participants and real data as the cohort developed first-hand experience in conducting research. The importance of these lessons to the development of the students cannot be overstated. It is this construction of knowledge, the creation of real-life experiences for the student, which provided the scaffolding upon which the
experience of the PhD program for the cohort was built. To learn how to become educational researchers, cohort members participated in the actual work of designing, analyzing, and writing research together and with the support of their faculty mentors (Vygotsky, 1978).

**Research Questions**

This study was designed to answer the following research questions:

1. In what ways, if any, are the beliefs of long-time engineering educators challenged by an introduction to constructivist teaching practices?

2. How do long-time engineering educators react to challenges to their own perceptions of privilege, STEM elitism, and diversity in engineering education?

**Research Design and Methodology**

**Context of the Study**

**Setting.** The cohort was created through a joint venture between Polytechnic University (the participants’ home institution) and Northern University (both pseudonyms) a nearby research university specializing in STEM education research. Dean Anderson of Polytechnic University was challenged by his provost to increase the percentage of PhD-prepared faculty in his college. Recognizing momentum in national educational reform efforts associated with STEM education, and few engineering institutions participating in STEM education, Dean Anderson developed a plan to advance his faculty and build an infrastructure for STEM education on his campus. The visionary goal of the dean to create a research center focused on advancing engineering education was well received by the Polytechnic University administration and monies were secured to support cohort of 10 successful, MS-prepared, faculty to participate in a STEM education PhD program.
**PhD Course Content.** The education doctoral program pursued by the engineering faculty cohort included foundational courses in statistical and qualitative research methods, writing for publications, securing external funding, and educational and learning research. Within our introduction to STEM education, our teachers exposed us to the majority of the literature referenced in the previous section. To focus the curriculum, additional specialty courses targeted culturally responsive pedagogical strategies, philosophy of technology, and the history of science education reform in the U.S. While some participants elected to delve more deeply into qualitative research and others focused more acutely on quantitative approaches, the majority of coursework was completed by all participants and they proceeded through the program as a cohort. This study focuses on the first year of the cohort’s pursuit of a STEM PhD, and focuses on participants’ initial beliefs most challenged by an initial course titled *Introduction to STEM Education*. Three initial themes, conceptions of science as fact, elitist STEM attitudes, and constructivist teaching practices, were prominent throughout the first year of the PhD program. These themes are consistent topics found within the culture of engineering education as demonstrated through current engineering education research (Johri & Olds, 2014).

**Participants.** The Participants in this study consisted of nine engineering faculty members from a large private institution currently participating in a STEM focused education PhD program. The participants were selected from 10 faculty members who, with encouragement from their dean, elected to participate in this PhD program as a single cohort. Tenure-track teaching experience within the pool of participants ranges from approximately five to more than 30 years. Selection of participants, to the extent possible with this limited pool size, followed purposeful sampling “… to select information-rich cases who study will illuminate the questions under study” (Patton, 1990). Unique to this study is the fact all participants are
masters prepared, tenured faculty members teaching in engineering related disciplines. Each member of the cohort completed undergraduate and graduate degrees within their specific engineering discipline and worked professionally as an engineer prior to embarking on a career as a faculty member. Prior to entering the PhD program, none of the participants completed any formal education outside of STEM fields. The PhD program represented the first non-technical academic major undertaken by any of the participants.

This study investigates the meaning of events which challenged the well-established beliefs of this cohort of engineering educators. All aspects of this study were approved through human subjects (Internal Review Board) review. Research participants signed informed consent forms as an initial task in the data collection process. To protect the privacy of individuals and institutions involved in this study, pseudonyms have replaced actual names.

**Role of the Researcher**

In any qualitative endeavor, the researcher is considered a critical component of the process of data collection and analysis. Unlike quantitative approaches where the researcher is required to be a distant, unobtrusive, and hidden in the background, the researcher in qualitative research in a “primary instrument” in the data gathering and analysis process. Erlandson (1993) describes “[t]he realization that objectivity in research is an illusion frees the naturalistic researcher to do truly effective data collection and analysis” (p. 39). I position myself as the researcher in a “complete participation” (Spradley, 1980) role for this phenomenological study. I was actively engaged in the pursuit of my own PhD, working side-by-side with my colleagues throughout the course of this three-year study. We shared successes and celebrated failures as we recognize both are essential components in our growth during this journey. As I describe the
findings, my own understanding of the experiences will be made explicit and will be compared and contrasted with those of the cohort members.

**Pilot Study**

The direction for this qualitative investigation has been guided in part through a pilot study performed with one member of the cohort. To develop understanding of the lived experiences of the cohort, I invited Edward, a longtime colleague and member of the cohort, to participate in a pilot study. Faculty and administrators at his home institution regarded him as a compassionate and successful teacher who related well to students. The pilot study was part of a research assignment for a doctoral class in which I was enrolled, served to evaluate initial research questions for this research, and identified the potential richness of the lived experiences of cohort members. Edward having shared some specific experiences with me related to his perceptions of privilege and constructivist teaching practices was one of the reasons he was selected as a representative member of the cohort. I was confident Edward would be open to sharing his thoughts related to the cohort experience which would, in turn, enable me to refine research and interview questions, and also to establish a timeline to better understand how cohort members accepted or rejected various components of the PhD program which challenged long-held beliefs.

**Data Collection**

The data collection and analysis stages of research are iterative and intertwined (Spradley, 1980) beginning with journal entries and field notes and including the pilot interview process. Each source of information informs how other portions of data collection are implemented. For example, information gleaned from field notes and journal entries aided the protocol development for in-depth pilot study interviews. These documents provided clues as to which
topics cohort members found most challenging, which they found most beneficial, and which ideas were developing in their writing samples.

Fitting the genre of qualitative research, and borrowing from phenomenological and ethnographic approaches, data were gathered from a variety of sources. Each source is constructed through the evaluation of a social situation consisting of three elements: location, participants, and actions by participants (Spradley, 1980). Creswell (1998) explained phenomenology typically invokes long interviews by which meaning-making is co-constructed through participant and interviewer discussions while ethnographic research also includes extensive observations and gathering artifacts “… looking for what people do…, what they say… and some tension between what they really do and what they ought to do as well as what they make and use” (p. 59). Interestingly, as participants’ beliefs were challenged early in the PhD program, considerable tension was evident in what faculty members described as their beliefs related to science as fact, STEM elitism, and constructivist teaching practices. In the findings I demonstrate how participation in the cohort influenced beliefs related to these three themes and identify points of internal conflict as these long-time engineering educators grapple with new ideas related to their profession. Multiple data sources were gathered to permit triangulation and devise a credible account of the lived experiences of the participants. Observational field notes, public discussion forum entries made by participants during in-course journaling activities, and interviews were gathered to aid in “… constructing a comprehensive, holistic portrayal of the social and cultural dimension in [this] particular context” (Erlandson, 1993, p. 81).

Researchers have explained the importance of triangulation as a form of cross-checking and posited “…no item of information ought to be accepted that cannot be verified from at least
two sources” (Guba, 1981). In this example, evidence represented by the convergence of three or more data sources demonstrates the most credible data and helps to establish trustworthiness. Figure 1 provides a graphic of the most credible data which are those found within the intersection of all three sources within this study. Each of the three primary data sources were analyzed individually and in conjunction with the others. Information supported by all three data sources, as shown by the arrow, is determined to be the most credible or trustworthy.

Utilizing a balance of resources through which to acquire data permits the researcher to perform triangulation which builds trustworthiness into the data gathering and analysis processes (Erlandson, 1993; Spradley, 1980) and enabled me to reconstruct the lived experiences of the participants through multiple means. Individual member checks were performed with each participant based on their interview data, journal entries, field notes, and artifacts to ensure I accurately captured the meaning of their experiences. Each type of data is briefly discussed in the following paragraphs.
Figure 1. Venn diagram representing triangulation of data sources. The most reliable evidence occurs at the intersection of all three sources of data. After data were collected and analyzed, member checks were used to further develop trustworthiness.

**Journal entries from PhD classes.** The *Introduction to STEM Education* course included extensive journal writing designed to permit participants to discuss ideas and beliefs, and as a means of reflection. These written records were public to the group and regularly shared between all students in the class. These weekly writing assignments challenged the cohort to think more deeply about their conceptions of science, pedagogical practices, and the importance of discipline-related discourse in the classroom. The passages written by participants provide unique insight into the intellectual growth experienced by the members of the cohort. Especially important within these writings are statements regarding long-held beliefs related to the nature of science, equity, and pedagogical practices, which researchers have identified as resistant to change (Yerrick, Parke, & Nugent, 1997).

**Observational field notes and artifacts.** Throughout the first year of PhD coursework, I collected field notes and artifacts from the cohort experience. Artifacts include video-recorded class segments and photographs taken of whiteboards and participant projects. Field notes include observations I made regarding informal discussions during lunch, group study sessions, and even car rides when commuting to class. This approach to data collection has been coined “memoing” (Miles & Huberman, 1994) and is common in phenomenological studies. While these data are less voluminous than other data sources, they proved valuable in informing the direction of interviews and provided triangulation with data collected from other avenues.

**Interviewing.** Interviewing was completed with one member of the cohort, Edward, and followed a semi-structured approach favored by Mishler (1991) and others. This approach
enabled me ask questions based on initial responses from Edward to develop a rich understanding of his individual experiences and perceptions while focusing on the material most salient to this investigation. As Mishler (1991) explained “… the idea of a standard stimulus is chimerical and… the quest for ‘equivalence of interviews in terms of interviewer-respondent interaction’ is misdirected and bound to fail”, as participant and interviewer are “… talking together, not ‘behaving’ as stimulus-senders and response-emitters” (pp. 21-22). My approach to interviewing was guided by perspectives shared as Edward and I worked together during the interview process to construct meaning of Edward’s lived experiences through two semi-structured interviews loosely following the approach described by Seidman (2006).

Data Analysis:

While I collected a variety of data for this research, chronologically, the interviews with Edward represent the first data analyzed. Both interviews were transcribed verbatim. The coding process for the initial interview consisted of first identifying those portions of the transcription that appeared most significant, and then digging more deeply to see what other portions of the interview either supported or opposed the initial ideas. This process resulted in the identification of six themes and served to determine areas for further examination in the final interview (Rubin & Rubin, 2005). As the interview process was semi-structured, I had the opportunity to explore areas identified by Edward as important his experience in the PhD program. These interviews were hand-coded using different colors for different codes. Codes were developed and categorized, resulting in the identification of new, and sometimes overlapping, themes important to Edward’s life in the PhD cohort.

In addition to the interviews, journal entries and field notes related to all participants were main data sources. Northern University’s course management system organized journal
entries alphabetically by author. The journal entries from the first semester represented well over 300 pages of written text. After looking for preliminary themes, I established codes to categorize data from journal entries and field notes I had taken during classes and in discussions with classmates outside of class. Though I had hand-coded my interviews during the Pilot Study, I selected a qualitative data analysis package, HyperRESEARCH (Researchware, 2014) to perform this coding. This proved a valuable decision because it simplified the coding process by making it easy to change, delete, or add codes.

On numerous occasions I modified codes during the process of coding journal entries and other artifacts. For example, one of my initial codes was Resistance to Ideas, which I used to highlight when participants, in their writing or conversation, disagreed with or pushed back on new concepts being introduced in our PhD coursework. However, as I proceeded with the coding process, I soon realized there were multiple sources of resistance described in my data. Once source of resistance was clearly participants resistance to new ideas. However, a second type of resistance described by the participants was resistance from their own students related to new teaching strategies the participants introduced in the classes they taught. Because of this realization, I broke the original code Resistance to Ideas into two separate codes: Resistance to Ideas – Participant, and Resistance to Ideas – Student. I used this code expansion technique in multiple instances as it provided a mechanism to finely categorize the events in my data.

Findings

The following sections summarize findings related to the first year of the cohort’s PhD journey. I begin with an overview, which addresses the general apprehension of the cohort early in the first semester. Subsequent sections investigate the three themes determined important to members of the cohort during initial coursework in the STEM focused education PhD program.
Uncertainty and discomfort as we begin the doctoral journey

As a member of the PhD cohort, I entered the STEM education program with a certain level of fear, uncertainty, and doubt. Having been a faculty member for nearly 20 years, I found somewhat daunting the prospect of being on the other side of the teacher-student relationship, sitting through lectures, and taking timed exams. After the cohort participated in an orientation session with other STEM PhD students on Northern University’s campus, the reality of what lie ahead came into focus. I was comfortable with my ability to teach and with my own content knowledge, but the unknown of what we would learn and how we would be assessed led to a palpable anxiety. Discussions with other members of the cohort confirmed we harbored similar concerns. How much work would this require? Can we manage to perform well in these classes and at our jobs? Soon after beginning the program, it became clear some apprehension was indeed appropriate. Interestingly, participation in the PhD program exposed holes in our preparation to be engineering faculty we never anticipated.

In the first semester, we were enrolled in a statistics course titled Understanding Quantitative Analysis in Research, and a seminar course called Introduction to STEM Education. Each course, in unique ways, quickly extracted us from our comfort zones, and unveiled the realization this educational experience would vary greatly from our previous academic endeavors in engineering and computer science. Throughout the first semester, categorized as “students” for the first time in many years, we completed an extensive reading list of more than a dozen books and dozens of research articles, participated in discussions, reflected on our beliefs and learnings via online journal postings, and were never asked to complete a timed exam.

The majority of our experiences in engineering courses involved sitting in rows of desks, facing the front of the room and copying notes written on a chalk-board by a white-haired
professor. Quizzes, exams, and lists of homework problems to solve were the norm. Student participation in classroom discourse was virtually non-existent, and teachers expected us to solve problems presented in a prescribed fashion through a series of sequential sections in a textbook.

Our first semester experience in the STEM PhD program diverged considerably from the university experiences of our youth. Our weekly meetings for the Introduction to STEM Education class included tables, or chairs organized in circles, instead of the customary long rows of desks. Quizzes and exams were replaced with copious amounts of reading, group discussions, and writing; none of which were common in the engineering courses we took as undergraduates. Each week meant new journal postings in an online forum. Typically these journal postings were in response to a suite of questions posed by our teacher, Dr. Smith, and related to several articles or books. The approach to education we were now experiencing was uncomfortably foreign. Never before had we been expected to assimilate so much information, find connections between seemingly disparate topics, and organize our thoughts into a 500-word essay. Dr. Smith introduced us to topics, which initially seemed disconnected from STEM teaching and research. This history of science was introduced through historical accounts of scientific conflict (Hellman, 1998) and a history of science education reform (DeBoer, 1991). We read the works of famous (but previously unknown to us) educational philosophers such as Schwab (1978), and Dewey (2013). We read about the history and philosophy of science (Duschl, 1994), and the work of science philosophers (Kuhn, 2012; Popper, 2014). We investigated classroom communication norms (Gallas, 1994; Lemke, 1990), and explored teaching for diverse learners (Barton, 2003; Gay, 2000; Rodríguez & Kitchen, 2004). All readings represented new territory for this cadre of engineers weaned on textbooks and ready-made problems. We struggled to synthesize the readings, make meaningful connections, or
develop deeper understanding. Dr. Smith pushed us to relate our existing conceptions of science with readings counter to our long-held beliefs. We understood science to be an unbiased, wholesome, noble search for truth. The readings clearly illuminated conceptions of science we had not considered. Rather than solving problems, we were expected to discuss the narrow and privileged nature of engineering education, conceptions of winners and losers in establishing scientific value, and conceptions of race, gender, and social class. In attempting to address the questions our Dr. Smith posed, we struggled to reach beyond summarizing the readings. What we thought we knew when we entered the program was no longer clear. The instructor’s continual prodding to dig more deeply at times left us frustrated by the pace and depth of information we were trying to process. The following excerpt is an example of Dr. Smith articulating his desire for us to dig more deeply in our thinking:

Dr. Smith: Okay, so now that I have a brief summary...what is the problem we face in defining science? Where did YOUR definition of science come from? How is it likely different from Kuhn and Popper? Are you finding your personal beliefs about science unfounded? (Dr. Smith, Journal Post, September 6, 2013).

Dr. Smith’s comments above are in-response to an original post from Edward related to the question “What is science?” Edward’s writing, like so many of our early journal entries consisted of little more than a regurgitation of a portion of our reading. In this example, he had explained what Kuhn wrote, mostly through direct quotes and citations. Edward did not include his own interpretation of Kuhn, any synthesis of ideas, or connections with other readings or his own beliefs. I believe Dr. Smith’s words – brief summary – were carefully select to let all of us know he expected more-substantial contributions to the online journal discussions. Dr. Smith is also encouraging all of us to explore our own, personal beliefs.

While Dr. Smith was pushing us to articulate how the readings conflicted with, or challenged, our own beliefs, members of the cohort experienced frustration with this approach
with which we were unfamiliar. The engineering courses with which we were experienced did not require us to consider our own opinions. Those courses required us to consider process, procedure, and known facts, not our own beliefs related to the philosophy of others. Edward articulated his inability to make sense of multiple readings when he described:

Edward: From reading all the threads on this week’s journal topic it appears that we were all pretty good at parrotting back the definitions of Science and Normal Science from the Kuhn’s book… I will be the first to admit that I’m still struggling to understand his philosophy and hope we can spend some class time discussing this in greater detail (Edward, Journal Post, September 2, 2013).

In his post, Edward displayed a certain frustration experienced by many in the cohort. As engineers, we feel almost pre-programmed to seek a correct answer; to find the truth. In this new learning environment, the teachers expected us to read extensively and consider the deeper meaning of the readings. Initially, we simply tried rephrase the readings in attempts to demonstrate we understood something. Group discussions challenged us to develop arguments for or against a particular concept and provide evidence from relevant literature to support our claims. These experiences represented a drastic departure from experiences in engineering education, which focused on following procedures and learning how to solve a specific type of problem. This was followed by completing assigned problems to practice, and ultimately demonstrate, the ability to complete the desired tasks. The methodical processes which served us so well in our engineering coursework, offered little support in adapting to the new expectations placed upon us.

Given our educational backgrounds, it is understandable we engineering educators were less comfortable with our ability to develop deep understanding when assimilating a wide variety of disparate, non-technical readings. We often reverted to the engineer’s desire to arrive quickly at a single solution. This behavior is consistent with pervious findings with engineering educators focused on arriving at a single, right answer as opposed to being able to understand
and interpret a wide array of options (Borrego, 2007a). Edward’s inclination was to scour the internet for a “Cliff notes” version of our readings. He distributed PowerPoints and written summaries he found online of Kuhn and Popper to other cohort members with the goal of helping everyone develop a better understanding of the material. Some of us felt more comfortable with an unknown individual’s bulleted list interpretation of salient points than the original manuscripts from the authors. These armed us with answers we could point to as correct. We solved the problem of finding meaning in the reading by pointing to the meaning written by someone else. For some of us, our engineering mindset aligned with efficiently and effectively arriving at a solution to the problems our instructor posed. Clearly, some of us failed to recognize Dr. Smith expected us to assimilate the readings and arrive at our own constructed meaning.

While we approached the doctoral experience with apprehension of the unknown, the unknown was not what we expected. We failed to anticipate challenges related to the scientific method, conceptions of doing science, or our own White privilege. In the following paragraphs, I will address how our experiences as trained engineers and practicing engineering educators predisposed us to certain beliefs constantly challenged during the doctoral program. These beliefs became evident during weekly, public journal posts in which we responded in writing to questions and prompts from Dr. Smith. The most prominent themes uncovered in these early journals included (a) challenges to our long-held understanding of science as a discipline, (b) STEM Elitism, and (c) teaching for diverse learners. The chronology of introduction of these topics during our introductory course was by no means random. Each built on the previous, though again, we struggled to synthesize the connections. Interestingly, participants
demonstrated varying levels of acceptance and resistance for each of these topics. The following paragraphs explore initial faculty perceptions and reactions associated with each of these themes.

**Challenging long-held beliefs related to science**

Had we paid closer attention to the details of the syllabus for our *Introduction to STEM Education* course, we likely would have better understood the journey ahead. However, as engineers trained to identify and solve problems, our focus was on the 13 complete books and dozens of philosophical and research articles Dr. Smith expected us to read, and presumably understand, during the 15-week semester. Unfortunately, I believe the foreshadowing offered in the syllabus was lost on us. In this document, Dr. Smith explained he would challenge and critique several portrayals of STEM during the semester including:

- STEM is a search to “prove” and discover things. An uncovering of “truths” and laws by which the world operates—with or without our notice.
- STEM is a group of concepts that have withstood the test of time.
- STEM is the disciplined practice from a positivist perspective and teaching STEM should be a process of retelling discoveries of scientists and mathematicians.
- STEM is objective and the same knowledge would be discovered and retained regardless of the time and culture of the scientist…
- STEM is a logical and rational organization of the world. (*Introduction to STEM Education*; Syllabus, p. 1).

In hindsight, during that initial semester in the doctoral program, I failed to consider the implications of Dr. Smith’s bold claims related to the nature of Science, Technology, Engineering, and Math. In retrospect, I now recognize Dr. Smith put in writing *what he knew* our beliefs to be, and explained he was going to challenge those beliefs. I also recognize my
beliefs, upon entering the PhD program, aligned with those five bullets. Today, due to what I have experienced on this journey, I consider each of these statements inaccurate and somewhat naïve.

In this section, I will use journal entries written by members of the cohort, interview data, and field notes from personal discussions, during our first semesters of doctoral classes to illustrate alignment between cohort members’ initial beliefs and the bulleted list provided by Dr. Smith. I will show how some cohort members actively engaged in readings and discussions as we struggled to resolve conflicts between how, through a lifetime of learning, we knew science, and the recent attack on what we considered stable ideas. Together and individually our life experiences were being challenged and we were in the process of constructing new knowledge.

In analyzing these data, I will identify areas where we felt uncertain about our beliefs as they were challenged and we tried to make meaning of the concepts to which we were being exposed. Understanding whether or not these new beliefs are enduring is at this time unknown.

**Understanding how science is done vs. how science is taught**

Early in the first semester we conducted an in-class experiment in which Dr. Smith grouped students in pairs and provided verbal instructions to find the “hottest portion of a candle flame” using a temperature probe. Each group lit a small wax candle and proceeded to determine the exact location of the hottest portion of the flame using an electronic temperature probe interfaced to a laptop computer. After analyzing numerical and graphical information captured via the temperature probe, groups discussed their findings. During the following week, Dr. Smith asked students to reflect on the experiment by answering the question “Was the candle experiment science?” in our weekly journal. At the time, we had been reading Thomas Kuhn
(2012) who challenged standard conceptions of science, how science was done and taught, and what “counted” as science.

While most in the cohort agreed the candle experiment was indeed science, teasing information from cohort members’ writing indicated the group held to a conception of science as formal, structured, repeatable, and objective. Caroline’s journal entry was typical of many members of the cohort:

Caroline: Yes I think it was science. We did not know what the correct “answer” was going into the experiment. From what I remember, we were following the scientific method. We had a hypothesis, we performed the experiment and then we compared the results to our hypothesis (Caroline, Journal Post, August 26, 2013).

The formal, procedural and objective approach to coming up with the right answer is evident in Caroline’s response. Science from Caroline’s perspective involves a scientific method and a confirmation of correctness. Alice, Gerald, and others shared similar conceptions of science which they explained using terms such as “validity”, “scientific method”, “control”, and “hypothesis”. Their terminology illuminated their positivist views of how science is taught and should be done.

Edward’s response varied somewhat from his colleagues. He admitted the experiment was science, but implied it was only because of a unique definition of science adopted for the course in which we were enrolled:

Edward: In THIS class, the study of science is about the journey to answer an unknown question, not proving that a GIVEN answer is true or false. Given this definition, this was science. BUT, in my opinion, the experiment was not valid, thus the results were not valid (Edward, Journal Post, August 26, 2013).

The emphasis Edward placed on the definition of science for this class is interesting. There was an implication Edward uses a different definition outside of class than he does inside. There also appeared to be a frustration in Edward’s writing as if he did not agree with the definition or process he was expected to follow. Researchers have explained engineering faculty who attempt
to apply engineering principles to engineering research become frustration because the approach is ineffective (Borrego, 2007a). Edward exposed his traditional, positivist view of science when he shared his concern the experiment was not valid. Dr. Smith took this opportunity to push Edward’s thinking:

Dr. Smith: I am just curious, what is your working definition of validity and where is it derived? Also what part of scientific work to your knowledge is also judged by that definition of validity. Please be specific. Apply Kuhn when you can (Dr. Smith, Journal Post, September 5, 2013).

In the statement above, Dr. Smith challenged Edward to think about his own beliefs of validity and to tie those beliefs to our reading of Kuhn (2012). As explained earlier, this level of synthesis was nonexistent in the engineering courses serving to underpin this cohort of engineering educators. The challenge offered was typical when Dr. Smith wanted more depth of thought and input from the cohort. Edward responded by explaining the experimental method used was not an acceptable means for determining the temperature of the flame.

Edward: My definition of validity, as it applies to scientific experimentation, is whether or not the results obtained are accurate for the question being asked. Specifically, in this candle experiment, are the measurements a true, or valid, representation of what is happening, or is the presence of the instrumentation affecting the results… I would hope that most scientific work would be judged, in part, by the definition of validity: ‘is the means in which I’ve collected my data valid?’ (Edward, Journal Post, September 5, 2013).

In the example above, Edward tried to defend and retain his own traditional conceptions of scientific method and validity while at the same time incorporating what he was trying to understand in reading Kuhn (2012). Edward’s concept of validity involved the precision of measurement. In fact, many in the considered the experiment to be science, but posited the measurement techniques were not well “controlled”, or were not precise. Edward, and likely other members of the cohort, had not yet come to understand the examples Kuhn offered of scientists indeed being very precise, but also being very incorrect. This included a brief description of the history of the phlogiston theory, among others. Precision, therefore does not
equate to validity as the group had believed. As a cohort we struggled to understand the
philosophies of Kuhn and Popper (2014) as they overtly challenged our long-held conceptions of
science. This is understandable, as research demonstrates learners struggle with misconceptions
when they try to accommodate new theories which conflict with long-held beliefs (Bransford et
al., 2000).

These examples demonstrate this cohort of engineering educators struggled to be
reflective about a discipline they believed they knew. We were reading, studying, and discussing
the philosophy of science and engineering. We are all engineers and believed we knew and
understood the discipline. Never before had we been expected to question what we were told in
an academic setting. We had been domesticated into the discipline of engineering and were
accustomed to taking for granted what we read in textbooks or were told by our teachers. Our
engineering education had not taught us to challenge or reflect on what we were reading,
learning, or doing. We had been indoctrinated to expect a right answer and be comfortable when
we found it. Dr. Smith challenged that in addition to knowing currently accepted theory, it was
incumbent on us to understand and articulate the competing theories, and why each failed.

It should be noted that both Caroline and Edward, when confronted with Dr. Smith’s
original journal assignment, submitted only brief posts which demonstrated little depth of
thought or connection to assigned readings. This was consistent with all members of the cohort
early in the first semester. We did not yet understand the expectations of reflecting on our own
learning, and struggled to produce the type of journal posts Dr. Smith expected. As can be seen
in Edward’s journal response to Dr. Smith above, we tried to explore our new understandings
more deeply when prodded. The style of communication and expectations of deeper thinking
were inconsistent with the well-defined, fact-based structure we knew education to be.
The examples above demonstrate how members of the cohort reacted when challenged with conceptions of science orthogonal to their own. While our behavior and struggles were consistent with that of any new learner, the fact we were studying conceptions of science, a field we thought we knew left us somewhat bewildered. However, the foibles of a positivistic approach to learning science were not the only surprise we encountered during our first year of study.

**Self-efficacy of engineers – STEM elitism**

Several perceptions of engineering conspire to promote an elite status for those in the engineering disciplines. The ability to problem solve, coupled with the public’s lack of understanding of the nature of engineering, and how engineers work (Petroski) may be cause for a certain elitism associated with engineering. The mystic nature of engineering and science may lead laymen to assume practitioners in these areas are “smart”, “intelligent”, or “accomplished”, while engineers typically view themselves as accomplished problem-solvers and knowledgeable “fixers”. As students, engineering majors are shown to perceive their major as more difficult than most others (Seymour & Hewitt, 1997) which attributes to a sense of “survival” and accomplishment less likely to be experienced in other majors.

In this section, I explore the beliefs and perceptions related to attitudes of elitism and intellectual superiority held by this cohort of engineering educators as they began their journey in the STEM PhD program. While some members of the cohort worked to assimilate their new learnings with previous beliefs, other members demonstrated unyielding resistance to new conceptions of the nature of engineering education.

Three weeks into the first semester, the cohort of engineering educators struggled to make sense of the content of our new educational path. Reading Hellman (1998), Kuhn (2012),
Popper (2014), and DeBoer (1991), created an immediate sense of discomfort and humility. None of us were in the habit of regularly reading education research, nor had we been exposed to educational philosophers or the long history of education reform. The readings served to challenge us on multiple levels. First, the writing style of philosophers was abstract and indirect compared to the dry and detailed cadence of engineering documentation with which we were familiar. Second, this group of traditionally trained engineers never contemplated conceptions of how to “do” science, or what counts as a scientific endeavor. Finally, we quickly recognized we lacked any background in the history of education reform. I personally felt exposed and somewhat embarrassed by the obvious lack of preparation for my career of nearly 20 years.

STEM Elitism, a discussion topic introduced by Dr. Smith early in our introductory course, was approached by cohort members with varying degrees of caution. Lulled into traditional STEM teaching methods based on our own undergraduate experiences, and reinforced through years of receiving solid teaching evaluations, we were confident in our classroom practices. Cohort members shared a wide range of reactions when challenged to think deeply about whether or not STEM education should be reserved for the most capable students. Written journal posts revealed underlying faculty beliefs, which individuals in the cohort may or may not have consciously understood. In the following sections I will evaluate written journal entries from Martin and Caroline who exhibited different reactions to a prepared request from Dr. Smith to explain if the reputation of STEM disciplines holding an elite status in higher education was deserved.

While initially distancing himself from stating his own beliefs, Martin conservatively shared his perspective that “…most STEM disciplines do consider themselves elite…” (Martin, Journal Post, September 6, 2015). He also discussed the irony of this position when the history
of education reform, with the sciences originally absent from the academy (DeBoer, 1991), is taken into account. Martin shared his belief the US Government reinforces the elitist attitude by holding STEM in such high esteem. Interestingly, Martin also posited “I do firmly believe in the importance of a solid STEM education but not the attitude taken by many in the field” in the same journal post.

Relatively cautious in his approach to discussing STEM elitism in his journal post, Martin almost seems internally conflicted. On one hand, he sees a certain irony in the fact some in STEM have an elitist attitude, but also strongly articulates his belief in STEM education as a cornerstone of our K-12 system. In this statement, he does expose his own level of STEM elitism which he initially shared as the perspective of “others”.

Caroline, on the other hand was comfortable and confident in asserting her long-held and deeply rooted beliefs that some individuals are simply not capable of success in, what she considers to be, more rigorous disciplines. Early in the semester she wrote a journal post based on a quote from Traweek (1988):

… a quote on pg. 124 of Traweek stood out to me. ‘on this model, scientists are not made but born…’ I would welcome the opportunity to have a class discussion on this topic. Retention is a huge initiative at [our university] which I truly do not agree with based on this [quote from Traweek] in which I am in strong agreement. [Caroline, Journal Post, September 13, 2013].

Having known Caroline for more than a decade, I was well aware she believed many of our students lacked the ability to become engineers. She related to the highly capable and hardest working students in her classroom, as in them, she saw herself. Students for whom that material did not come easily, or those who seemed less engaged, in her mind, could not become successful engineers. Based on her life experiences, and consistent with most of us in the engineering professions, this position is somewhat understandable. We all felt we worked hard to earn our place in engineering and often viewed those who did not achieve at our level as less
deserving or less capable. Caroline articulated her belief engineering and science were indeed to be reserved for the privileged few:

Of course I think of science as being reserved for only the brightest students because I have been among their ranks since high school. In my family of 7 siblings, 5 of us have Engineering and or Computer Science degrees (Caroline, Journal Post, September 6, 2013).

While no other participants expressed Caroline’s depth of elitism, this sense of superiority is consistent with the traditional mindset of students at our university. Because her undergraduate engineering degree was considerably more rigorous than degrees pursued by students in non-STEM majors, Caroline perceived of herself as “… intellectually superior to those who are not [in STEM fields]” (Caroline, Journal Post, September 6, 2013) and defended her belief students in STEM worked harder than students in other disciplines.

In another journal post, Gerald shared an example of STEM elitism present at our university. It is common for students, staff, and faculty to describe the engineering programs as having the most prestige at our school. Clearly, a pecking-order exists, and those from the sciences see themselves as holding a status similar to the engineering disciplines. Gerald’s journal post described the experience of a family member who enrolled in a class known as imaging science, which fulfills a general education science requirement at our university. During the first lecture of this particular imaging science course, the professor explained that he was aware the students were only taking the class because they did not want to take a “real” science course like physics or chemistry.

The event shared by Gerald is consistent with a long history of elite perspectives of STEM majors at our university. STEM students on our campus commonly elicit a decades-old refrain, which clearly articulates the hierarchy of majors at the university. The well-known description places engineering and sciences at the top of the intellectual heap while poking fun at
students enrolled in less demanding majors such as marketing, business, photography, or hospitality. In our environment, students in STEM disciplines commonly refer to art students as “cutty-pasties”. While not all engineers exhibit that depth of insensitivity, there can be a certain sense of self-importance and privilege on display. This type of behavior, consistently applied, breeds an elitism which has remained for decades and is ingrained in the culture of engineering at our university.

Mary’s first STEM elitism post shared a much more balanced perspective on the correlation between STEM and intelligence. Recognizing plenty of “bright” people enter non-STEM career paths, she explained many highly qualified individuals choose fields which advantage their own skills which may lie outside a narrow definition of STEM. Additionally, she described concern for self-deprecat ing people who apologize for their own lack of understanding of STEM disciplines:

[Some people] go so far to criticize themselves saying ‘oh, I was so bad in math’ as if they are not ‘good enough’. It bothers me when I hear that because I do believe [STEM subjects] can be learned if the content is taught in the student’s learning style (Mary, Journal Post, September 6, 2013).

Martin responded to Mary with similar concerns and shared his recognition that yes indeed, individuals have been excluded from pursuing STEM for a variety of reasons, including choosing to be “self-excluded” (Martin, Journal Post, September 8, 2013). In the same journal post, Martin explained his understanding that many being excluded could indeed “… have a great career in STEM.”

The contrast between the beliefs shared by Caroline, and those posed by Mary and Martin is striking. Clearly everyone recognized elitism in STEM does indeed exist. And each was beginning to interpret the meaning for themselves in different, but important ways. In the
following paragraphs, I relate an experience shared by Edward as he began to recognize the elitism and privilege often unnoticed by those in the dominant culture.

Prior to embarking on his educational journey in the PhD cohort, Edward was a firm believer that his teaching strategies were unbiased and color-neutral. During our interview, he explained he would confidently treat all students in the same fashion, and while not necessarily being the “…arbiter of facts…”, he understood his role of being the “authority in the classroom”. As a White male in a STEM classroom, he clearly believed the success he achieved was a result of the “hard work” he and performed rather than the result of opportunities available to him that may not have been afforded others of lesser privilege. Edward’s early reaction to being referred to as privileged by his doctoral instructor was immediate and strong:

When you’re told you’re privileged, it comes across as a slight if you will, like you’ve got something you haven’t earned. We’ve got to our place in our life because we’ve worked very hard. And to say your privileged almost implies you were given these opportunities. So, it, it, puts you back in your heels and makes you defensive, and you tend not to listen to that. Ya know, no one wants to hear that (Edward, Interview 1).

Beginning in the first semester, Edward and his colleagues were challenged with readings and discussions related to equity in the classroom and opportunities reserved for the middle class, and especially for White males. Readings from the first year or so included topics such as pedagogy for diverse learners (Gay, 2000; Rodriguez et al., 2005; Rodríguez & Kitchen, 2004; Songer, Lee, & Kam, 2002), social justice (Barton, 2003), and more. Throughout much of that first year, Edward’s resistance to the professor’s prodding about privilege and White-male centric pedagogical practices and opportunities remained stalwart. He continued to assert that he had earned everything he had acquired from his middle-class status to his comfortable suburban home, and that opportunities afforded him were no different than those available to everyone else in the country (Field Notes, November, 2013).
Admittedly, even the extensive readings and discussions did not sway Edward’s beliefs of privilege and opportunity in the classroom. Eventually, however, events in Edward’s life occurred in conjunction with continued discussions of equity in the classroom. This intersection of events conspired to create what Edward referred to as an “aha moment”:

Edward: It really wasn’t coursework that made me realize [I was privileged]. The aha moment for me was in the spring my son had an opportunity to do a research project at Boston University. My parents never went to college. I went to college. I never would have been able to do [an unpaid research project] when I was in college because I worked part time to pay for things. So there’s one generation change, now he’s the next generation. Because I could afford to pay his expenses, he didn’t have to get a job. He could take this unpaid internship. And it gave him eight months of experience which was invaluable to him (Edward, Interview 2).

Edward reflected on his changing belief almost ruefully as he explained “… acknowledging that [we were privileged] was a bitter pill to swallow…” (Edward, Interview 2). Edward explained this recognition has led him to view students differently, and to seek more personal connections with all of his students.

Over time, this group of engineering educators slowly began to “test drive”, or “try on” the concepts to which we had been exposed. Some claims were cumbersome, some were misguided, but all were valid attempts to make sense of why and how our long-held beliefs were being challenged.

**Grappling with constructivist ideas**

A third theme uncovered in the research was overt practices of constructing notions of constructivism. While in many higher education contexts, constructivism is a construct of lectures, this cohort actively participated in the process of socially constructing the notion of constructivism. To a person, the term “constructivism” (Dewey, 2013; Kuhn, 2012; Popper, 2014; von Glasersfeld, 1995; Windschitl, 2002) was completely foreign prior to entering the STEM PhD program. During the first semester, members of the cohort were introduced to
constructivist teaching practices through a variety of readings, in-class discussions, and teaching practices within the *Introduction to STEM Education* course in which they were enrolled. Interestingly, all members of the cohort entered the program practitioners of hands-on, laboratory based teaching strategies, and most were familiar with terms such as “active learning” (Brent & Felder, 2009; Felder, Brent, & Prince, 2011) and “problem based learning” (Savin-Baden, 2008) as they have been prevalent in the engineering disciplines for years. None, however, had any understanding of constructivist philosophy, or any foundation in inquiry-based or student-centered learning theory, and all practiced traditional, didactic methods for lecture courses. I will demonstrate the dearth of exposure cohort members received in prior preparation for their careers as engineering educators through quotes from personal discussions, the interviews with Edward, and journal writings. Thrust into this new educational environment, our teachers and our readings challenged us to reconsider our approach to science and engineering content similar to how Dewey (1938) challenged educators, nearly a century ago, to eschew traditional teaching methods:

…that which is taught is thought of as essentially static. It is taught as a finished product, with little regard either to the ways in which it was originally built up or to changes that will surely occur in the future (p. 19).

We were dumbfounded that repeated calls for such progressive education reform (DeBoer, 1991) could continue to go unfulfilled for so long, and concerned an undergirding in the history of education reform and educational philosophers (Dewey, 1902; Kuhn, 2012; Matthews, 1994; Popper, 2014) was absent in our prior preparation as educators.

Researchers have described professional experiences influence teachers’ beliefs regarding inquiry-based learning, and those with inquiry-related professional experiences are likely to be more successful teaching inquiry in the classroom (Windschitl, 2003). Working as a practicing engineer in an industrial setting prior to pursuing a career in academia is a unique characteristic
shared by all members of this cohort of engineering educators. Because we understand engineering as done by engineers, this cohort of engineering educators has an established foundation upon which to build successful inquiry-based teaching strategies.

In the following paragraphs, I reconstruct three examples of cohort members’ responses to initial understanding of constructivist teaching practices. Each example demonstrates an acceptance of new approaches to teaching and learning. Enthusiasm and initial acceptance of constructivism are demonstrated as I share my own early ideas of constructivist teaching practices and my desire to make a difference at Northern University. I have elected to lead with my own early impressions of constructivism because my conception of my own understanding is much more complete than that of others in the cohort. Therefore, I share my own wide-ranging perspectives, and use the perspectives of other cohort members to address specific aspects of constructivism important to their learning process. In the second example, Gerald described his early adoption of constructivism in classes he taught during our very first semester of the PhD program. The final example focuses on Edward who entered the cohort believing his teaching exemplified authentic learning, but came to the realization his well-intended approach was missing the mark. All three examples demonstrate enthusiasm and willingness to make changes in the enactment of engineering education. Each provides a sense of hope that real change is possible, even if changes must occur one faculty member at a time.

I envisioned opportunity in constructivist philosophy. My initial reactions to constructivist teaching practices included both enthusiasm and vexation. I was both surprised and frustrated to read about Charles Eliot’s desire for students to receive a practical education in which they were active participants (DeBoer, 1991; Eliot, 1898). I was surprised turn-of-the-century philosophers so clearly articulated these ideas, and frustrated with the lack of implementation and follow
through despite repeated calls for reform lasting over a century. My frustration was apparent in one of my weekly journal offerings:

Mike: Many aspects of STEM classrooms at [Polytechnic University] reflect a distorted concept of science and how science should be taught… We see misguided attempts to STEM education through dogmatic teaching of facts, and managed discourse as a defense mechanism for teachers to retain classroom control (Lemke, 1990). We see numerous examples of professors acting as gate-keepers and protecting the throne of knowledge for the chosen few. Even in [our department], where we believe we provide students with considerably more freedom to explore and learn through inquiry and self-directed leaning, in retrospect, we fall short of what I now believe we can accomplish through teaching and learning approaches as described by Dewey (1902), Gallas (1993), and others (Mike, Journal Post, October 25, 2013)

The introduction to readings on constructivism illuminated problems with our own curriculum and exposed ineffective teaching strategies. As a department chair, I had opportunity to witness many less-than-ideal classrooms. I felt an uncomfortable gap others did not seem to perceive.

However, previously unarmed with the research, the vernacular, or the understanding to redirect individuals’ teaching, I often felt unable to drive change in teaching philosophy. At the end of the paragraph above, I expressed hope by looking forward to what we, as a cohort, could accomplish at our university. I continued that theme in the next paragraph of my journal entry:

Mike: I believe our cohort can and will have a profound impact at [Polytechnic University]. To enact substantive change we will be required to work in concert to demonstrate our ability to succeed in order to create believers of those outside the cohort. My tact will be to implement relatively small changes where I can (Mike, Journal Post, October 25, 2013).

In this writing I also cited Rodriguez and Kitchen (2004) who introduced me to the term “minds-on” in conjunction with “hands-on”. I enthusiastically embraced this term as I described my shifting views of our ability to teach all students:

Mike: Additionally, I believe we can slowly erode the concept of teaching solely to the top tier students and embrace the opportunities we have to become advocates for all of our students through the social constructivist pedagogical techniques (Rodriguez & Kitchen) about which we are only just learning (Mike, Journal Post, October 25, 2013).
The opportunities I saw in the readings gave me hope for meaningful change consistent with current calls at the national level for reform in engineering education (Jamieson & Lohmann, 2012; Johri & Olds, 2014; NAE, 2005). I envisioned a methodical and substantive change capable of building a unique culture at our university which moved away from the traditional gatekeeping associated with the culture of engineering education. This journey into constructivism encouraged me to foster change, albeit at a somewhat less aggressive pace than Gerald demonstrated both in his journal entries and in his actions. I anticipated an inability for faculty members to see themselves honestly teaching in a constructivist fashion which gave me cause for concern that profound change might not be possible. The following section describes how Gerald enthusiastically embraced constructivist teaching practices, and began to immediately enact change in his own classroom.

**How one cohort member became an early-adopter of constructivism.** An interesting example of cohort members beginning to understand constructivist teaching practices (Dewey, 2013; Eliot, 1898; J. J. Schwab, 1978; Windschitl, 2002) can be seen in the writing of Gerald, who quickly adopted a less controlling and less authoritative stance in his own classes and gave students more freedom to solve problems in groups:

Gerald: In these past few weeks I have been making the transition from my more “traditional” methods of lecturing to a constructivist form of inquiry. This has taken quite a bit of time to modify my lecture notes and construct some lessons that are driven by the student rather than by myself. Both in my lectures and laboratories, I have started with a problem statement, had students work in small groups (3 students each) then having them assemble their work on the white board for a class discussion of the ideas and concerns that the groups had (Gerald, Journal Post, October 25, 2013).

Researchers have emphasized the importance of a teacher’s deep understanding of constructivism in determining success in practice (Windschitl, 2002). However, Gerald rapidly embraced his early understanding of constructivism and immediately incorporated changes into
the classes he taught. In his journal he explained how he requested student feedback to learn what they liked and didn’t like about his now non-traditional courses. Overall Gerald believed the early changes he implemented were effective and only a relatively small subset of the students preferred more traditional teaching methods. He provided evidence in his journal in the form of discussions with students:

Gerald: The majority of [the students] have responded favorably and I have been getting a lot of positive feedback from students. One student came up to me after last Monday's Lecture and asked me if I could come to his next class and do that one too, as the Professor in that class is SO BORING and he liked what I was doing so much better (Gerald, Journal Post, October 25, 2013).

As with any teaching approach, constructivist teaching practices are susceptible to student resistance. Within the same journal post, Gerald admitted he “… encountered some resistance from a small group that has stated that I am not ‘teaching’ them anything anymore”.

From Gerald’s descriptions, it was clear some students were not comfortable in controlling their own learning, and resistance to modification of classroom norms is common and expected.

Gerald used the weekly journal as a mechanism to explain his beliefs as to why some students preferred didactic methods:

Gerald: What I now realize that it is easier for some students, as they just have to sit there and scribble down whatever I put on the board. They don’t have to do ANY thinking, they don’t have to voice their opinions, they just need to memorize what might be on the test so they can get a good grade (Gerald, Journal Post, October 25, 2013).

Gerald was comfortable with analyzing a situation such as this and offering justification as to the cause and effect relationship. I found this to be a common recurrence during both journal exercises and classroom discussions. As an engineer he was accustomed to identifying problems, understanding their root cause, and developing solutions. Too, this was not the first time Gerald had encountered adverse reactions from students due to attempts to move students out of their comfort zones. Gerald described a situation earlier in his career in which students
complained because he moved away from traditional teaching methods. Reflecting on this experience, he explained why faculty may resort to old techniques with which they are comfortable:

Gerald: There is a risk involved with making changes and I am sure I am not the only person that has encountered problems in the classroom. “Once Burned, Twice Shy” could be a reason that faculty make “excuses” for not making changes (October 27, 2013).

While Gerald explained his experiences made him more cautious with implementing changes in his classroom, he was still the first to fully embrace a constructivist approach in his own classroom. Clearly Gerald was attempting to change his teaching. Otherwise, the student resistance, and comparisons with prior modes of teaching would not have occurred.

Both Gerald and I sought to embrace constructivism and inquiry in our own ways. Not everyone in the cohort was a comfortable or accepting of the new material. The following example demonstrates Edward was initially resistant to ideas espoused by educational philosophers, but eventually began to accept at least some of the ideas presented.

A cohort member recognized himself in the readings. Edward offered an insightful reflection on beginning to understand constructivism both during and after a group discussion. During a class discussion about ten weeks into the first semester in which we had been discussing Schwab (1978), Edward asked a question related to interpreting Schwab’s writing. Dr. Smith explained “I’m not really certain what Schwab meant in this instance.” Upon receiving this response, Edward looked at me and exclaimed “He doesn’t even know what Schwab means. How am I supposed to figure this out?” (Field Notes, October 21, 2013).

This reaction from Edward is understandable for a variety of reasons, especially given the circumstances. First, all of us in the cohort struggled to understand several assigned readings including Dewey (2013), Popper (2014), and Kuhn (2012). Many of us found reading Schwab (1978) even more difficult than those earlier works. Edward, a self-professed “non-reader”
likely experienced some pent-up frustration with coming to terms with the challenging writing style of Schwab. Second, Edward’s instinct as a trained engineer was from the positivist perspective. He fully expected Dr. Smith to be the authority in the classroom, and to provide the “right” answer to the class. The concept of discussing possible meanings within the group was inefficient and foreign to Edward. This reaction on Edward’s part with consistent with how faculty members entered the PhD program. Edward understood quality teaching to be in the received view. Ultimately, Edward returned to the drawing board and attempted to arrive at his own conclusions. This led him to develop the Venn diagram shown in Figure 2 which he included in the weekly journal post (Edward, Journal Post, October 27, 2013).

Figure 2. Edward’s representation of authentic STEM learning resides at the intersection of ontological and epistemological. These were two terms unknown to the cohort prior to beginning the PhD program.

A series of readings and group discussions led Edward to seriously review and reflect on his own teaching and learning strategies. Earlier in the semester, while discussing Dewey’s (2013) three evils of the curriculum passage, “… even the most scientific matter, arranged in the most logical fashion, loses this quality, when presented in external, ready-made fashion by the
time it gets to the [student]” (p. 26). Edward exclaimed: “I feel like that is exactly what I do with my laboratory assignments. I always believed I was making it easier for the students to learn” (Field Notes, October 10, 2013). Interestingly, and perhaps ironically, Edward’s self-reflection as he began to understand some of the constructivist readings was, in itself, an enactment of his own constructive learning. The significance Edward seeing himself in the readings is consistent with conversations with the “other” as described by constructivist philosophers (von Glasersfeld, 1995).

Subsequently, in his writing after the Schwab discussion, Edward explained, prior to entering the cohort he always considered his teaching to be at the intersection of authentic STEM learning as he drew in the diagram. However, further reflection on his budding understanding of constructivism led him to believe otherwise as he wrote: “I’m rapidly realizing just how far from [authentic STEM learning] I am” (Edward, Journal Post, October 27, 2013). Edward recognized, through reflecting on readings; writing and reading journal entries; and classroom discussions, his teaching style was highly structured and didactic and left little room for students to construct their own understanding. Edward recognized at that moment his strategy of providing detailed laboratory instructions to students resulted in a cookbook approach, and left students with little room for error, creativity, or authentic learning. As a long-time friend, and colleague, I knew Edward as a caring instructor who had worked diligently to develop highly structured teaching materials he believed would benefit student learning. He was meticulous, thorough, and organized in his pedagogical creations. However, our introduction to inquiry and constructivist teaching practices had convinced even Edward to consider change.

The examples above are representative of the reactions from most members of the cohort in response to our introduction to constructivist teaching strategies. Not only were engineering
educators receptive newly presented education theory, they reflected on their own institution and their own classrooms as they identified instances to improve their own teaching. From my perspective, a long, well-documented history of calls for reform in STEM education coupled with the illumination we as educators have the ability to reach more students proved a powerful combination which served to instigate new ideas and enthusiasm for meaningful change.

Discussion

This paper explored lived experiences of nine long-time engineering educators enrolled as part of a cohort in a STEM focused PhD program in education. Concentrating on the first year of the program we analyzed the culture of engineering education through participants understanding of notions of science, STEM elitism and privilege, and constructivist teaching practices. In particular, this research points to three significant considerations related to the culture of engineering education: a) to meet national needs in engineering, teaching needs to change; b) despite a long history of calls for engineering education reform, the majority of engineering educators continue to teach using positivist, didactic methods, and remain unaware of, or unwilling to adopt, a suite of alternative teaching approaches; and c) the current reward structure fails to reward those individuals who recognize the need for and desire to enact engineering education reform. Each of these concepts is addressed in the following paragraphs.

A Need for Change in How Engineering Educators Teach

The recently published compendium on engineering education research (Johri & Olds, 2014) is replete with research describing improvements required in engineering education. Researchers have argued engineering educators continue to implement the same, ineffective teaching methods by which they themselves were taught (Jamieson & Lohmann, 2012). One of numerous recent examples of attempts to influence change is the National Science Foundation’s
solicitation aimed at “Revolutionizing Engineering Departments” (NSF, 2014), with the goal of helping universities “… overcome long-standing issues in their undergraduate programs and educate inclusive communities of engineering students prepared to solve 21st century challenges” (p. 1). The need for impactful change in engineering education has been clearly articulated. This research studies a group of enthusiastic, open-minded, long-time engineering faculty members willing, and even seeking, to improve teaching and the culture of engineering education. Explicit within the findings was the participants’ sense of frustration and dismay with the lack of fundamental educational underpinning present in their preparation as engineering educators. These revelations came during their initial exposure to topics such as the history and philosophy of science, the history of education reform, STEM elitism, and teaching for diverse learners. This small cohort of faculty has begun to appreciate what substantive change in engineering education might look like, and understand the magnitude of effort required to enact that change. These findings indicate a necessary step toward change, which includes introducing more faculty to and engaging more faculty in educational research to help them understand what could be accomplished with focused and meaningful changes to the way we interact with students and the way we teach.

**Changing the Status Quo**

As seen in reviewing the long history of education reform, changes in classroom teaching have remained relatively stagnant despite numerous calls for improvement. Engineering education has historically favored the dominant culture of White males (Foor et al., 2007), a trend that continues today despite repeated calls for change. Authors have demonstrated examples of constructivist teaching practices which benefit all learners (Rodriguez, 1998). In the analysis of this cohort, findings indicate these willing engineering educators entered the PhD
program believing they treated all students fairly. However, their words and actions exposed an elitist attitude, favoring individuals who looked like them. While their bias and behavior were unintentional, they were present nonetheless. Though these well-meaning educators didn’t know what they didn’t know, researchers have explained that ignorance does not absolve blame, and the culture of engineering education continues to hire and reward those educators who publish, garner external funds, and teach to the privileged few:

If educators continue to be ignorant of, ignore, impugn, and silence the cultural orientations, values, and performance styles of ethnically different students, they will persist in imposing cultural hegemony, personal denigration, educational inequity, and academic underachievement upon them (Gay, 2000).

As seen with Edward’s realization of his own son’s privilege, it may take multiple exposures, and a personal connection for deeply rooted beliefs to be modified. The process of enacting lasting change in the culture of engineering education will be neither easy nor swift. It will require groups, like this cohort, coming together, locking arms, and enacting meaningful change as positive examples for others to see and emulate.

**A New Infrastructure for Faculty Rewards and Incentives**

The journey undertaken by this cohort of long-time engineering educators as they pursue a PhD in STEM education represents a unique opportunity to analyze the culture of engineering education. Most engineering faculty would be unwilling or unable to participate in such an aggressive and time-consuming example of professional development to improve their teaching and research skills. The commitment required to pursue a PhD would be extraordinary for even the most dedicated teachers. However, it is incumbent upon academic administrators to begin to value effective teaching strategies which support all learners. While it is customary for
engineering faculty to be evaluated for their teaching ability as part of annual review, the
incentive and reward system for engineering educators has historically focused on scholarly
publications and external funding. The most prestigious institutions are those categorized as
“Research 1” and specialize in graduate education. Though faculty may devote most of their
attention and time to graduate students, these universities often attract large numbers of
undergraduates. These undergraduates are often left by the wayside as faculty deflect the
responsibility of teaching to graduate teaching assistants. In fact, in their seminal work on
students leaving science, math, and engineering majors, Seymour & Hewitt (1997) argued:

... many [science, math, and engineering] faculty are poor role models as teachers, either
for the acquisition of good teaching skills, or for the development of positive attitudes
toward the value of learning them. On the other hand, [science, math, and engineering]
faculty often delegate a high degree of responsibility to their teaching assistants for
teaching the fundamentals of their disciplines, and for responding to undergraduates’
questions and problems (Seymour & Hewitt, 1997).

Educational institutions have continued to tolerate substandard teaching at the expense of
undergraduate students. Additionally, the changing demographic of students entering
engineering programs has resulted in:

...a much broader cross section of the student population, many of who have the potential
to be excellent engineers, but who have to overcome deficiencies in their pre-college
preparation, [which] means that ineffective teaching is no longer acceptable (Felder et al.,
2011, p. 91)

The problem here is twofold as the current infrastructure permits poor teaching while rewarding
other accomplishments. This situation has led researchers to argue the necessity for change in
the academic support structure toward incentivizing and rewarding development, transfer, and adoption of educational innovations (Jamieson & Lohmann, 2012). Until academic institutions create an environment in which faculty are expected to be outstanding teachers, outstanding teaching will remain only in small pockets and led by individuals with the passion and conviction to do what is right.
References


An imprint of Simon & Schuster, Inc.


Phase II: National Academies Press.


