AC 2010-2369: CHALLENGES AND OPPORTUNITIES IN BRIDGING K-12 AND ENGINEERING EDUCATION RESEARCH

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Challenges and Opportunities in Bridging K-12 and Engineering Education Research:
A Researcher's Narrative

This paper describes the process of selecting a theoretical framework conceptualized, tested and used in the K-12 research arena, and applying the framework to a proposed research project in engineering education. Through describing my own experience, I raise questions about the differences between K-12 and post-secondary educational research, highlight interesting questions that emerge when we use theory from K-12 in the post-secondary engineering realm, and advocate for further efforts in bridging the gap between these realms. Based on the early stages of my doctoral thesis on teaching practices in engineering, I attempt to highlight questions, challenges and opportunities though a narrative about my own experience that may resonate with other researchers who are attempting to apply experience from the K-12 realm to the post-secondary, engineering education research space.

My doctoral dissertation research will examine teaching practices in engineering. More specifically, I am using the following research questions:

- How do engineering instructors understand the role of exploring technology/society interactions in engineering education?
- How do faculty describe the process they use in exploring technology/society interactions in their own teaching?
- Are there challenges or barriers to teaching about technology/society interactions in engineering education?

Where "society" includes both social issues (such as poverty, or environmental conservation) and social structures (such as political and economic systems).

As a lecturer of education and technology & society studies, and an education specialist within an engineering faculty, I have become intrigued with the beliefs behind curriculum selection, and also how professors choose to contextualize their technical curriculum. I believe that we need to do more to connect how we understand technology to the world's most pressing challenges, and I attempt to emphasize this in my own teaching.

Through this proposed research, I am working in a relatively new area that isn't well-defined by existing theory and methodology formed in higher education. Although there is a body of research on the teaching of engineering ethics and the integration of the social sciences with engineering, and that is certainly relevant to examining the technology/society interface, I am examining faculty beliefs and processes around curriculum choice with respect to contextualizing science and technology curriculum. After some early reviews of existing literature, I decided that the existing theoretical frameworks most relevant to my research questions are 1) the history and pedagogy of engineering education, which is widely supported through organizations such as ASEE; 2) STSE (formerly STS) education and 3) Teacher Identity. The selection of STSE and Teacher Identity have been informed by my own experience conducting research with pre-service and new science teachers, and their use of an STSE approach in their teaching of science. However, acknowledgement of context is critical in educational research, and as I reflected further on these theoretical strands, I realized the inherent challenges in utilizing theory from the K-12 realm in the framing of my post-secondary research project.

STSE Model of Science Education

STSE (Science, Technology, Society and the Environment) is a documented approach to the teaching of science, which addresses science as "issues" in context. The nature of science and technology, its effects on society and society's reciprocal effects on science are explored thorough the approach. STSE-oriented instruction is based on the philosophy that science education should include a variety of perspectives about science – historical, philosophical, cultural, sociological, political and ethical[1, 2]. STSE education may explore a technological artifact, or process, a societal issue related to science, engineering or technology, or an issue within the scientific community, relevant to an interaction between science/technology and society[3].

The STSE educational approach may include the following features[4]:

- An understanding of the environmental threats, including those of a global nature, to our quality of life
- The economic and industrial aspects of technology
- An understanding of the fallible nature of science
- Discussion of personal opinion and values, as well as democratic action
- The multi-cultural dimension of science

The progression of an STSE "unit" typically follows a series of steps, as proposed by Derek Hodson[5], one of Canada's preeminent science education researchers. The first step is represented by gaining an appreciation of the social impact of scientific and technological change. The second step involves students making decisions about scientific and technological developments, and weighing the costs and benefits of these developments. Next, students develop their own views and value positions on science and technological issues, before finally taking action. Hodson proposes the action-taking as a necessary conclusion to STSE instruction. More specifically, he notes, "It is almost always much easier to proclaim that one cares about an issue than to do something about it!"

The STSE approach has been applied to general science, biology, physics and chemistry courses in the K-12 realm, where "engineering education" is essentially non-existent, the motivations of students and teachers are considerably different, and essentially all situational factors related to courses and teaching are dissimilar to what we find in engineering schools. In high schools, the approach has been used to expand the contextual knowledge of students who will pursue science, technology, engineering or mathematics (STEM) in their post-secondary pursuits, but also to encourage the scientific literacy of students who will not pursue a STEM degree after completing high school. Herein lies a fundamental difference in the approach between science classrooms of high schools and the engineering classrooms of universities; high school teachers work with students who have a more diverse set of motivations, and needs, for the learning of science and technology.

STSE education has proven to provide many advantages to students. A synthesis of research, conducted by Aikenhead[6] made the following conclusions:
1) Students in STSE education classes improve their understanding of social issues and the interactions between science, technology and society
2) Students in STSE education classes improve their attitudes towards science and learning
3) Students make gains in applying science to everyday situations, critical thinking, creative thinking and decision making
4) Achievement at the next level (for example, university, in the high school context) will not be compromised.
Solbes and Vilches[7] also found that students who had been taught using an STSE education-oriented approach developed a more realistic conception of science. When looking at the K-12 realm, teachers can be introduced to these benefits of an STSE approach. However, the difference in context, motivations and attitudes between even high school students and university students is extensive. Do these benefits persist in university education? How might engineering faculty perceive these benefits?

As mentioned, my interest in this model has been informed by my own experience in conducting research on pre-service and new high school science teachers with colleagues from the Faculty of Education (OISE-UT) at the University of Toronto[8]. Through this experience, we examined science teacher beliefs about using STSE in their own classrooms, through discussions on how their subject matter (which would be defined as "biology", "chemistry" or "physics") provided opportunities or challenges for STSE, and how they might overcome subject-matter or professional challenges related to STSE-oriented instruction. This presents us with another key difference in the examination of teaching at the high school level versus university, and that is the specificity of the subject matter. More broadly, how do we understand and describe the differences between a faculty member's conception of "Signal Processing" versus a grade 11 teacher's conception of "Physics", and the inherent obligations around facilitating learning of the subject matter? Our research participants noted concerns about losing control of the classroom and the "scientific content" when using a STSE approach. Might engineering faculty share these concerns, or does a presumed greater confidence in the specific teachable subject matter allow engineering faculty to more easily incorporate technology/society elements in their teaching? Or will they feel even more strongly about building strictly technical competency in their students? Is there a perception that STSE should be relegated to one "engineering and society course" in a students' engineering program?

Through this particular research experience, we also worked with these teachers to determine how they viewed their role as a science teacher, and how STSE interplayed with their concerns about "politicizing" science or sharing too much about their own political or social ideologies with their students. The teachers expressed concern about whether politicization and action is part of the teacher's role, and also expressed concern about exposing their bias and ideological bents around socio-technical issues. Will professors be more or less likely to expose their own political or social ideologies? Does the university provide a more "free" environment that encourages this, or conversely might engineering faculty feel constricted by being in a professional faculty with a particular set of norms and values?

The STSE framework, and demonstrated challenges and benefits of the approach as demonstrated in the K-12 sector, are helpful in considering my own research in how engineering faculty choose to contextualize technical content. However, the differences between the K-12 and post-secondary contexts leave me with a number of questions to consider about STSE as a theoretical framework in my post-secondary engineering research:

1. Do engineering faculty feel they have additional responsibilities with respect to covering specific technical content, and providing employment preparation that simply are not factored into the current research on STSE?
2. Without teaching preparation, would an engineering faculty member have the confidence and skills to use a STSE approach without considerable support? Are teachers more likely to use this model because of pre-service preparation, in-school teaching collaboration and coaching, and regular in-service learning?
3. Is such instruction already taking place in engineering, but we simply use different language to describe it? How should I consider semantics and adjust language when developing research tools, such as a survey or set of interview questions?
4. What are the differences in how "societal context" might be embedded in pure science, rather than engineering?
5. If an engineering professor's role is to produce confident, competent engineers, might they see a conflict with presenting the "fallible nature of science and technology"?

Teacher Identity

Teacher identity is a broad, well-established area of research in the K-12 literature through the work of scholars such as Elbaz[9], Goodson[10], Siskin[11], and Beijaard et al[12]. The literature suggests that a teachers' sense of self develops from experience, life history and socialization into the professional (teaching) community. There appears to be a gap in the K-12 research around the notion of science teacher identity, and the sense, if any, of how professional or personal identity originates in how individual teachers identify with their subject matter. The notion of teacher identity is relevant to my research, as I am examining the choices and beliefs of faculty around the curriculum and teaching practices they employ, which surely relate to how individuals identify themselves as an individual, an instructor, as well as an engineer.

The literature on "teacher identity" is limited in higher education, especially outside of teaching preparation programs and medical education. While some of the research from the K-12 sector can be quite useful in anticipating the challenges engineering faculty may cite, it is difficult to predict how the teacher identity theoretical framework applies to engineering. One can anticipate that the same characteristics that form "teacher identity" may be found in university faculty as well, albeit with some key differences. The notion of a "professional community" is significantly different in the world of higher education.

In K-12 teaching, the professional community is one of teachers; in engineering education, a faculty member might typically consider their research community as their key professional community. There are certainly some common themes around loyalty to subject matter; but where a K-12 science teacher may have concerns about their own subject-matter knowledge and confidence, the university professor may perhaps be more concerned with a lack of pedagogical knowledge!

In the abovementioned research[8], the teachers spoke to a concern about support from their school and subject-matter colleagues, and a need for a sense of belonging in their school community, and within the norms and practices that constitute teaching science in their school. In the research, the teachers presented concerns about being "outside" of tradition by taking an STSE approach. In the professoriate, there is a serious lack of support between faculty with respect to teaching as a whole, and the notion that they would not have the support of other faculty may not even register as a concern. That said, in a system that relies heavily on pre and co-requisites, some faculty do feel an obligation to teach their subject matter in a particular way.

One of the most interesting considerations in teaching & curriculum selection is the notion of academic freedom in universities. While academic freedom has its limitations, university faculty are typically provided with a greater ability to select curriculum and delivery modes than their K-12 counterparts; however, other limitations exist, including class size and the competing priorities of research and administration. Also, as faculty members are encouraged to focus more on teaching, there is still little opportunity for them to receive training to support trying new approaches, or developing curriculum modules that would allow them to contextualize technical content in a social issue.

Evidently, given my own experience working with pre-service and new teachers, I must openly consider how my understanding of "the teacher" and teacher identity compares with the "professor as teacher", and also how my data collection methods will differ from my past experiences with high school science teachers. I do feel, however, that there are some interesting commonalities that universities could capitalize on through their own teacher education and faculty development programs that would have benefits to create a more seamless view of "K-16" education, and those who teach in it. Specific questions that this exploration has raised for me include:

1. How does the creation of "teacher identity" differ between the K-12 and post-secondary sector, and how do these differences impact choices around curriculum and pedagogical approaches?
2. How does the relationship between teacher and subject matter differ between the two educational realms, and how might this impact pedagogical and curriculum content choices?
3. How do the vast differences in professional development between the teaching communities of K-12 and post-secondary impact pedagogical and curriculum content choices?
4. Can the vast literature on teacher identity in the K-12 sector provide us with a framework for understanding more about faculty identity?

Conclusions

This paper has described my experience, thus far, in establishing a research project that branches the work in the K-12 sector with new research possibilities in higher education, and the questions that arise about the two sectors when planning this research. I see my entire research process as an opportunity to bring together the often disparate worlds of curriculum, teaching and learning in the K-12 spectrum and higher education, albeit in one research area - the teaching of engineering. In reviewing key differences between K-12 and higher education, it becomes clear that it is critical to test vocabulary and methodological approaches before full deployment of research tools. For example, if I use my understanding of STSE from the K-12 sector in the development of data collection tools, will I risk missing the opportunity to explore deeper questions about why professors choose particular approaches to teaching engineering because I have misunderstood how they might contextualize their technical curriculum? Are there dangers in making assumptions about the factors that construct "teacher identity" in engineering education that could risk derailing my main research questions? These are challenges I will work through as I move forward in my research.

Notes

In the mid 1990's science, technology, society and environment (STSE) replaced science, technology and society (STS) education.

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