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Board 166: Perceptions of Hands-on High School Education Alumni on their Preparation for Engineering (Work in Progress)

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Hands-on High School Education Alumni's Perception of Preparation for an Engineering Career (Work in Progress)

Engineering university students come from a variety of socioeconomic backgrounds which influence their engagement with engineering. While these diverse backgrounds have been the focus of engineering education research, such as with diversity equity inclusion justice (DEIJ) topics, students from secondary Career and Technical Education (CTE) programs have largely been omitted [1]. Previously known by the name "vocational education," CTE has a history of being seen as the alternative for students who are not pursing higher education due to their perceived deficits in ability or behavioral, psychological, or social problems, which make normal participation in traditional public schools difficult [1, 2, 3]. These stereotypes frame CTE negatively and often inaccurately. Given that there is wide-spread lack of familiarity with CTE high schools, and a historically negative perspective of CTE, this study seeks to provide an empirically grounded understanding of the outcomes of participation in a CTE high school as preparation for engineering education at the post-secondary level.

The goal for CTE is for students to learn both as students and as semi-professionals [4, 5]. CTE addresses this dual goal by building competence within a given discipline through disciplinary instruction, framing, and occupational specific professional practices [5, 6, 7]. While not always realized in schooling, some engineering educators have cited similar goals for preparing engineers through engineering framing and practices [8, 9]. Similarly, educators have proposed that an engineering student becomes an engineer through engaging in engineering practices, including systems thinking and the ability to work in teams [10, 11]. In fact, many CTE high schools have engineering associated programs, such as environmental science, robotics, advanced manufacturing, and biotechnology [1, 12]. Here, we argue that, given the focus on developing disciplinary and professional practices, the CTE high school experience may result in equally valid preparation for post-secondary engineering than that of a traditional high school [10, 12].

There is sparse research conducted about CTE in general [1], and the limited research mainly focuses on survey quantitative data and subsequent inference. Hence, a deep understanding of students' CTE experiences and how those connect to their learning and career trajectories is lacking. This study seeks to address this gap by investigating CTE high school graduates' perceptions of CTE as preparation for post-secondary engineering [13]. To do this, we ask the following research questions:

- What practices do secondary CTE graduates identify as the most critical from high school in preparing them for their current post-secondary engineering engagement?
- What challenges do secondary CTE graduates cite in their experiences as university engineering students?

Theoretical Framework

This study uses the theory and language of *Communities of Practice* [14] and *Landscapes of Practice* [15] to couch the student experience in practices, as they navigate post-secondary engineering. In brief, a community of practice is made of competent practitioners of a given discipline, where competence is defined as: knowing current standards; being currently engaged with the rest of the community of practice; and having disciplinary experience. One example of a community of practice given by Wegner is the musician community, where members are often familiar with following scores, direction, and terminology of music [15]. Related communities of practice may, together, be considered the body of knowledge in a field, which constitutes a landscape of practice. These landscapes are not physical, but rather defined by the intersecting communities of practice and their members. An individual's understanding of the composition and practices in a landscape, and how communities within it interact and are necessary, is defined as knowledgeability. One example of a landscape of practice Wegner provides is higher education, which is partly composed of the researcher community of practice and lecturer community of practice. There may be boundaries between communities of practice based on language, credentials, discrimination, and conflicts of competence. Moving through boundaries, as well as participation in multiple communities of practice may result in personal or community tensions. These tensions may come in the form of different community prioritizations and framings, and these may in turn put strain on the identity of the individual or community, as they have to negotiate these conflicting interests.

Literature Review

A historically negative view of secondary CTE has existed since its beginning in the US [3, 13, 16], specifically as an unfavorable alternative to the college preparatory track [3]. However, public attitudes are shifting to view CTE as a necessary form of education given recent changes in perception surrounding skilled labor and higher education and more federal and public investment in CTE programs. Simultaneously, CTE programs have been moving towards a joint preparedness of college and work readiness, with increasing integration of academic material [12, 13, 16-18]. Consequently, the practices in CTE have become focused on STEM [10, 19, 20], and align with practices which are found in the engineering workplace [8, 11]. The Career Ready Practices and the Common Core State Standards were recently generated through several research projects to describe what successful CTE looks like in the United States [21-23]. These practices are set to guide the development of CTE in the future, and they are also general and intended for all CTE areas of concentration, including engineering. Notably, there is considerable alignment between the new CTE standards [22] with engineering epistemic practices identified in the engineering studies literature [8].

Methods

To understand outcomes of CTE participation, a semi-structured interview study is currently being conducted; the initial findings are reported here. Recruitment of interview subjects began with an interest and demographic survey was sent to over 30 CTE high schools in Massachusetts and over 45 individual teachers, administrators, and alumni. Survey responses led to five qualified participants among all fields. The two pursuing university engineering degrees are the focus this report. One participant was a sophomore and the other a senior year and one identified as man and one as a woman. Both were enrolled in private, 4-year universities and both enrolled in the engineering CTE area of the same high school. The respective pseudonyms used for these participants are Eclipse and Horizon. The study was approved by the IRB and both participants consented. Initial interview questions were generated from the research questions. Two mock interviews were conducted with the purpose of refining the interview questions. With the refined protocol, participant interviews were audio and video recorded, then transcribed for analysis and anonymized (including pseudonym use). Eclipse's interview lasted 1.5 hours and Horizon's interview 0.75 hours.

The analysis of the interview study included iterative rounds of emergent coding. In rounds, qualitative descriptors were added, using ATLAS.TI software, to transcripts of the interviews. Broad, situating codes were generated by taking initial *a priori* themes from *Landscapes* language (e.g. academic landscape, high school practices, occupational practices), including: University Practices, CTE High School Practices, Engineering Practices, and Professional Practices [15]. More specific codes, such as Exam Taking, Study Skills, Interdisciplinary Communication, were then generated and contextualized through categorization into the broader codes. Along with the object of the code, such as Exam Taking, the connection to CTE High school experience was also considered. For example, the coding of "I still don't know how to take exams, or study for them" may be [University Practices](category code), [Academic Practices](round 2 category code), [Exam Taking](object of code), [Preparedness: Not: Academic Practices](conclusion code). Utilizing this code to form a written result may be: "CTE High school did not prepare the student for the university's academic practice of exam taking." As coding continued, codes were reexamined and refined, sometimes consolidating codes. The final codes were used to identify themes of the CTE experience, as related to the research questions.

Findings

From the Eclipse and Horizon interviews, five main themes were identified as follows:

1 <u>Instruction and Administration</u>: Both participants felt that CTE program instructors form closer bonds with students than traditional high school teachers do. In university, the practices of extensive lecture and the separation between lecturer and student was off-putting to Horizon and resulted in her feeling left with little guidance. Eclipse found that CTE had prepared him to self-advocate with professors at the university, such that he received guidance he needed. Both Eclipse and Horizon cited rough turnover in high school when several CTE instructors left their programs and there were new replacements who were unfamiliar with the school and CTE generally. Horizon expressed dismay at the more traditionally oriented practice of authority, when one of the new high school CTE instructors overrode the class's choices for senior projects. In college, Horizon found similar practices of authority common. Eclipse felt that one of the most critical parts of high school CTE was the independence that was granted to attending students. In university, he found that the main sources of similar independent experience were lab classes, research labs, and internships.

2 <u>Hands-on Activities</u>: Independence in high school CTE allowed Eclipse and Horizon to gain competency with engineering equipment. Eclipse described the interdisciplinary practice of fixing and working on equipment in at least two other CTE areas with other students, both from engineering and respective areas. He also found that the competences gained from high school put him at an advantage relative to other students in the project-based introductory university engineering course, as he had several years of hands-on competence building, such as circuit building, whereas other students had zero prior exposure. Horizon expressed similar sentiments of being ahead in college introductory hands-on engineering specific courses, citing prior exposure to circuits.

3 <u>Academic Practices</u>: Eclipse and Horizon had a tremendous focus on the university engineering academic practices of exam taking, studying, time management, and working independently. Both cited failing several exams in college and having no idea how to study. Horizon found that the focus on individual homework and work was completely different than

the collaboration and hands-on centered instruction in the CTE high school. She could not keep up with the time management now required by university courses. One factor of this struggle she cited as not understanding how to study in the first place, so that university studies became daunting, especially working by herself. She also had no idea how to take notes. For Horizon, this added to her difficulty in university engineering, eventually resulting in her dropping. Eclipse stated that even as a senior in university engineering, he still felt as though he had no idea how to study well or take an exam well, especially in comparison to university peers.

4 Understanding Engineering: The interviewees discussed the use of building engineering knowledgeability in their high school CTE programs, citing exposure to civil, chemical, electrical, biomedical, and mechanical engineering. For Eclipse, this changed his trajectory, steering him from civil and towards electrical engineering. He stated that his high school CTE experiences allowed him certainty as to trajectory in college, feeling that he did not need to explore other engineering fields further and could focus his energy on his studies. In contrast, Horizon found the practical hands-on engineering work that she thought of as engineering was almost gone from her experience in university. She discussed how her perspective of engineering changed from problem-solving and design to doing math in an office all day. She felt disappointed as her desired trajectory was to learn how to engineer machines from scratch. Eclipse echoed similar surprise at the level and amount of math required in university, seeing it initially as a deviation from what engineering really is. Despite this perspective, he recommended CTE education for students to get exposure to different fields and set a trajectory before university, as changing track in university would be so costly. He cited university as not the place a student should start exploring what they want to do as a career.

5 Math as a Barrier: As discussed from Horizon's perspective above, the largest obstical in university engineering for Eclipse was also math. Both students cited feeling unprepared by CTE high school for the difficulty and amount of the math that their university courses focused on. Horizon cited that calculus at the university felt completely abstract, and that due to the amount of work expected, she never had time to understand the material. Eclipse described the need for a large amount of remedial math study upon entering college. Despite this, he is now minoring in math, as only a small number of courses are required past that of his engineering major.

Discussion

Analysis of Eclipse's and Horizon's experience suggests that CTE students are prepared differently for university engineering than traditional high school students. The two CTE students interviewed stated they had the opportunity to develop professional engineering skills which traditional university engineering students may not be exposed to until later years in their studies or through co-curricular activity [10, 24]. However, CTE students described being less prepared for university engineering academic practices. Despite recent trend in alignment of CTE practices with STEM [10, 19, 20], the heavy focus on math in university engineering was a large obstacle for CTE-background university students. This practice resulted in both interviewees reconsidering their understanding of the landscape of engineering, as their history in the CTE high school community provided an understanding that was framed by the professional engineering community, which foregrounded authentic engineering rather than emphasizing math. With that emphasis, students revealed knowledgeability when choosing to pursue engineering and choosing a specific engineering field. By being able to explore some of the engineering landscape while in high school, there seemed to be a sense of trajectory developed through experience which both students connected to their career trajectory. However, these CTE students faced tension when reconciling their views of engineering with university engineering practice. These students felt surprise at what practices the university framed as 'engineering,' given the disconnect between those and the CTE framing of 'engineering' practices.

These findings are summarized in Figures 1 and 2 where more rectangular shapes indicate academic practices and rounder shapes indicate professional practices. Figure 1 shows a path from traditional high school where students are well prepared for university engineering practices but not so prepared for professional practice. Conversely, Figure 1 also shows a path from a CTE high school education aligned with professional aspects of engineering practices, but not with university engineering practices [10, 11, 24]. There are implications to retention and inclusion - the tension from this misalignment caused Horizon to drop out of engineering and the university altogether. Figure 2 shows our conception of a reimagined university practice. By aligning the practices in university engineering programs with professional engineering practices, while maintaining those practices integral to the university landscape, students with either a focus on academic practices (traditional) or professional practices (CTE) in high school may more readily have opportunity to become professional engineers. In such an approach, each students' competencies would need to be rewarded (rather than their deficits exposed). The alignment of university engineering practices would enable professionally prepared students and be inclusive of CTE students. These CTE students could be an asset to traditional high school students, expanding their knowledgeability of the engineering profession, while the traditional students could be an asset, helping the students develop more formal mathematics and scientific skills – a true landscape of practice.

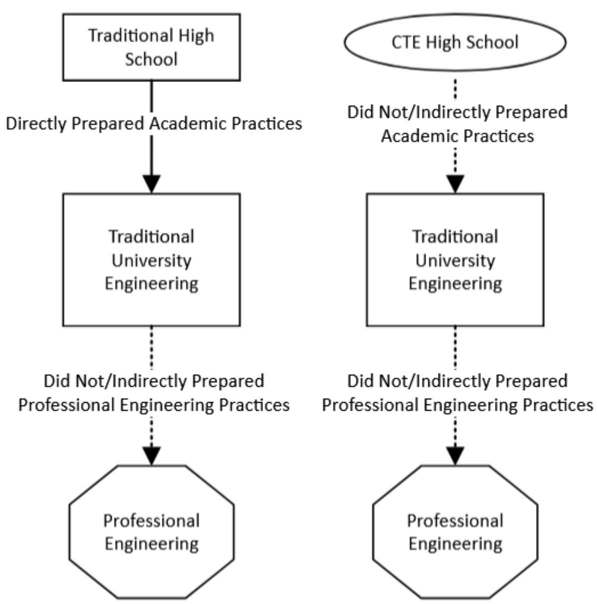

Figure 1: Traditional Engineering Pathway

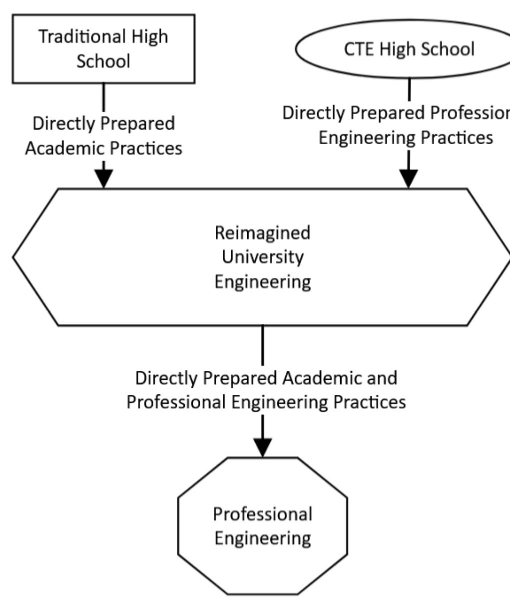

Figure 2: Professionally Aligned University Pathway

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