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Exploring Knowledge, Skills, Attributes and Technical Learning in a Work-Integrated Learning Engineering Program

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Work-In-Progress: Exploring Knowledge, Skills, Attributes and Technical Learning in a Work-Integrated Learning Engineering Program

Introduction

Throughout the history of engineering education there have been continued calls for the need to educate and prepare engineering students for the "future of work" [1]. According to scholars, these calls can be traced back to the 1918 Mann Report [2] and continue through the recent Transforming Undergraduate Education in Engineering reports [3]-[6]. Additionally, there have been tensions between academia and industry on competency development and what it means for students to be "prepared" for work [1], [6]. In the midst of these discussions, work-integrated learning has emerged as a high-impact practice that has the potential to support competency development, address tensions in engineering student preparation, and influence students' perceptions of themselves as future professional engineers [1], [7].

This work-in-progress paper explores students' initial perceptions of competency development in a work-integrated learning engineering program before starting their internship. Specifically, we explore competency development through the lens of the Knowledge, Skills, and Attributes model and focus on students' perceptions of technical learning. The research questions for this paper focused on:

1. How do students describe technical knowledge, skills, and attributes (KSAs) in the early stages of a work-integrated learning program?
2. What context do students draw from when they identify technical knowledge, skills, and attributes (KSAs)?

Future work will focus on an in-depth exploration of engineering students perceptions' of knowledge, skills, and attributes as they relate to the technical, professional, and personal domains while engaging in work-integrated learning. This work-in-progress was part of a larger NSF-funded study and focused on students' perceptions in the early stages of the program.

Background

In response to the need to reimagine undergraduate engineering education to better serve students and industry, a small private College in the Mid-Atlantic and an Educational Non-Profit in the Northeast partnered to design an innovative work-integrated learning program in engineering. The semester-long program includes a three-week bootcamp and a twelve-week internship placement with an engineering company. During the entire 15-week semester students were enrolled in a 14-credit courseload including a math course, sustainability and community-based design project courses, and professional development courses. The program used a work-integrated learning approach to leverage connections between students' work placement and the coursework to allow for real-life, real-time application of engineering skills. The pilot semester included four engineering students, described in additional detail in the participants section, and two instructors.

During the planning phases of this pilot, the research team conducted a literature review and found a significant amount of literature on learning in engineering coops and internships, often focused on professional skill development (e.g. communication, writing, teamwork) [8]. Due to the focus of integrating engineering work and curriculum, the team also searched for literature on technical learning in engineering coops and internships and was surprised to find significantly fewer publications in this area. In a search of ASEE Proceedings from 2000-2023, the authors found a single paper focused on technical learning, a study by Peters and Arbor [9] that explored the connection between students' work experiences and a Statics course [8]. Despite calls to prepare students for the future of work and continued tensions between industry and academia, there are fewer studies focused on technical learning during engineering internships and work experiences in engineering education. While we acknowledge that professional skills are crucial for preparing engineers for work, we also recognize the need to explore and understand technical learning particularly for work-integrated engineering programs. This finding motivated the current work-in-progress paper to focus on technical learning. As discussed later in the paper, future work will further focus on exploring students' perceptions or the professional and personal domains during the work-integrated learning experience.

Literature and Conceptual Framework

To explore competency-based learning in a work-integrated learning program where all student participants are in different work contexts, we explored the Knowledge, Skills, Abilities or the KSAs model as a conceptual framework to guide the study and analysis. This model is more commonly used to discuss competencies in industry contexts compared to academic or classroom contexts. Scholars posit that that term originated from the field of human resources and "typically relates to the needs that an industry or an employer has for the performance of particular workplace activities" [10], [11]. Hlavac [11] proposed that knowledge, skills and abilities (KSAs) be used as a metric to re-conceptualise aptitude across multiple stakeholder groups in training contexts. Due to the unique context of work-integrated learning this model is useful to consider multiple stakeholders in engineering approaches to training and work-based learning.

Furthermore, the American Society of Engineering Education has engaged in several initiatives focused on KSAs and competency-based education [1]-[5]. The ASEE Transforming Undergraduate Education in Engineering (TUEE) initiative held multi-year workshops aiming "to produce a clear understanding of the qualities engineering graduates should possess and to promote changes in curricula, pedagogy, and academic culture needed to instil those qualities in the coming generation of engineers" [2] . The outcome of this work was a report that lists the 36 KSAs that were considered most important, which included both technical and professional competencies [2], [12]. Additionally, in the ASEE Preparing Engineering Students for the Future report, a competency-based education approach was discussed and the long-term goal of the project is to develop a taxonomy of engineering competencies for "future ready engineers" [1]. Notably in this iteration, the "A" in KSAs was shifted to focus on "attributes" as opposed to "abilities" [13]. We theorize that this change in language was to shift to an asset-based approach. The guiding question for the project was "What knowledge, skills, and attributes are needed by engineering graduates to perform as competent engineers in the future?" Since KSAs are commonly used as a framework in industry contexts and there is a growing focus on KSAs in engineering education, we chose to leverage this model to explore competency in work-integrated learning contexts.

For the purposes of this work-in-progress, it is useful to define the terminology we will refer to throughout this paper. We used the same definition of competency as ASEE in their

Preparing Engineering Students for the Future Report [1] from Passow and Passow [14]. We also leveraged ASEE's definitions of knowledge, skills, and attributes in this study for alignment. Similarly to the ASEE Preparing Engineering Students for the Future report, our adapted model of KSAs includes "Attributes" instead of "Abilities." The specific definitions are as follows:

- **Competencies**: "*the knowledge, skills, abilities, attitudes, and other characteristics that enable a person to perform skillfully (i.e., to make sound decisions and take effective action) in complex and uncertain situations such as professional work, civic engagement, and personal life*" [1],[14].
- **Knowledge (K)**: "*Knowledge is what one knows (i.e., What I know)*" [1].
- **Skills (S)**: "*Skills are what one can do (i.e., What I do)*" [1].
- **Attributes (A)**: "*Attributes contribute to who one is (i.e., Who I am)*" [1].

For the purposes of this study we used the framework to guide the research questions, data collection, and data analysis. This framework aligned with the exploratory nature of our study and students were able to frame their technical skills using the lens of KSAs.

Methods

For this exploratory qualitative study, our goal was to explore students' perceptions of technical learning in their work-integrated learning experience. We chose exploratory qualitative methods because of the limited literature on this topic. An inductive approach allowed us to begin with specific observations from students to move from specific to general or in this case from specific student experiences towards a general understanding of technical learning at work.

Participants

Due to the small sample size and identifiability, participant characteristics will be described in aggregate. All four participants were engineering majors and their concentrations included Environmental Engineering, Mechatronics, and Biomedical Engineering. All four students were in their second-year enrolled at [Partner Institution]. In terms of work placements, all four students had different work placements within 30 miles from campus in a rural area of a Northeastern state. Half of the students were placed at a company that conducted work related to Solar Energy and half of the students also worked at a company that was employee-owned.

Data Collection and Analysis

The data was collected during a focus group which was conducted as part of a larger mixed methods study. The focus group for this work-in-progress paper was conducted at the beginning of the program before students' began their internships with the goal of assessing their initial understanding. Future data collection will explore students' perspectives on their Knowledge, Skills, and Attributes at the end of the work-integrated learning program and after participating in their internship. The data collected from this focus group includes students' completed handouts, the post-focus group survey, and observations during the session. While the focus group was part of a larger study, the data analysis for this work-in-progress were scoped to explore students' technical learning through the framework of KSAs.

The focus group was one-hour long with four student participants. The students were introduced to the activity and were provided with a handout to complete. The handout can be found in Appendix A. The handout was adapted from the ASEE Preparing Engineering Students for the Future report [1] and focused on exploring students' perceptions of their Knowledge, Skills, and Attributes as well as how each of these three items relates to the technical, professional, and personal domains.

The activity included five minutes of introduction followed by 15 minutes to complete the handout. After completing the handout, students had five minutes to speak with a partner to share about what they wrote and to ask each other questions. Following the individual reflection and partner discussions, a member of the research team facilitated a large group discussion. In this discussion, overarching trends were identified and students were asked to reflect again on their perceptions of KSAs and work-integrated learning. After the focus group, individual surveys were disseminated to ask follow up questions to the participants.

Thematic analysis was used to guide the data analysis and identify preliminary findings [15], [16]. The focus group and accompanying handouts were used to identify trends and tensions in students' perceptions before discussing them with their peers. The initial findings of this data analysis in the early-stages of the program will be used to guide future research and practice in the work-integrated program.

Preliminary Findings

Through the focus group and preliminary analysis we saw that students struggled in defining the technical KSAs and technical learning. When first starting the activity, many students skipped to one of the other domains of professional KSAs or personal KSAs to begin the handout because they felt that they were easier. Students told us that the technical domain was the most difficult to identify, in comparison to professional and personal. Within the technical domain, they specifically felt that technical attributes were the most difficult area to define on the entire handout. Interestingly, we found that none of the four engineering students defined themselves as engineers in describing their technical attributes or “Who I am” from the technical standpoint.

Furthermore, when analyzing students’ results we found that they struggled to differentiate between knowledge, skills, and attributes particularly when it came to technical knowledge, technical skills, and technical attributes. Two commonly listed items under knowledge and skills were math courses and machining equipment. For example, one student listed the courses they had taken under Technical Knowledge only including math courses, specifically “*Calc 1, II, III, and Diff Eq.*” In contrast, another student listed “Calculus, Physics” under technical skills. In addition to courses, another student listed two machines they knew how to use under technical knowledge including “*Drill Press, Sand Belt.*” A student who appeared to do well in the activity accurately included “*CAD*” and “*programming*” as technical skills. In terms of technical attributes, students' responses ranged quite significantly from “*strategic thinking*” and “*math and logic based mind*” to “*human being.*” Interestingly, we found that none of the four engineering students defined themselves as engineers in describing their technical attributes or “Who I am” from the technical standpoint.

Preliminary Discussion

From this activity and preliminary work, we found that students struggled to conceptualize and distinguish technical knowledge ("What I know"), technical skills ("What I do"), and technical attributes ("Who I am"). Students appeared to struggle both with separating knowledge from skills and also had a difficult time reflecting deeper on their own attributes. During the activity they felt that the technical attributes or who they were as a technical person were most difficult to identify but were more easily able to identify who they were professionally and personally. While they recognized the importance of reflection, it appeared that they had not done a significant amount of reflection on technical knowledge, skills, and attributes. We found that students' technical attributes ranged significantly, however, none of the four engineering students defined themselves as engineers. This may allude to a lack of engineering identity.

Furthermore, throughout the activity students conceptualizations of technical learning, particularly in the technical knowledge and technical skills, focused on coursework and classes they either already had taken or were currently taking. It is worthwhile to note that while outside of the scope of this work-in-progress paper, we also saw that students discussed professional knowledge, skills, and attributes mostly in the context of prior workplaces, but also drew upon classroom knowledge and experiences both at their home institution and in the work-integrated learning program. These findings together demonstrated that students' understanding of the technical KSAs is limited to the context of school, while their understanding of the professional KSAs span both work and school. This might reflect the fact that many of these students have not had a professional engineering experience before this work-integrated learning experience, and therefore have not yet had the opportunity to learn and grow technically in a workplace setting.

Limitations of this work-in-progress paper include the small sample size of the data which makes the findings potentially transferable but not generalizable. Furthermore, due to small sample size it was difficult to obtain a representative sample and future work could explore the results of implementing this activity and data collection with larger sample sizes and with a more representative sample across gender, race/ethnicity, disability, etc.

Implications and Future Work

The preliminary findings describe students' perceptions of technical KSAs and learning in the early stages of a work-integrated learning program. Specifically, we found that students struggled to define technical KSAs and especially had difficulty identifying their own technical attributes or who they were as a technical person.

The findings from this work-in-progress paper have implications for both researchers and practitioners. The preliminary findings from this work reinforce the importance of reflection for engineering students. While reflection is often promoted in engineering education, based on this study, we specifically recommend that engineering educators and practitioners consider ways in which to prompt reflection on technical knowledge, skills, and attributes. It is also important to consider the wide range of contexts technical knowledge, skills, and attributes can emerge beyond just the engineering classroom.

As the field of engineering education continues to work to prepare "future ready engineers," researchers should consider the ways in which technical learning is applied and studied in engineering students' work contexts such as internships and coops. Furthermore, we urge practitioners who work with engineering students, whether in academia or industry, to consider ways in which they can push the boundaries of traditional engineering education and integrate real-world engineering experiences in students' learning. While much of the focus on coop and internship literature published with ASEE has focused on professional skill development, these findings demonstrate the potential impact of work-integrated learning for the development of technical knowledge, skills, and attributes amongst engineering students. Much of the previous research and many engineering programs separate classroom learning from work-based learning, we argue that work-integrated learning can promote both professional and technical skills which are necessary to be successful in the workplace. Our preliminary findings reinforce the potential for work-integrated learning in building well-rounded engineering students with strong professional and technical skills.

Future work will deeper explore technical knowledge, skills, and attributes as they change throughout the work-integrated learning experience. The research team hopes to conduct a second round of data collection at the end of the program to compare and contrast students' perceptions in the early stages. Due to the project's initial literature review and need to support technical competency development, this work focused on the intersection between KSAs and technical learning. Future analysis will also explore the intersection of students' perceptions of KSAs in the professional and personal domains. Overall, the goal of the larger project is to pilot and evaluate a work-integrated program for engineering students. As work and engineering continue to evolve it is imperative that we promote deep reflection on technical learning and ensure that students are able to apply technical knowledge, skills, and attributes beyond the classroom.

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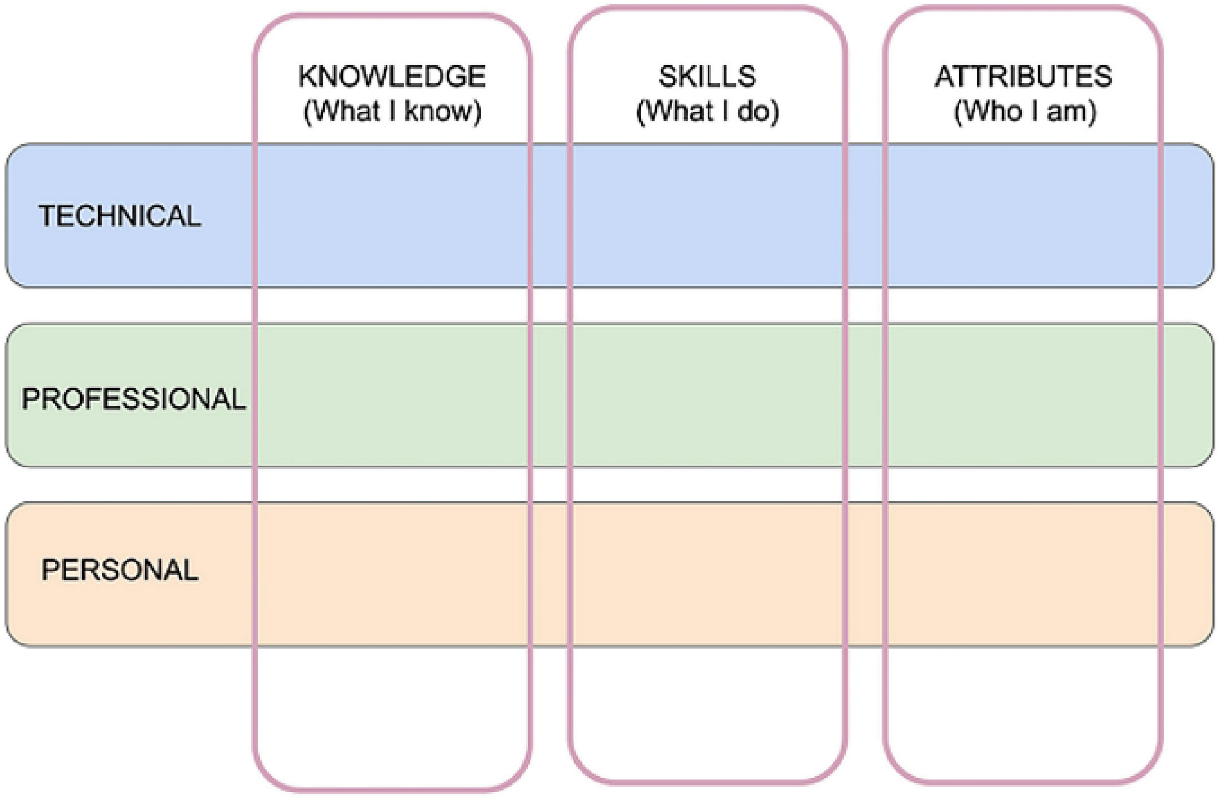
Appendix

A. KSA Competency Matrix Handout [1]



B. Transforming Undergraduate Engineering Education Competencies List [2] , [12]

Table 1: TUEE Knowledge Areas

Number	Knowledge Area
KSA 2	**Physical sciences and engineering science fundamentals**
KSA 4	**Systems integration**
KSA 7	**Cultural awareness in the broad sense: nationality, ethnicity, linguistic, gender, sexual orientation**
KSA 8	**Economics and business acumen**
KSA 18	*Informational technology – IT*
KSA 21	*Security knowledge: cyber, data, etc.*
KSA 34	*Understanding of design*
KSA 35	*Conflict resolution*
KSA 17	*Public safety*

Table 2: TUEE Skills

Number	Skill
KSA 1	**Good communication skills**
KSA 3	**Ability to identify, formulate, and solve engineering problems**
KSA 10	**Critical thinking**
KSA 12	**Ability to prioritize efficiently**
KSA 13	**Project management: supervising, planning, scheduling, budgeting, etc.**
KSA 16	*Ability to use new technology and modern engineering tools necessary for engineering practice*
KSA 19	*Applied knowledge of engineering core sciences and implementation skills to apply them in the real world*
KSA 20	*Data interpretation and visualization*
KSA 22	*Leadership*
KSA 24	*Systems thinking*
KSA 26	*Application-based research and evaluation skills*
KSA 27	*Ability to create a vision*
KSA 29	*Mentoring skills*
KSA 31	*Ability to deal with ambiguity and complexity*

Table 3: TUEE Abilities

Number	Abilities
KSA 5	**Curiosity and persistent desire for continuous learning**
KSA 6	**Self-drive and motivation**
KSA 9	**High ethical standards, integrity, and global, social, intellectual, and technological responsibility**
KSA 11	**Willingness to take calculated risk**
KSA 14	**Teamwork skills and ability to function on multidisciplinary teams**
KSA 15	**Entrepreneurship and intrapreneurship**
KSA 23	*Creativity*
KSA 25	*Emotional intelligence*
KSA 28	*Good personal and professional judgment*
KSA 30	*Flexibility and the ability to adapt to rapid change*
KSA 32	*Innovation*
KSA 33	*Technical intuition/metacognition*
KSA 36	*Ownership and accountability*