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Examining Learner-driven Constructs in Co-curricular Engineering Environments: The Role of Student Reflection in Assessment Development

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Informal learning experiences are under-utilized in engineering education. Because of the voluntary nature of these experiences, many students may be unaware of their existence or how to access these experiences. Other students may not understand the benefits and, therefore, opt out. As such, students may be missing opportunities to extend their engineering understanding and skills to make them more competitive in the workforce. Therefore, it is important to examine the learning processes and outcomes supported by informal learning experiences.

Co-curricular engineering experiences range from unstructured environments, such as social networking, to structured, such as engineering competitions that more closely approximate the workplace. Such experiences situate learning within an environment that may foster integration of knowledge and skills to solve problems (Pierrakos, Borrego, & Lo, 2007). These informal learning environments represent degrees of complexity. Therefore, students application of design or problem solving within such environments may also lead to other desired outcomes, such as increases in innovative thinking, the development of adaptive expertise, or being able to flexibly navigate multiple types of engineering environments (Kusano & Johri, 2014; Pellegrino, DiBello, & Brophy, 2014; Sawyer & Greeno, 2008; Stevens et al., 2008). However, research about how to assess outcomes attained via participation in informal learning environments is nascent. In this paper, we applied situated learning theory as a theoretical framework because our focus was on learning within engineering competitions (Johri & Olds, 2011; Johri, Olds, & O'Connor, 2014). Situated learning theory allowed us to focus on the activities in which students' engaged in order to understand the interactions that engendered different types of learning.

Faculty study learning because it allows us to help students to improve, such as for formative purposes, or to certify that students have learned, such as for summative purposes. Thus, faculty make judgments about student learning based on assessment data. Validity is the most important criteria to examine the nature of the judgments and decisions related to test use. Validity does not exist as a property of a test. Rather, validity is about providing evidence that good and appropriate decisions were made based on assessment data (AERA, APA, & NCME, 2014). Therefore, validation processes must begin with the conception of the assessment. Validity is not simply a box to be checked for due diligence. Rather, validity must undergird every decision that is made to develop the assessment, demonstrate that it works for the purposes intended, and to draw any conclusions from assessment data, whether those decisions are about students, faculty teaching, programs, or policy.

Response processes are one source of validity evidence. Gathering data about how students respond to assessment tasks or test items allows psychometricians to understand how learners think about, process, and respond to given performance tasks or test items. Messick (1990) stated, that response processes "probe the ways in which individuals cope with the items or tasks, in an effort to illuminate the processes underlying item response and task performance" (p. 5). For this paper, we extended the definition of response processes to elucidate the processes in extended performances, such as a competitions, which mirror workplace learning.

Purpose. This study was one part of a larger study to develop and validate instruments to assess student outcomes resulting from participation in informal engineering learning environments. The purpose for this study was to identify the learning outcomes as defined by the students, and as situated within engineering competitions. We empirically examined student outcomes within an engineering competition. We specifically examined student discourse as related to the ABET (2013) technical outcomes including (outcome a) content knowledge, (outcome b) experimentation, (outcome c) design, outcome (e) problem solving, and outcome (k) use of tools. These outcomes are critical to becoming an engineer (Balascio, 2014). Our research questions included:

1. How do students describe their learning experiences within engineering competitions?
2. What is the nature of their reflective discourse that revealed their learning?

This paper is a work in progress has not yet been completed.

Methods. The design for the study was qualitative. Qualitative methods provided the means to understand students' learning using students' reflections on their processes within the competition (Rossman & Rallis, 2012).

Context. This study took place at a large university in the southeastern section of the United States. This university had a large engineering program representing multiple engineering disciplines. Multiple types of informal learning environments are provided for students to enhance their educational experiences. This context for this study was the IAM3D competition (American Society of Mechanical Engineers [ASME], 2016). IAM3D requires students to address an engineering problem by designing a 3D printed model of a prototype they will develop for the competition to solve the problem.

Participants and Sampling. Participants were undergraduate engineering students who participated in the IAM3D competition (ASME, 2016). All students in the competition were invited to participate. Eighteen students volunteered. These students represented multiple engineering majors.

Data Collection and Analysis. Nine focus groups were conducted with students participating in the challenge. Focus groups provided insight into the collective learning experiences (Ryan, Gandha, Culbertson, & Carlson, 2014). We used focus groups because the competition was a team activity and allowed us to retain the situated nature of the competition. Data were collected across multiple points in time during the competition time period, and as students were developing their competition products.

We wanted to understand students' perceptions of their own learning. Qualitative methods provided an inductive means to examine student learning in their natural language. Using the students' natural language in terms of how they thought about their tasks allowed us to investigate response processes over the course of the competition, as students were engaged in the competition (AERA, APA, & NCME, 2014). During the interviews, students were prompted to discuss their experiences in the competitions. We used the students' statements as the indicators of their learning processes and outcomes. Understanding response processes as students' reflected on their learning experiences within the informal learning environment was an important part of the validation process. Thus, the interview protocol focused on students' experience of the given project within the informal environment, as well as, their understanding their learning through this non-curricular setting. Open-ended questions were developed to encourage students' natural statements about their experiences.

The interview protocol included open-ended questions. The open-ended questions provided the means to explore students' thinking about their learning. Sample questions included "How would you describe your process?" The purpose for this question was to understand how students thought about the design of their product (ABET student outcome [c]), problem solving (ABET student outcome [e]), and experimentation processes (ABET student outcome [b]). We did not specifically prompt them to consider these processes because we were looking to understand the critical learning processes for students as they experienced and reflected upon their own learning (Rossman & Rallis, 2012). Another question was: "How often would you say that you use things that you learn in your classes?" The purpose for this question was to understand how students were linking their technical knowledge and skills, ABET student outcome (a) with the other technical skills (ABET student outcomes b, c, e, and k).

Interviews were transcribed. We examined the response processes for each of these codes by examining the students' descriptions of their experiences within the competitions and their reflections about those experiences. We coded using the ABET student outcomes a, b, c, e, and k as a priori, elemental codes (Saldana, 2016). In our initial readings of the interview transcriptions students often described multiple processes and outcomes resulting from their experiences within the same unit of discussion. Therefore, we also investigated the interactive nature among the technical outcomes. To ensure that our coding was accurate, we applied constant comparative analysis (Corbin & Strauss, 2015). In addition, two researchers examined the data and codes were compared. For differences, we reached consensus on the coding.

Results. Preliminary Results indicated the incidence of learning outcomes associated with each of the ABET (2013) student technical skills. The incidence of discussion of each of the technical skills out of the 744 statements made about technical skills is shown in Figure 1. Percent of Student Reported Learning Outcomes for each ABET (2013) Technical Skill.

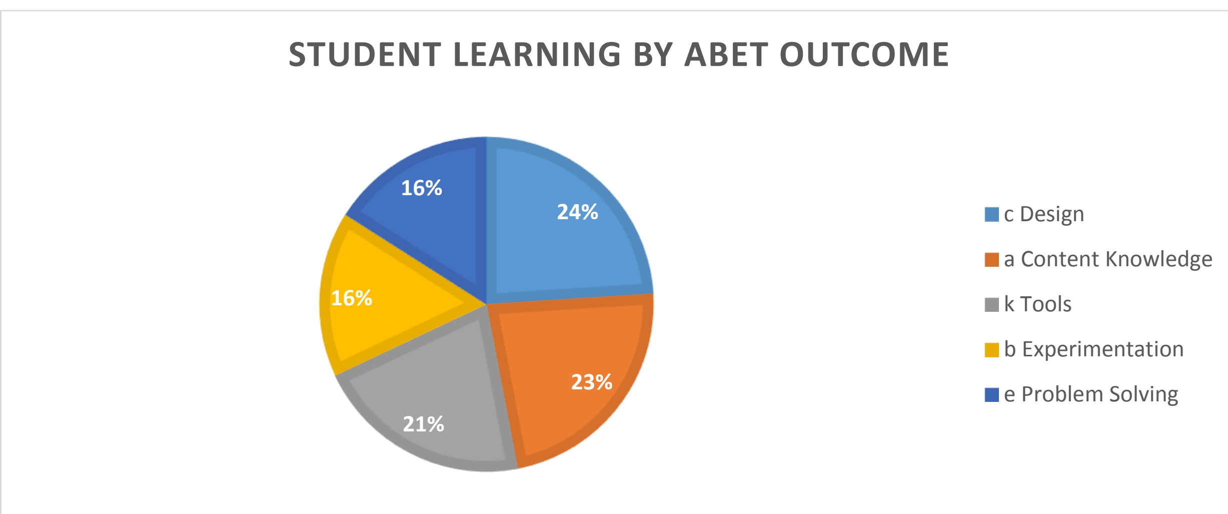

Figure 1. Percent of Student Reported Learning Outcomes for each ABET (2013) Technical Skill.

Discourse about ABET student outcome (c), which is about designing systems, components, or processes, had the highest percent of responses (24%). The responses focused on the nature of the team's or an individual's thinking related to the design of the final product in order to perform well. A student explained:

> We each sorta came up with our own ideas, and sorta presented them to our group 'cause everyone had an idea. …we took what was essentially what we thought was best from each design… we took the one that …uses two of the given motors, two of the given wheels. We're 3d printing a ball and socket, acting as a wheel. And a small chassis, about 3-5 inches.

Discourse about ABET student outcome (a), which is applying math, science, and engineering content knowledge, had the next highest percent of responses (23%). The responses generally addressed learning new material to complete the competition. For example, one student stated: "[This helped me] just to understand how the different electrical and electronic components integrate together, and about mechatronics and design."

Discourse about ABET student outcome (k), which is about the use of engineering tools, skills, and techniques represented 21% of the responses. The first group of responses focused on either the 3-d printing as a design, visualization, and experimentation tool or discussion of the competition kit itself. A second group of responses typically focused on the use of software tools, primarily CAD and MATLAB. The third group of responses focused on a physical element that would assist with construction or experimentation related to the final product, such as an arduino or type of circuit.

Discourse about ABET student outcome (b), experimentation, and (e), problem solving, each represented 16% of the discussion. Students did not use the word "experiment" to describe their process. Rather, students discussed "trying out" their ideas:

> "I did look a little bit into [their] designs. But it's hard … [be]cause I haven't been on their design process the entire time, and I think completely different to how they think. I'm a bit more iterative, and they're more deliberate, they go all the way into their design. But I have access to a 3d printer, and cad stuff. …When I have a new idea for a … design, I just print it out, and [think,] "Oh, this doesn't work." And, [so] I made this change and I try again."

ABET student outcome (e), identifying, formulating, and solving engineering problems, addressed how students figured out an issue. Some discussion focused on problem-solving related to the process of doing the work. For example, one student stated, "Our biggest problem was we didn't know when we were going to prototype or when we were going to actually start testing." Another student focused on problem solving related to the product: "… giving us the kit of parts… really helped us find more accurate dimensions. We could actually take a pair of calipers to it and we would know that it would fit." Problem formulation was discussed with framing experimentation as trial and error. For example, one student stated:

"So, we were designing the arms, we started with 'oh let's start with a solid beam – you know, what happens as the moment, the internal moment is increased along the distance of the arm, and stuff like that?' Once we had the overall shape of something, then we let inventor do all the math, like oh this needs to be this far from this thing and this thing."

Some of the previous examples about experimentation and problem solving indicated that many of the student outcomes were inter-related across the ABET criteria, and that students thought of them as inter-related. Students' reflections often integrated their learning processes across the ABET technical skills. See Figure 2. Percent of Integrated Processing about Technical ABET (2013) Technical Outcomes.

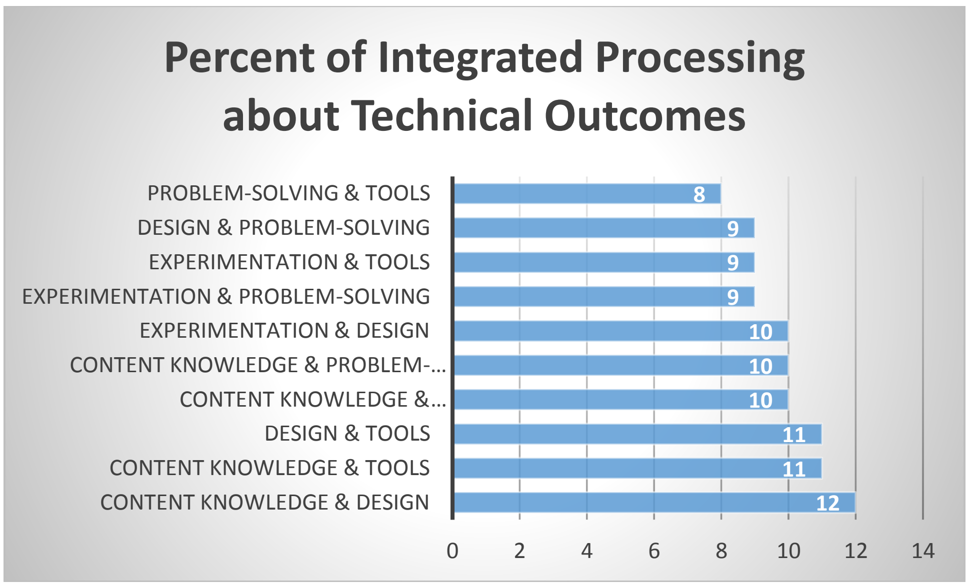

Figure 2. Percent of Integrated Processing about ABET (2013) Technical Outcomes.

Discussion. This study provided evidence of student learning across the ABET technical skills within the context of an engineering competition. The study adds to the growing body of research examining learning in informal environments. We found that the most discussed student outcome within this competition was design. Importantly, the students were often unable to talk about any one technical outcome without discussing another outcome within the same unit of discussion. This indicates that students understand the integrated nature of design, problem solving, and product development within engineering. This is an important finding when considering how to assess students and provide them credit for complex performances. Results indicated that students understood the need for adaptation and evaluation to solve a problem (Walker, Cordray, King, & Brophy, 2006; Zimmerman, 2002), which potentially extends assessment of outcomes from competitions, and possibly other informal learning activities beyond the ABET standards. Examining the student responses processes allowed us to empirically identify how students think about their learning within a competition. This method could be used to examine student learning within other types of informal learning environments in engineering. Response processes represent a promising method that can be used for assessment development.

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