# Applying Psychometric Theory to the Examination of Learning within Informal Engineering Learning Environments

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## Abstract

Learning occurs in formal and informal environments across the lifespan. Informal learning has becoming increasingly present within engineering students' experiences as co-curricular opportunities. Multiple positive outcomes have been reported by students related to technical and professional skills, beliefs, attitudes, and executive control functions. Identifying methods to assess these outcomes has been difficult. The variety across informal learning environments related to the voluntary nature and structure leads to complexity in assessing outcomes. Determining the nature or extent of student learning in informal engineering environments has largely relied on self-report. It is important to examine assessment of outcomes from a psychometric perspective to ensure that decisions based on the data from the measures are valid and reliable. The purposes for this work-in-progress paper are to: (a) describe the process to develop a measure of student outcomes from informal learning environments in engineering, such as engineering competitions; and (b) if available, report the results of a pilot study.

## Keywords

Informal learning, co-curricular, outcomes assessment, professional skills, test development

## Introduction

Learning occurs in formal and informal environments across the lifespan. Multiple disciplines have obtained empirical evidence of learning and non-cognitive outcomes, such as self-regulation or improved skills, resulting from participation in informal learning environments across educational, workplace, and life experiences[1,2,3]. In engineering informal learning opportunities take many forms, such as engineering clubs or maker spaces, engineering competitions, or service learning projects. Numerous studies have reported multiple types of outcomes for participants in informal engineering environments, and include but are certainly not limited to autonomy or metacognition[4,5]. Thus, both academic learning outcomes and non-cognitive outcomes have resulted from informal engineering environments. Identifying methods to assess the learning processes associated with the outcomes and the actual outcomes has been difficult because informal learning environments are complex.

The voluntary nature, structure, and complexity of informal environments leads to complexity in assessing outcomes. Therefore, research about the assessment of informal learning in engineering education is nascent[6]. Determining the nature or extent of student learning in informal engineering environments has largely relied on self-report. As students may desire credit for experiences learned outside of the formal curricula, assessment of informal learning has been increasingly discussed, such as by earning micro-credentials or badges[7]. When higher stakes are considered, such as providing credentials, it is important to examine assessment grounded in standard psychometric practices. The purposes for this work-in-progress paper are to: (a) describe the test development process to develop a measure of student outcomes acquired during informal learning environments in engineering, such as engineering competitions; (b) potentially report the results of a pilot study.

## Methods

This study was grounded in a psychometric development process based on the *Standards for Educational and Psychological Testing*[8]. In this methods section, I discuss the first two parts to this study because each part contributed to validation evidence. The first part of the study focused on evidence derived from response processes and the second part focused on item development and initial content validation.

## Participants

Data were collected from undergraduate engineering students in a large public university in the southeast U.S. with a highly subscribed and ranked engineering program, with more than 10 engineering majors and a high volume and variety of informal learning opportunities for engineering students. Students participating in a two engineering competitions were invited to participate in the study. Forty students were included in this study. Eighteen students participated in the IAM3D competition. Twenty-two students participated in from Formula SAE. Six of the students were female. The other study participants were white males. Various engineering disciplines and years in the undergraduate program were represented.

**Examining Response Processes.** One type of validity evidence is evidence based on assessee response processes[8]. Within the assessment of a construct, such as professional responsibilities, assessors make assumptions about the cognitive processes in which assessee's engage during the learning and assessment activities. Both theoretical and empirical analyses of assessee response processes offer evidence that the theoretical construct was operationalized in line with the in-depth characteristics of the performance. Evidence based on response processes has been typically applied within the context of multiple-choice test items or essays. Examinees are asked about the strategies they used during testing to respond to a given item or essay. The purposes for this line of questioning were to: (a) develop a rich definition of the construct assessed; and (b) ensure that the expected construct is enacted via examinee processes.

**Data Collection and Analysis.** The first part of this study was qualitative and was reported elsewhere[9]. The methods and results are summarized here to demonstrate the reasoning related to the assessment development process. Data were collected via ten focus groups. Sample questions included: "How would you describe your process?" "What would you want your engineering professors to know about your experience?" Data were coded initially based on the ABET[11] student outcomes. We used descriptive statistics to identify the frequency of each of the ABET outcomes. Based on the results, we mapped out the terrain of student processes and outcomes. We found that students discussed their understandings of professional responsibility most often (40%)[9]. Therefore, we further analyzed student statements about professional responsibility. We identified several more specific themes. We grouped the themes into three categories: Selfmanagement, Task Management, and Team Management. We, then, organized these categories as a Framework of Professional Responsibilities (FPR)[9].

For this paper, we focused on the Task Management category. Task Management addressed the skills the students needed to organize and complete the tasks within the competition. These skills included: setting goals, analyzing tasks, analyzing constraints, seeking help, actively learning new skills and information, and executing tasks.

**Developing Assessment Content.** In this study, we focused on developing a measure of task analysis. We selected task analysis because it was the most important to students when discussing the informal learning activity, representing 38% of the total discussion within the Task Management category. We used the definitions and descriptions of the components of task analysis from the FPR[9] to develop a blueprint and items to measure task analysis.

Currently assessment of informal learning environments relies on student self-report data to identify student outcomes from these experiences. However, self-report data are subject to multiple problems[14,15]. Therefore, the purpose for this study was to compare different item types to identify those types of items that might yield self-report data with fewer sources of bias. Three item types were written: (a) traditional self-report items; (b) items with anchoring vignettes; and (c) situational judgment items. Each of these item types will be pilot tested. This work is still in progress, and the paper will be updated as data are collected.

The co-curricular activity acted as the assessment of student processes and outcomes. This study adapted the response process validation method[8] to engage in dialogue with the examinees about the strategies they used during their performance across task completion for the co-curricular learning opportunity. Instead of asking examinees to discuss their responses to answer a multiple-choice test item, examinees were asked to describe the processes and their performance to develop a rich definition of the constructs, resulting in the FPR. Thus, the data from the first study were used to enrich our understanding of how students thought about and enacted professional responsibilities within the informal learning environment.

## References


1 Carberry, Adam, Hee-Sun Lee, and Christopher Swan, "Student Perceptions of Engineering Service Experiences as a Source of Learning Technical and Professional Skills, International Journal for Service Learning in Engineering, 2013, 1-17.

2 Dabbaugh, Nada and Anastasia Kitsantas, "Personal Learning Environments, Social Media, and Self-regulated Learning: A Natural Formula for Connecting Formal and Informal Learning," Internet and Higher Education, 2012, 3-8.

3 Swanick, Tim, "Informal Learning in Postgraduate Medical Education: From Cognitivism to Culturism," Medical Education, 2005, 859-865.

4 Kusano, Stephanie & Aditya Johri, "Student Autonomy: Implications of Design-based Informal Learning Experiences in Engineering," Proceedings of the 121st ASEE Annual Conference & Exhibition, Indianapolis, 2014, 24.1110.1-24.1110.12.

5 Lemons, Gay, Adam Carberry, Chris Swan, & Linda Jarvin, "The Effects of Service-Based Learning on Meta-Cognitive Strategies During an Engineering Design Task," International Journal for Service Learning in Engineering, 2011, 1-18.

6 Johri, Aditya, Barbara Olds, and Kevin O'Connor, "Situative Frameworks for Engineering Learning Research," In Barbara Olds and Aditya Johri (Eds.), Cambridge Handbook of Engineering Education Research, New York: Cambridge University Press, 2014, pp. 47-66.
7 Ifenthaler, Dirk, Nicole Bellin-Mularski, & Dana-Kristen Mah, "Foundation of Digital Badges and Micro-Credentials: Demonstrating and Recognizing Knowledge and Competencies," 2016, Springer, NY.
8 American Psychological Association (APA), American Educational Research Association, & National Council on Measurement in Education, "Standards for Educational and Psychological Testing," APA, Washington, DC, 2014.
9 Bland, Lori, Aditya Johri, Stephanie Kusano, & Xingya Xu, "Engineering Competitions as Pathways to Development of Professional Engineering Skills," Proceedings of the 2016 ASEE Annual Conference & Exhibition, New Orleans, 2016, 26629.
10 Ryan, Katherine E., Tysza Gandha, Michael J. Culbertson, & Crystal Carlson, "Focus Group Evidence: Implications for Design and Analysis," American Journal of Evaluation, 2013, 328-345.
11 Accreditation Board for Engineering and Technology (ABET)/Engineering Accreditation Commission (EAC). "Criteria for accrediting engineering programs," 2013.
12 Colaizzi, P. "Psychological Research as the Phenomenologist Views It." In: Valle, R.S., & King, M. (Eds.). Existential phenomenological alternatives for psychology New York: Oxford University Press, 1978, 48-71.
13 van Manen, Max, "Phenomenology of Practice," Walnut Creek, CA: Left Coast Press, 2014.
14 Vispoel, Walter & Ellen Forte Fast, "Response Biases and Their Relation to Sex Differences in Multiple Domains of Self-Concept," Applied Measurement in Education, 2002, 79-97.
15 Hamby, Tyler, & Wyn Taylor, "Survey Satisficing Inflates Reliability and Validity Measures: An Experimental Comparison of College and Amazon Mechanical Turk Samples," Educational and Psychological Measurement, 2016, 912-932.

## Biographical Data

Lori C. Bland, Ph.D., is an associate professor focusing on assessment, program evaluation, data-driven decision-making, and research methods at George Mason University. I am currently conducting research, as co-PI on a NSF EEC grant, to develop and validate of measures of technical and professional skills acquired in informal learning environments in engineering education. I am also examining the data derived from online STEM maker communities to assess learner-driven constructs, those constructs in which learners are agentive in informal environments. I am an evaluator on a NSF WIDER grant investigating faculty use of interactive teaching strategies in STEM graduate and undergraduate education.