Board 159: Developing An Assessment Toolkit for Pre-college Summer Engineering Workshops (Works-in-Progress)

Dr. Tamecia R. Jones, North Carolina State University at Raleigh

Tamecia Jones is an assistant professor in the STEM Education Department at North Carolina State University College of Education with a research focus on K-12 engineering education, assessment, and informal and formal learning environments.

Dr. Leah Bug, North Carolina State University at Raleigh

Dr. Leah Bug has over 35 years of experience teaching both formal and informal K-20 STEM education, with over 20 years in designing and providing teacher professional development.

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Abstract

Many universities have engineering outreach programming that expose students to engineering that include day camps, overnight camps, and multi-week programs. As the projects occur over hours, days, or weeks, rich content is delivered in a very abbreviated timeframe. Often only anecdotal evidence or evaluative surveys reflect what students' experience. This works-in-progress project describes the strategic plan and first stage towards development of tools for assessing engineering learning in weekly summer experiences across the precollege continuum for outreach programming at North Carolina State University. These tools will investigate development of engineering habits of mind, perceptions, self-efficacy, acquired disciplinary knowledge, and other making skills. This work has broader impact of training other universities how to assess informal engineering summer programs or providing guidelines for faculty who do precollege engineering outreach.

Introduction

Some universities have large K12 engineering outreach programming that includes afterschool, weekend, and summer programming. As summer programming requires huge administrative and program delivery demands, staff in outreach offices must prioritize curriculum development, teacher training, community building, and camp administration. Evaluation is conducted, but there may not be as many dedicated research goals related to learning because of the person power necessary for day-to-day operations. It truly is a missed opportunity as often engineering faculty are developing projects for elementary, middle, and high school students, and their content knowledge offers unique experiences that students might not get in traditional formal classrooms. There is an expectation that engineering skills are developed and conceptual knowledge is acquired, but engineering faculty do not assess the K12 students the same way they would traditionally assess undergraduates. Utilizing the summer camp program at North Carolina State University, we aim to develop tools for assessing engineering learning in weekly summer engineering experiences.

North Carolina State University's College of Engineering's (with 18 engineering majors) K12 outreach office, The Engineering Place, offers approximately twenty-five 1-week long summer engineering programs for rising kindergarten through twelve grade students. The rising 11^{th} and 12^{th} graders attend residential camp during their week, living in student dorms and experiencing life on a college campus. It is within this context the research will be conducted.

Theoretical Frameworks for Tools

A literature review identified resources to guide the development of the assessment tool kit. These theoretical frameworks are research-based in engineering conceptual learning, socioemotional learning, and EHoM. To assess the engineering knowledge gained in challenges, we will create assessments that are inspired by and adapted from concept inventories in

mechanical engineering [2, 3], structural and civil engineering [4-6], chemical engineering [2, 3, 7, 8], electrical engineering [9, 10], structural and civil engineering [4-6], materials engineering [11, 12], and physics [13] and chemistry [14, 15]. To assess perceptions, we will take current findings from recent literature on engineering perceptions in first year students, marginalized students, and girls [16-19].

We understand that socioemotional learning may be harder to assess from a weeklong experience, but we have created a literature base with which to inform our evaluations and student surveys. These findings will also influence the changes to applications for incoming and returning students. We know that engineering identity in precollege is still being heavily studied, but we have gathered instruments and literature to integrate into our programming, mantras, and pedagogical methods. We will find the appropriate aspects to assess based on the developmental stages of the students [20-28]. The research team will be taking current instruments and findings from research with undergrads and high school students to identify which aspects of its programming aligns with increasing and improving self-efficacy [29-34]. The engineering outreach subscribes to the EHoM [35] [36] [37] [38] [39] and integrates systems thinking, problem-finding, visualizing, improving, creative problem-solving, and adapting.

Opportunities, Priorities, and 10-year Strategic Plan

The Summer Engineering Camp program has amassed over 500 challenges since 1999. This collection encompasses engineering disciplines and processes expressed in projects. Each grade level band (K-2, 3-5, 6-8, 9/10, and 11/12) participates in engineering challenges, and many are related to the Grand Challenges or NC State engineering faculty's research. The curriculum highlights engineering habits of mind, the engineering design process, and has one or more design challenges each week. Table 1 shows the typical camp week content by grade band.

Grade Band	K-2	3-5	6-8	9/10	11/12
Habits of Mind	x	x	x	x	x
Engineering Design Process	X	X	X	X	X
Engineering Challenges	5	5	5	5 Mini + 1 Large	Disciplinary Challenge
				Lab Tour	Lab Tour

Table 1 Curricular priorities for grade bands

The outreach program aims to investigate the efficacy of its curricula and impact on student's engineering perceptions and learning, partnering with engineering education research team to expand the assessment tools for the program. The team created a five-year plan for creating an assessment toolkit. The strategic plan is described in Figure 1 and its timeline is Table 3.

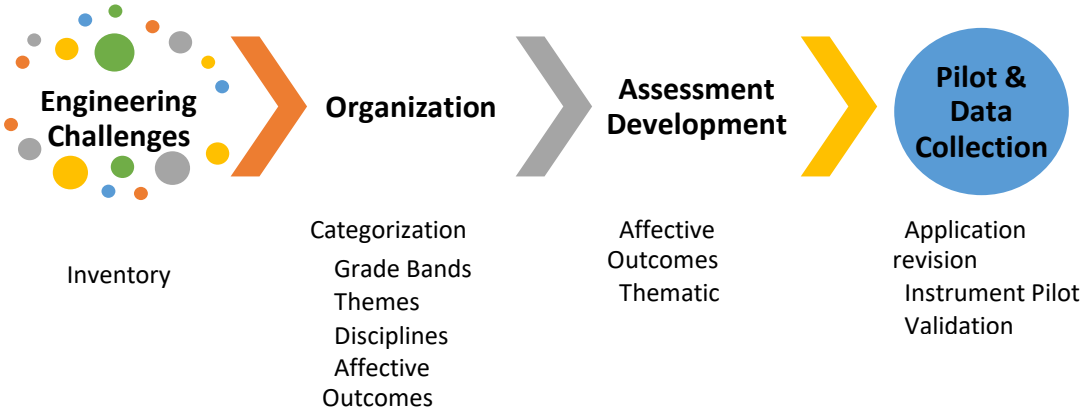

Figure 1. Overall Assessment Strategic Plan for K12 Summer Informal Engineering Programming

This is an expected 10-year process with two stages. Stage 1 involves assessment development and Stage 2 is assessment validation and revision. The five-year plan (Stage 1) prioritizes kindergarten through 2nd grade (K-2) challenges, identity, and engineering habits of mind (EHoM). The rationale for this prioritization is to begin assessment as students enter the pathway and have the potential to collect longitudinal data if students attend multiple summers. The second priority is developing assessments for the residential high school challenges and engineering perceptions. The rationale for this is to (1) assess the longer engineering challenges that are more intensive and utilize technical equipment and (2) capture high school campers engineering perceptions. We prioritize engineering perceptions in year 2 because we aim to assess these changes over time. With this strategy, we will have created tools to capture programming entrance and exit data. The third priority would be 3rd-5th grade challenges, fourth priority is 6th-8th grade challenges, and concludes with the 9th-10th challenges. We will analyze the camp application baseline and demographic data, and revise applications to capture longitudinal data of returning students. After assessments are developed, the next 5 years will include validation and revision in Stage 2 (Table 3).

Activity	*Year*									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Application Revision										
Assessment Development										
K-2 Challenges										
Engineering Habits of Mind										
Identity										
Residential HS Challenges										
Engineering Perceptions										
3-5 Challenges										
6-8 Challenges										
9-10 Challenges										
Assessment Validation and Revision										

Table 3 10 year plan for assessment development

Strategic Plan Progress: Inventory

First, an inventory of the engineering challenges was needed. We conducted the inventory of engineering camp challenges, resulting in 160 engineering challenges. The challenges were organized into themes, skills, engineering disciplines, and socioemotional learning priorities. These categories and subcategories are shown below (Table 2) with the number of challenges affiliated with each subcategory.

Inventory of Engineering Challenges			
Themes	**Skills**	**Engineering Disciplines**	**Socioemotional Learning**
Water (9) Vehicles (8) Sound (5) Solar (6) Furniture (3) Food (5) Eggs (13) Magnets (1) Math (1) Miscellaneous (6) Energy (5)	Processes (4) Skills (4) Engineering Design Process	Biological (7) Biomedical (5) Electrical (11) Computer (5) Chemical & Material (15) Civil and Structural (6) Aerospace & Aeronautical (16) Nuclear (3) Packaging (4) Mechanical (10) Environmental (5)	**E**ngineering **H**abits of **M**ind Self-efficacy Identity
62	**8**	**87**	**3**

Table 2 Inventory of Engineering Challenges

Strategic Plan Progress: Organization

The initial review of the challenges revealed that some challenges are related and overlap across categories or disciplines, so we will need to categorize them further and add tags and grade designations to challenges within themes. We will conduct a content analysis [1] of the whole collection of challenges.

Second, the team plans to organize the engineering challenges by grade band, themes, discipline, and affective outcomes. Third, assessments will be developed in three ways: by engineering discipline and grade band, by connecting themes to disciplines, and to measure affective outcomes. Finally, the research team will pilot the instruments in summer camps over five years to validate and refine them.

Strategic Plan Assessment Development Methods

The research team is planning a suite of assessment tools. These include surveys, interviews, rubrics, and an online learning community with a website for extended engagement with timed quizzes. We have searched for current tools used in undergraduate engineering education and high school and will adapt the existing rubrics. We will use self- and peer-assessment for EHoM as we develop reflection and observation tools.

For each discipline and theme, we will identify the concepts using concept inventories and content analysis. Then we will connect EHoM to each challenge. Figure 2 shows a first iteration at the analysis of the nuclear engineering disciplinary challenges across grade bands.

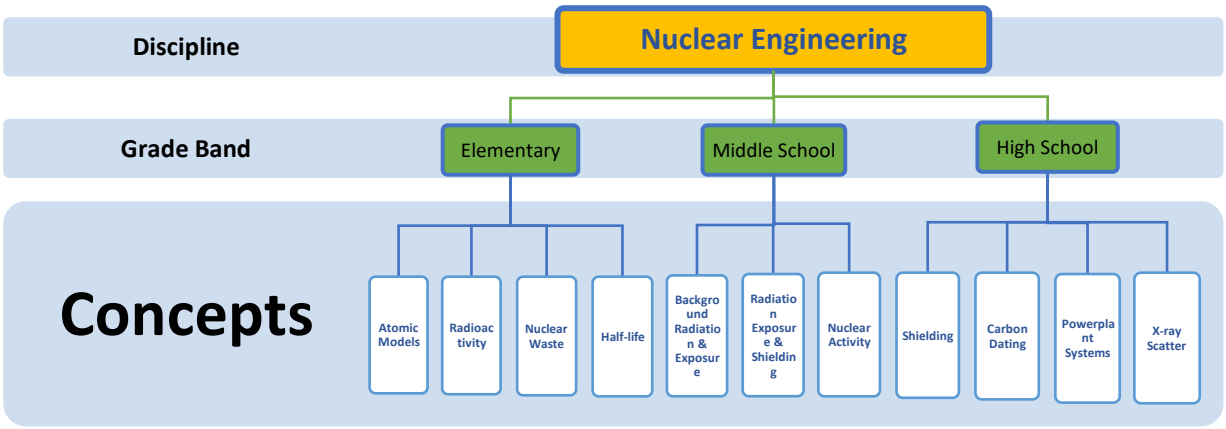

Figure 2 Example of Nuclear Engineering Discipline Conceptual Map

After alignment of the concepts, skills, and EHoM we will develop questions to be put into mini quizzes for each camp. These mini quizzes (1-2 minutes) will be embedded in a website that campers can visit throughout the summer and academic year. The quizzes will be timed with rundown clocks to make it into a game and decrease researching cutting and pasting. The research team will also generate prompts that will be sent out in daily reflective interviews to parents and students.

Next Steps / Continued Work

As we have established a literature base and completed the initial inventory, the next steps are to finish inventorying the challenges until all challenges are tagged and cross-referenced. We will continue the content analysis of challenges by engineering discipline and grade band, connecting themes to disciplines, and measuring affective outcomes. We will also continue developing the technology infrastructure to capture audio and video assessment data from interviews and in-class recordings. Since the summer programming year is beginning this June, we will begin with the K-2 challenges for this calendar year and develop initial identity questions. We have an average of 75 students each week for the weeklong camps and will pilot assessments for each week. Our first set of collected assessment data will conclude summer 2023. We will analyze data in the fall and revise existing instruments and applications. Then from October to January we will develop assessments for the rest of the K-2 challenges. We will develop assessments on a quarterly schedule until we have a full suite of assessment tools.

Resources

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