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Impact of Makerspaces on Student Idea Generation, Self-Efficacy and More: Results of a Five-year Longitudinal Study

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As a member of the Integrated STEM Education Research Center (ISERC) at LaTech, Ethan's primary research area is engineering design education with a focus on developing prototyping skills through both class-based projects and extra-curricular clubs, competitions, and activities. This includes a focus on hand-drawn sketches and how they are used as tools for generating ideas and visual communication, especially when it involves the skill to generate quick and realistic sketches of an object or idea. He has also conducted research on the impact involvement in academic makerspaces has on students in engineering programs.

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Dr. Julie S. Linsey is an Associate Professor in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technological. Dr. Linsey received her Ph.D. in Mechanical Engineering at The University of Texas. Her research area is design cognition including systematic methods and tools for innovative design with a particular focus on concept generation and design-by-analogy. Her research seeks to understand designers' cognitive processes with the goal of creating better tools and approaches to enhance engineering design. She has authored over 150 technical publications including over forty journal papers, and ten book chapters.

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Introduction

Makerspaces are community learning spaces for students and faculty to solve engineering related problems. For students specifically, makerspaces provide opportunities for hands-on experience in problem solving, design, prototyping, and manufacturing. Given the collaborative-learning nature of makerspaces, and how prevalently they're used by students, the question posed is how does makerspace involvement impact student performance. In this longitudinal study, student performance is qualified by experimental measurements of idea generation ability and engineering design self-efficacy (EDSE).

Method

The data presented here is a part of a 5-year longitudinal study (removed). In this paper we focus impact to idea generation. The participants of this study were freshman and senior undergraduate students from mechanical engineering design courses. Freshmen and seniors were chosen specifically to compare the effect of makerspace exposure at the start of the curriculum and the end of the curriculum. The generalized experimental setting was a research-focused ABET accredited university in the Southeastern United States. The makerspace is student-run, has operated for over a decade, and is open to all students. Participants who reported makerspace involvement referenced the aforementioned makerspace the most.

Idea generation data collection used four problem statements as instruments. These statements were the following: "Device to Shell Peanuts", "Device to Aid in Shucking Corn", "Device to Ain in Coconut Harvesting", and "Personal Alarm Clock". Freshman data included data from all four statements while Senior data focused on "Device to Shell Peanuts" because continued research shows the Peanut Sheller problem to be comparable to the Corn Shucking and the Peanut Sheller continues to be a problem well-understood by students with many solutions in the mechanical engineering domain. Makerspaces likely enhance engineering idea generation ability by exposing students to a wide range of design ideas. Idea generation ability was measured by Shah's metrics of idea generation effectiveness (Shah, Kulkarni et al. 2000, Shah, Smith et al. 2003). These metrics were modified with an approach developed by Linsey et al. (Linsey, Murphy et al. 2006, Linsey, Wood et al. 2008, Levy 2017) to score participants' solution sketches for the given design problem.

In addition to this, a separate survey instrument gathered self-reported data concerning makerspace involvement, engineering design self-efficacy (EDSE), and demographic information. Makerspace involvement denoted three categories of involvement due to prior work by (removed).: no involvement (students who reported never using anu makerspaces or their equipment), class-only involvement (students who reported using makerspace equipment only for required course projects), and voluntary involvement (students who reported using makerspace equipment for anything beyond class projects, I.e., personal, club/organization, or research related topics). The instrument specific to measuring EDSE, developed by Carberry et al. (Carberry, Lee et al. 2010), collected self-reported data concerning students' confidence, motivation, expectation of success, and anxiety relative to engineering design. Makerspace involvement are gauged from responses to a survey instrument developed in prior work from (removed).

In order to illustrate students' abilities at the start and finish of the undergraduate engineering curriculum, and therefore in order to accurately measure the impact of makerspace, strategic data collection points were chosen. These collection points were freshman-level introduction to engineering graphics (CAD) and senior-level capstone design courses. The experiment required that participants work individually to provide idea generation solutions. During the idea generation portion of the experiment, participants were instructed to sketch and label as many design solutions as possible within forty-five minutes. Instructions included participants limiting idea generation solutions to one sketch per page in order to make data processing easier.

Results

EDSE scores and the quantity, quality, novelty and variety of solutions generated by freshman and seniors was analyzed along with their makerspace involvement. As expected, Seniors show increased EDSE scores including increased confidence for design, motivation to do design, and increased expectation of success with decreased anxiety about design tasks as compared to freshman (Figure 1). T-tests were used to statistically compare the data (Confidence $t(58) = -2.28$, $p=0.013$; Expectation of Success $t(55) = -3.119$, $p=0.014$; Anxiety $t(57) = 1.529$, $p=0.066$).

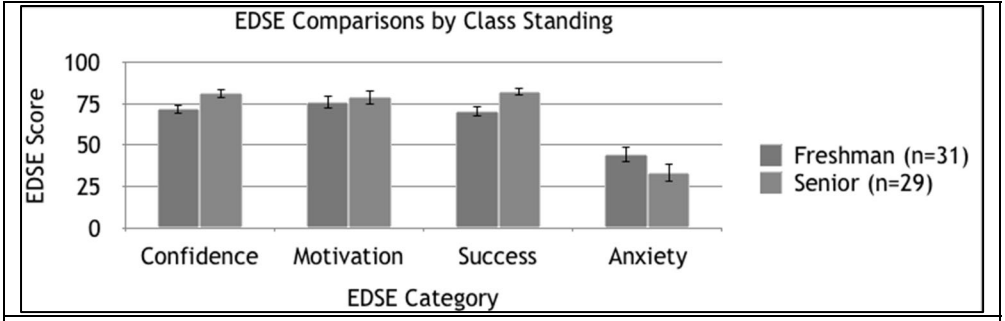

Figure 1: Seniors have increased confidence, motivation, expectation of success and decreased anxiety about design tasks as compared to freshman.

Seniors showed higher quality scores with respect to frequency of makerspace use, time spent in makerspaces, number of makerspace projects involved in, involvement level (voluntary vs. class-only), and co-op/internship experience Figure 2.

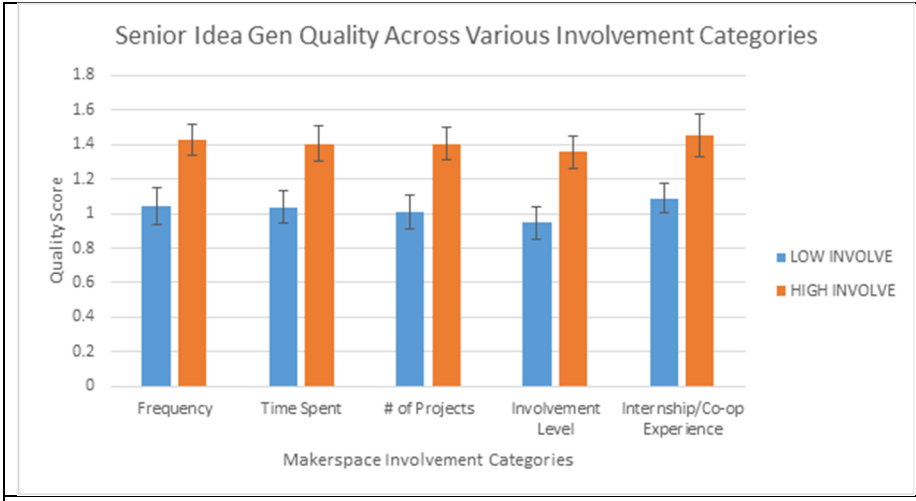

Figure 2: Seniors with greater makerspace involvement tend to produce higher quality ideas. Makerspace involvement

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