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BCSER Understanding how Making contributes to student self-efficacy across multiple disciplines

Dr. Erin Henslee, Wake Forest University

Dr. Erin Henslee is a Founding Faculty and Associate Professor of Engineering at Wake Forest University. Her research spans biomedical engineering, STEM education, and Makerspace pedagogy. Prior to joining Wake Forest, she was a Researcher Development Officer at the University of Surrey where she supported Early Career Researchers working in the area of inclusive researcher development. She has taught over 20 different engineering courses across a variety of institutions and departments.

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Introduction

This work was part of an NSF Building Capacity in STEM Education Research (BCSER) funded project aimed at investigating Making and student learning. Specifically, how/if Making contributes to student self-efficacy and character development across multiple STEM disciplines and student identities. Current literature supports the value of implementing Making pedagogies to improve student outcomes [1-4]. Empirical evidence supports the value of implementing Maker-learning pedagogies (MLPs) in K-12 and higher education STEM classrooms – from the positive impacts on student learning [5]. However, disciplinary differences, minority social identities, and the ways in which Making is implemented may all have compounding effects that could ultimately lead to inequitable, and in some cases, negative outcomes [4-9]. Some recent work in K-12 Makerspaces has shown gender gaps in self-efficacy gains, as well as inequitable gains in belonging across racial groups [8]. Making as a pedagogical tool offers a unique opportunity to bring several dimensions of active learning pedagogies together, such as problem-based learning, peer teaching, and project-based learning together, however more research into the frameworks, methods, benefits (and challenges) of these practices, especially as they pertain to students with social minority identities, is needed [8-10].

While the literature into the use of Makerspaces has increased over the last decade, Making pedagogies are still an understudied area [8-10], particularly with respect to higher education and when used as a pedagogical tool in a formal classroom setting. This project sought to understand how student learning and efficacy outcomes were impacted by engaging with Making-based activities, with a future goal to understand how these outcomes may vary across disciplines and student social identities. This pilot study aimed to develop an assessment strategy that included quantitative data from a survey instrument, interview protocols, and establish a method of data collection appropriate across disciplines and Making activities.

Summary of Grant Activities

The grant PI invited faculty across the college of arts and sciences to participate in a summer course development cohort to design and plan implementation and assessment of their Making pedagogical approach(es). The faculty development activities of this project are described in a separate paper. Eight different courses that faculty committed to incorporating a central Making activity included 3 Engineering, 2 Education, 1 Math, 1 Physics, and 1 Law School classes over the course of three semesters. Making activities included final projects (with open-ended options for student choice), design challenges to achieve an end goal/task, communication projects, as well as two classes that used Making throughout the semester integrated into the course.

Students from each of the faculty cohort's courses were invited to participate in a pre-post survey aimed at informing faculty (and subsequent course designs) of the following:

1. *How do Making activities contribute to student self-efficacy in their course, in their discipline, and in their character development?*
2. *What characteristics of the Making activities contribute most to student self-efficacy in these domains?*
3. *How can we better understand the relationship between psychosocial factors, such as mindset, and self-efficacy in these domains?*
4. *Are the contributions of Making on self-efficacy consistent across disciplines and under-represented student groups?*

Self-efficacy, as described by Bandura and others, was chosen to ground this work as it has been shown to have significant impacts on student recruitment, retention, and progression, particularly across underrepresented student groups [11-15]. With faculty cohort input, a student self-efficacy survey was developed. Along with demographics data, the survey included three distinct areas of measurement: general self-efficacy, self-efficacy in context to course outcomes, and self-efficacy with regards to growth mindset and Making [16-18]. Validation of this instrument is ongoing and part of a larger NSF-supported project. Students were invited to complete the pre-survey at the start of each semester and the post-survey at the conclusion of the course. The Likert scale (1-7) questions and categorization are shown in Table 1.

Student pre- and post- surveys were administered across eight different courses that committed to incorporating a central Making activity (including 3 Engineering, 2 Education, 1 Math, 1 Physics, and 1 Law School) over the course of three semesters. Likert-scale surveys were used to gauge overall student efficacy with the course as well as their attitudes towards Making and hands-on learning. A Likert scale of 1-7, 1–Does not describe me at all, 2– Barely describes me, 3–Somewhat describes me, 4–Neutral, 5– Generally describes me, 6–Mostly describes me, 7–Completely describes me, was used to gauge overall student efficacy with the course as well as their attitudes towards Making and hands-on learning. In addition to the surveys, interviews were conducted with 12 students across the various courses which aimed at further understanding student mindsets (previous Making experiences, attitudes towards the course, other experiences impacting their overall mindset) when engaging with the Making activities.

Summary of Results

Table 1 summarizes demographic data of the respondents. In this final iteration of the project survey instrument, 88 students completed the pre-survey and 78 completed the post-survey (Table 2). Of the respondents, 67% indicated they had previously used campus Makerspaces, 18% indicated they had never previously used any Makerspaces. 3D printing, Cricut, and Laser cutting were the top listed previously used tools used by respondents.

Table 1: Demographic data of survey participants

Race/ethnicity identity (check all that apply):	American Indian or Alaska Native	<1%	Gender Identity (open response):	Male	51%
	Asian	10%		Female	47%
	Black or African	6%		Non-Binary	<2%
	Native Hawaiian or Other Pacific Islander	<1%	Sexual Identity/Sexual Orientation (open response):	Heterosexual	83%
	White	64%		Homosexual	4%
	Hispanic or Latino or Spanish Origin	6%		Bisexual	8%
	More than 1 listed	13%		Pansexual	<3%
			Do you identify as a person with a disability (open response)?	Yes	97%
				No	3%

*Table 2: Average results for the pre- and post- survey. Green highlighted rows are improved post means, while orange are decreased (based on the question structure) post means. *indicates if a result was statistically significant using independent t-tests.*

		Pre-Data Average (n=88)	Post-Data Average (n=78)
Course-related Efficacy and Attitudes	I'm certain I can understand the most difficult material presented in the readings for this course.	5.29	5.56*
	I'm confident I can learn the basic concepts taught in this course.	6.15	6.17
	I'm confident I can understand the most complex material presented by the instructor in this course.	5.48	5.42
	I'm certain I can master the skills being taught in this class.	5.52	5.64*
	Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.	5.79	5.66*
Growth Mindset Efficacy and Attitudes	I am confident in my ability to work on a problem until I find the best solution.	5.88	5.86
	If I get stuck on a problem on my first try, I usually try to figure out a different way that works.	5.83	5.87
	Working with other students gives me more confidence to solve problems.	5.49	5.52
	After I study a topic and feel that I understand it, I have difficulty solving problems on the same topic.	3.42	3.05*
	If I get stuck on a problem, there is no chance I'll figure it out on my own.	2.62	2.53
	I am confident I could explain the course concepts to another student.	5.20	5.21
	I view challenging situations as an opportunity to grow and learn.	5.81	5.79
	I seek out situations where it is likely that I will have to think in depth about something.	5.27	5.54*
	I enjoy learning about subjects that are unfamiliar to me.	5.58	5.68
	I find it fascinating to learn new information.	6.09	6.19
	I can spend hours on a single problem because I just can't rest without knowing the answer.	4.60	4.74
	I feel frustrated if I can't figure out the solution to a problem, so I work even harder to solve it.	5.17	5.12
	I am not satisfied until I understand why something works the way it does.	5.40	5.36
Making Efficacy and Attitudes	I enjoy hands-on/Making activities (i.e. building, DIY, creating etc).	5.97	5.90
	I find hands-on/Making activities frustrating to the point I do not enjoy them.	2.40	2.49
	I find the challenges presented by hands-on/Making activities as an opportunity to grow and learn.	5.71	5.74
	Design constraints are an enjoyable challenge in Making activities.	4.66	4.93*
	I am confident in my ability to create new and unique solutions when presented with design challenges.	5.44	5.40
	I find the most value in Making activities that relate to real-world challenges.	5.42	5.60*
	I find Making activities that require me to learn new equipment or techniques exciting.	5.69	5.81
	Hands-on/Making improves my understanding of course concepts.	5.84	5.65
	Making activities take away class time from more important things.	2.79	2.52*

Students indicated overall more confidence in being successful in the class, which is not surprising given they had completed a majority of the class (and in some cases all) at the time of the post-survey. However, there was a decrease in their belief they would do well (perhaps reflecting their final grades or attitudes about finals). Of note in survey data, and consistent across identity groups (gender, sexuality, ethnicity, disability), students indicated a decrease in their overall attitudes towards Making (finding it more frustrating, less exciting, and useful in improving their overall understanding of the course). In interviews, it was noted that the open-ended projects (i.e. students were free to choose methods and media) left students feeling more overwhelmed by the Making task and not as connected to the course learning. The lack of previous experience (which showed a slight increased presence in female students) with Makerspaces was a significant factor in students feeling more anxious than engaged in the activities. Students across all disciplines felt like the instructor did not make the link between the Making and learning outcomes clear. Students did, however, find time spent on Making more valuable when the projects related to real-world challenges. From interviews, the timing of Making activities appeared to have a larger impact on their attitudes towards Making rather than the Making project itself. When attempting to engage with an open-ended Making project (which students viewed as requiring substantial out of class time) during a busy exam period, students saw less value to their learning compared to studying time.

Conclusions and Future Directions

This work also aimed to pilot student outcomes from their Making experiences for cross-discipline analysis. After a year of review from the project advisory board and pilot implementation, we have established a survey instrument which gauges student's attitudes about their course, mindset, and Making that was successfully deployed across disciplines (STEM and non-STEM). Some key findings help us, at least anecdotally, understand how this project is impacting student learning. Crucially, it seems more effort should be spent linking the Making activities to student learning of course concepts (either in the project design or in the communication of that link to students) so students can better articulate and connect to the value of the learning experience. Further, timing of projects coinciding with exams seems to have a negative impact on student engagement, particularly for open-ended projects. This is certainly a point of discussion as the tension between hands-on, project-based learning in one class, may be at odds with traditional exam-style courses (and students' expectations).

Since response numbers were limited in this pilot study, future work, with more data will include comparing these bulk results across disciplines, student demographics, and types of Making projects. We aim to conduct exploratory factor analysis to better understand which student (or course) factors are contributing to students' positive and negative responses. In addition to this original instrument, we have developed a sense of belonging-based set of questions to add to the survey to better ascertain if space (differences/similarities between the two campus Makerspaces) contribute to student attitudes. We also aim to pair pre- and post- results to better track individual student pre- and post- results from the bulk responses. Further qualitative interviews will also be conducted to better understand students' final responses and motivations.

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