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Impact of Scaffolding ‘Making’ Assignments within Mechatronics on the Three Student Learning Outcomes of KEEN’s Entrepreneurial Mindset: Curiosity, Connections, and Creating Value

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Abstract

Scaffolding learning has been a proven technique within education. Hands-on activities that involve 'making' have also been shown to increase student engagement. Here we present a scaffolding 'making' approach used within a required, second-year mechanical engineering course that aims to advance our students' entrepreneurial mindset. Notably, time spent 'making' is integrated into every course meeting so that theoretical and 'making' skills are both developed consistently across the course timeline. The ultimate goal of the work presented here is to extract the impact that scaffold 'making' exercises have on developing the three student learning outcomes associated with KEEN's entrepreneurial mindset: curiosity, connections, and creating value. To do this assessment, we divided the students (N=73) into 2 groups based on their participation / performance in the 'making' assignments. The High Participation (HP) group (N=52) was defined as those students achieving or exceeding a mean of 96% on 'making' assignments, while the remainder (N=21) were defined as the Low Participation (LP) group. By creating this distinction, the impact of 'making' can be compared within the same course based on student relative engagement in the learning process. Beyond summative results from the students, additional data was collected via pre- and post- surveys. The pre-survey gathered information at the start of the semester on prior experiences related to the course and on student perception of self-efficacy in engineering design related to the course. The post-survey gathered information in the final week of the semester on time spent performing the assignments and again on the same student perception of self-efficacy questionnaire as the pre-survey. Using Pearson correlations, the results show that prior experiences such as number of programming courses or making / robotics / STEM activities had no statistical influence on summative scores within any of the assignments given in the course. However, comparing the two groups of students within the course, the HP group scored ~10% higher on 'non-making' assignments ($p<0.001$), ~18% higher on the final ('making') project ($p<0.001$), and ~4% higher on exams ($p=0.07$). While the latter was not statistically different, the trends were consistent. From the self-efficacy pre- and post- questionnaire, specific questions were grouped together to infer development in each of the 3 student learning outcomes. Using a Wilcoxon Signed Rank statistical analysis, the HP group was found to increase across all three components ($p<0.001$ for each) while the LP group showed no statistical differences. The conclusion of this assessment is that there exist multiple benefits to student learning via integration of 'making' activities,

ranging from demonstrated improvements in their learning to progressing their entrepreneurial mindsets. Further, if such activities are completely new to students, it does not necessarily mean that such advantages are lost if introduced via scaffolding techniques.

Introduction

A growing movement within engineering education has been to educate beyond the technical skills and foster within students the 3Cs: curiosity, connections, and creating value. These 3Cs form the primary student learning outcomes of what is referred to as the entrepreneurial mindset (EM), as defined by the Kern Entrepreneurial Engineering Network (KEEN) which presently consists of over 3500 faculty and staff across 340 institutions [1]. The goal of KEEN is to help educators within its network 'focus on one mission: To reach all their undergraduate engineering students with an EM so that they can create personal, economic, and societal value through a lifetime of meaningful work.' As such, KEEN has created a multitude of ways to train educators to incorporate EM within curricula and allow sharing of findings among its members within its online repository. While KEEN has certainly been a catalyst for growth in EM within engineering education, validated assessment tools for these techniques with respect to the 3Cs are only now starting to take form [2-3].

Within EM the 3Cs are considered to be learned behaviors, meaning that educators should aspire to guide their students to develop within these areas. Further, educators should assess if such progressions are being made so as to inform training of EM methods. Within the first student learning outcome, KEEN states that 'for engineers to succeed in a world with rapidly changing needs and tools, they need a sense of curiosity.' Examples of KEEN promoted techniques in developing curiosity have included brainstorming, question-formulation, and storytelling. Assessments have included validated tools such as those based on interpreting motivation [4] or classifications of curiosity scales [5].

Within the second student learning outcome, KEEN states that 'interdisciplinary connection-making is essential to the advancement of knowledge.' Examples of KEEN promoted techniques in developing connections have included concept mapping, problem-based learning, and innovation through bio-inspired concepts. A common assessment has been the validated tool for interpreting connectivity within concept mapping [6].

Within the third student outcome, KEEN states that 'teaching your students the importance of creating value helps redirect their mindset and motivation—leading to more impactful engineering solutions.' Examples of KEEN promoted techniques for developing 'creating value' skills have included exploring success via case studies, evaluating impact of biases, and encouraging students to define their own projects within capstone courses. However, validated tools for such assessment appear to be less known within the community.

While the 3Cs certainly have numerous educational techniques aimed at advancing each, additional assessments via validated tools would appear to be welcomed. Here we introduce the usage of an engineering design self-efficacy tool [7] as a means to assess across all 3Cs. Via modifying the wording within this questionnaire, one can tailor to specific learning aspects within a course and establish a relation to at least one of the 3Cs. Here we use this tool to assess a course that implements the combination of two best practices: 1) scaffold learning [8-11] and 2) hands-on learning [12-13] via ‘making’ assignments of increasing complexity. The aim was to extract the impact that these ‘making’ assignments have on developing students’ EM.

Methods

Teaching methods

Here we provide a brief description of the course used for the 3Cs assessment. The course, known as Mechatronics, is a required component of our Mechanical Engineering curriculum. The course content inherently requires students to make connections and integrate knowledge across the realms of mechanical, electrical, and computer science disciplines. Our version is considered unique within the curriculum in that it has each student purchase a ‘making’ kit in lieu of a textbook, as the course provides ample notes and worked examples for referencing. Within the kit is a commercial Arduino kit (Elegoo Super Starter Kit) and a custom set of other electronics that is used throughout the semester. While learning fundamental electrical engineering concepts, the students also perform hands-on activities by building basic circuits, taking of measurements, and troubleshooting exercises. From there they advance to including sensors and actuators to their Arduino microprocessor (Uno) to create circuits that are programmable in function, thereby connecting this field to their major. By using an open-source platform, teaching of the hardware and programming is readily accessible to both the instructors and students. This allows for the students to gain additional technical skills and inspiration from a wide variety of internet content and to develop the 3Cs in a hands-on manner. Using a laser cut wooden chassis included in the custom part of the kit, which is made by our Makerspace, the students ultimately scaffold their knowledge to construct a custom mobile robot. With the wide range of sensors included in the kit, the capabilities of the robot are wide-open, meaning that its objectives can be creatively changed from year to year by the instructor. For example, within this work the students created a demonstration of an automated agricultural robot using line following and depth detection. Prior years constructed sumo bots, interactive games, and drawing robots using the same kits.

Figure 1: Example of a 'making' assignment. (Table 1: see #5 Reflectance sensing, Robot Chassis, LED)

In an earlier implementation of this course, class time and assignments alternated every few weeks between theory-based circuit analysis and the hands-on applied assignments using the kits. This appeared to result in uneven progress in scaffolding student skills in both areas and fewer connections established between the two contexts. For the course implementation presented in this work, every class time was evenly split between theory work and hands-on applied, or ‘making’, assignments. Each week a theory-based assignment and a ‘making’ assignment were due with reductions in number of problems/requirements to allow students to work on both each week.

Each ‘making’ assignment introduced new concepts in coding and electrical engineering, and new mechanical equipment. See Table 1 for outline of all the ‘making’ assignments. To provide motivation and create connections to products the students were more familiar with, each ‘making’ assignment had an associated product example. These began with simple products such as a “light switch” and moved to complex concepts such as “self-parking car”. These product examples served to reinforce their understanding for the required performance of each system. Students typically began by learning some background about new electrical engineering concepts and their associated mechanical devices. To help form connections between different styles of diagrams, students were provided both electrical circuit style diagrams and the associated Fritzing (pictorial) style diagram for each circuit to be created. Students would use these diagrams to create their circuits using solderless breadboards. For each ‘making’ assignment a code outline was provided that typically required 10-20 modifications to be made in order for the system to produce the required performance. Coding of logic frameworks was scaffolded across the course beginning with simple IF statements (assignment 2) and moving to IF…ELSE statements with anywhere from three branches (assignment 3) up to five branches (assignments 7/8). Logic conditions were also scaffolded, starting with assessments of equality ==, moving to the use of inequalities >= and <=, and ending with conditions which used Booleans && to test multiple requirements. At each stage, the instructors supported student learning with large and small group discussions, diagrams, and tables. For each assignment the system was required to demonstrate specific requirements.

Table 1: Outline of all the 'making' assignments

Number	Code Concept	Code Changes	Mechanical Equipment	Electrical Concept	Measurements	Product Inspiration
1	NA	NA	Breadboard, Resistors, LEDs	Series/Parallel wiring	Voltage, Current	
2	If logic, conditions of equality	0	Buttons, LED, UNO	Open and closed circuits	Button Presses	Light Switch
3	If Else logic, conditions of greater/less than, delays	10	UNO	Serial communication	Value comparisons	User Interface
4	Analog inputs, For loops, Arrays	14	Photoresistor, LED, UNO	Variable resistance sensors	Initial calibration, Light level	Automatic Night Light
5	Analog inputs, If Else logic, conditions with AND and OR	20	Reflectance sensors, Robot Chassis, LED	Analog sensors	Threshold values for black vs white surfaces	Stud Finder
6	Libraries, function inputs, delays	18	Servos, Red Green Blue LED	Pulse Width Modification	Timed colors and movements	Baby or Pet toy
7	If Else logic, conditons with AND and OR	12	Ultrasonic sensor, Servos, Red Green Blue LED	Triggering, Ultrasonic ocsillations, sampling rate	Distance to target	Self Parking Car
8	If Else logic, conditons with AND	18	Reflectance sensors, Robot Chassis, LED	Serial communication, mechanical-electrical integration	Location of target path (black line)	Line Tracking Robot
9	Switch Case, Bit-wise signals	12	IR Receiver, Positional Servo	IR signals and receivers	Remote button press detection	Remote Control Car

A Final Project in the course focused on the ability of students to integrate the multiple systems they had created into a single mechatronic product. Within this work, the context of the Final Project was an autonomous agricultural robot capable of following prescribed paths in the "field" and differentiating between "plants" and "weeds" (wooden blocks of different dimensions) and then correctly "watering" or "weeding" (showing a correct LED color). Students read news articles and watched videos to understand the potential applications (weeding, plowing, harvesting) and to gain knowledge of currently available products. Students were subsequently able to identify and discuss the stakeholders and possible value creation of agricultural robots including aspects of human rights and environmental impact.

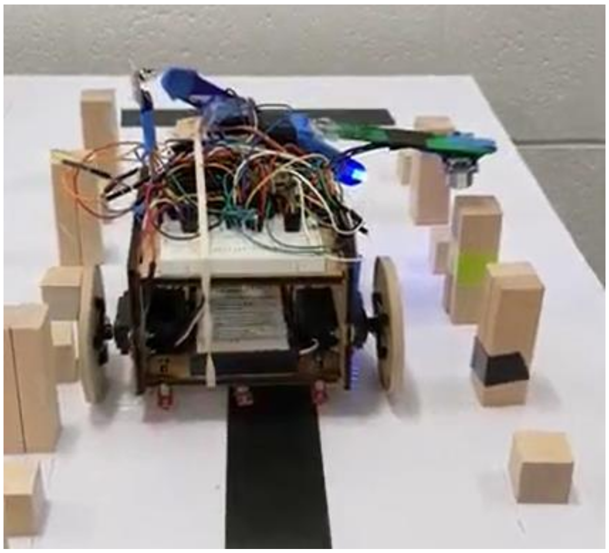

Figure 2: A representative final project done by a student (shown here following the line and correctly identifying with a blue LED attached to a mechanized boom to "water a plant")

Course Assessment Methods

Hands-on 'making' assignments were typically graded on a binary scale, meaning either their final system demonstrated the requested performance, or it did not. Instructors would use the language "Are you ready to check off?" to distinguish between receiving general support versus a full demonstration. While the requirements to be "checked off" as complete were fixed, students were allowed as many attempts as needed to show their system performance and each attempt was supported with formative feedback about any performance requirements that were not yet met. Aspects of this assessment approach are consistent with EM goals of self-evaluation, learning from mistakes, and taking action. Students in training generally accept the idea of partial credit or partial effort as being good enough. However, engineers in industry must make sure that performance requirements are fully met before a system is demonstrated to stakeholders, investors, or customers. In early training as engineers, supervisors or peers will provide low stakes feedback to ensure that partially completed systems are not presented outside of the working group. This binary scale for assessment forces students to quickly learn from mistakes in a low stakes environment, but also to take action and make sure all requirements were met. By experiencing this style of assessment throughout the course, students appeared to better "self-assess" or correctly determine if they were ready to demonstrate or if they still needed support. Another aspect of assessment that was designed to more closely represent experience in industry was the late policy. In part because scoring was binary, a very flexible late policy was used with 75% credit up to 1 week late and 50% credit up to 2 weeks late. Instructors emphasized the importance of completing the assignment even if it could not be accomplished on time. In industry, deliverable requirements don't vanish when a deadline passes but the engineer will receive a decreasing amount of appreciation for finally achieving them.

An aspect of EM not addressed with a binary scoring system is the ability of engineers to recognize opportunities and create value. For some regular 'making' assignments, optional bonus performance challenges were offered. In the Final Project a points system with possible extra credit was utilized. Students were presented with a variety of ways to score points up to about 150 points possible and with a final score capped at 110/100. The majority of points (~70) could be scored by simply integrating prior robot performance abilities and demonstrating them in a continuous time period (3 minutes). To score beyond this, students had to apply prior knowledge to slightly different new equipment (ex: a positional servo as opposed to a continuous rotation servo) or slightly more advanced coding was required. While the demonstration time period was fixed, students could demonstrate multiple times to keep improving their score.

3Cs Assessment Method

There were 83 students in the course. However, only 73 students who completed both the pre- and post-surveys were included for this study. The study protocol was approved by the University of Dayton's Institutional Review Board.

The pre- and post-surveys included a mechatronics-modified version of Carberry et al.'s engineering design self-efficacy tool [7], which consisted of 4 similar sections of 12 questions each. Each question allowed a response rating of 1 to 10 using a Likert Scale. Each section represented a self-efficacy sub-section: 'Confidence,' 'Motivation,' 'Success,' and 'Anxiety.' The 12 questions in these 4 sections remained the same, except for the first word, which was changed between sections to represent the section. From the survey data, 'Curiosity' was determined as the average of the ratings on questions 1, 2, and 8, 'Connections' was determined as the average of the ratings on questions 3, 4, 6, 9, 10 and 11, and 'Creating Value' was determined as the average of the ratings on questions 5, 7 and 12 in each category (Table 2).

Table 2: Example of survey questions in the Confidence Rating section, grouped into the learning outcomes of the entrepreneurial mindset: curiosity, connection and creating value.

Curiosity	Question 1	Confidence in taking apart and putting back together, in working order, a mechanical toy
	Question 2	Confidence in taking apart and putting back together, in working order, an electronic toy
	Question 8	Confidence in prototyping a new mechatronic system
Connection	Question 3	Confidence in connecting material from prior courses to this course in mechatronics
	Question 4	Confidence in identifying ways a mechatronic system could perform a desired task or process
	Question 6	Confidence in developing programming solutions to automate a calculation or process
	Question 9	Confidence in evaluating and testing a mechatronic design
	Question 10	Confidence in explaining a mechatronic system to a non-engineer
	Question 11	Confidence in redesigning an existing mechatronic system
Creating Value	Question 5	Confidence in researching an opportunity for a new mechatronic system
	Question 7	Confidence in selecting the best mechatronic design for a desired task or process
	Question 12	Confidence in creating a Kickstarter (or similar) for a new mechatronic product

For the purpose of analysis, the students were divided into 2 groups. The High Participation (HP) group and the Low Participation group (LP). The HP group (52 students) consisted of students who scored a mean score of above 96% on the 'making' assignments, and the LP group (21 students) comprised of the remaining students, who typically missed an assignment or did assignments late. There were 19 missing 'making' assignments in the LP group, as opposed to zero in the HP group. Differentiating these groups was done to more accurately define the impact of the scaffolding 'making' approach on EM, based on actual student participation in such learning methods. The 96% cutoff captured all the students who ultimately made two, or less than two mistakes, across the 9 'making' assignments, in the HP group. Thus this group was considered more intently involved in the 'making' assignments.

Statistical analyses were performed using NCSS statistical software (NCSS, LCC., Kaysville, UT, USA). Plots were created in MATLAB (The MathWorks®, Natick, MA, USA) and edited in Inkscape (The Inkscape Project, Boston, MA, USA). Pearson Correlation was performed to determine whether time spent per week in completing theoretical and hands-on 'making' assignments were correlated to prior experiences with programming courses or 'making'/electronics/robotics courses. Wilcoxon Signed Rank test was used to compare the learning outcomes of EM: curiosity, connection and creating (3Cs) ratings between the pre- and post-surveys. The differences between the pre- and post-survey results of the 3Cs were also analyzed separately within the 4 self-efficacy sections using Wilcoxon Signed Rank test. Significance was determined at $p < 0.05$.

Results

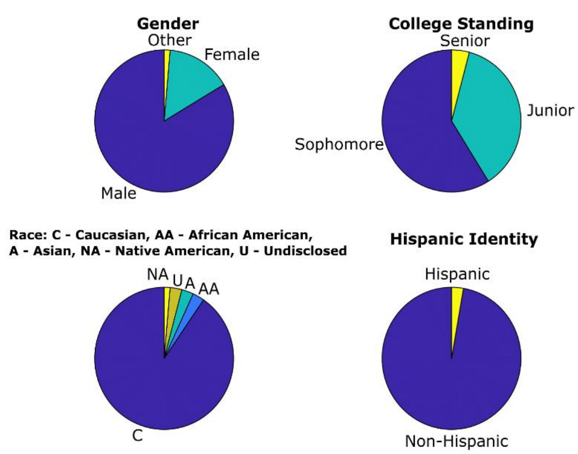

Figure 3:Demographic information

Seventy-three (61 males, 11 females and 1 other) students who completed both the pre- and post-surveys were included for this analysis. The demographics of the analyzed set of students is represented in Figure 3. The group consisted of 43 sophomores, 27 juniors and 3 seniors in the undergraduate mechanical engineering program. In the survey, 66 students identified as Caucasian, 2 identified as African American, 2 identified as Asian, 1 identified as Native American and 2 students did not disclose their race in the survey. Two students in the group considered themselves as having Hispanic origins.

As shown in Table 3, more than half of the students did not have any prior experience in 'making,' electronics and robotics. 41 of the students had never taken a course on 'making,' mechatronics or robotics before, and 43 of the students had never been in a robotics or STEM related club. However, most students (64) had taken at least one course of programming.

Table 3: Prior experience in 'making,' electronics and robotics

Number of prior classes in 'making', electronics or robotics	**0**	**1**	**2**	**3**
Number of students	41	21	9	2

Number of prior classes in programming	**0**	**1**	**2**	**3**	**4**
Number of students	9	52	9	2	1

Number of years prior involvement in robotics or STEM clubs	**0**	**0.5**	**1**	**2**	**3**	**4**	**5**	**5+**
Number of students	43	6	7	4	6	3	2	2

The results from the post-survey about the time spent by students per week on the theory assignments and hands-on applied, or 'making', assignments are shown in Figure 4. There were no correlations between the average hours spent on theory assignments and prior experience with programming courses ($r (71) = -0.037$, $p = 0.76$) or electronics/ making/ robotics courses ($r (71) = 0.066$, $p = 0.58$). Similarly, there were no correlations between 'making' assignments and prior experience with programming courses ($r (71) = -0.142$, $p = 0.23$) or electronics/ making/ robotics courses ($r (71) = -0.007$, $p = 0.95$).

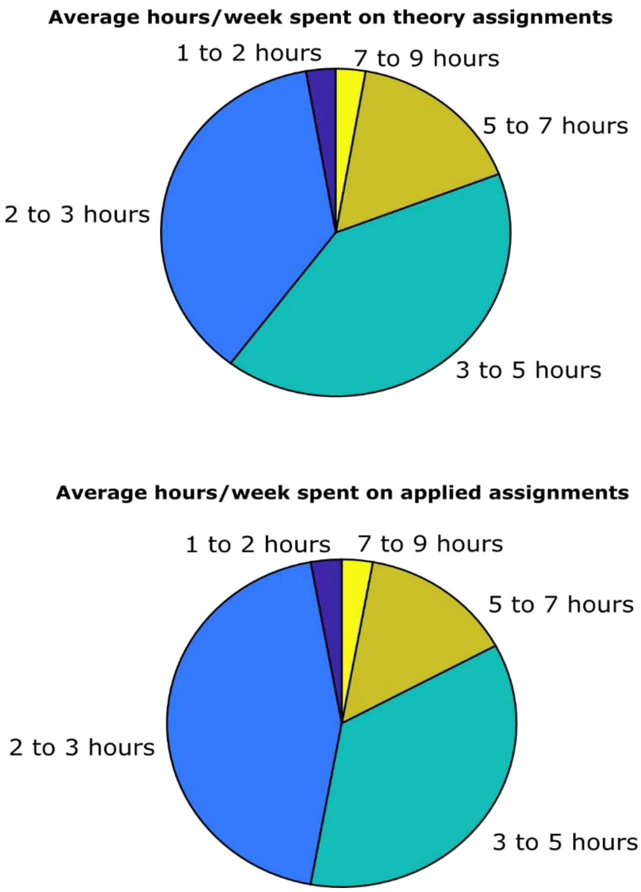

Figure 4: Average hours per week spent of theory and applied, or 'making', assignments.

The results from any correlations between the groups and the distribution of the summative assessment scores are shown in Figure 5. The HP (mean = 93.29 %) group scored significantly higher than the LP (mean = 83.18 %) group in the theory assignments ($p=0.0003$). The HP (mean = 103.12%) group scored significantly higher than the LP (mean = 84.90 %) group in the final project ($p=0.0005$). No significant differences in exam average ($p=0.07$) were noted between the HP (mean = 87.13 %) group and the LP (mean = 83.02 %) group.

The results from the engineering design self-efficacy questionnaires were analyzed with respect to each of the 3Cs based on pre- and post- surveys. The mean rating of the measured learning outcome Curiosity increased significantly from 6.29 to 6.75 for the entire group between the pre- and post-surveys ($z = 4.597$, $p < 0.001$). The mean rating of the measured learning outcome Connections increased significantly from

6.25 to 6.68 for the entire group between the pre- and post-surveys (z = 4.556, p < 0.001). The mean rating of the measured learning outcome Creating Value increased significantly from 6.05 to 6.44 for the entire group between the pre- and post- surveys (z = 3.785, p < 0.001).

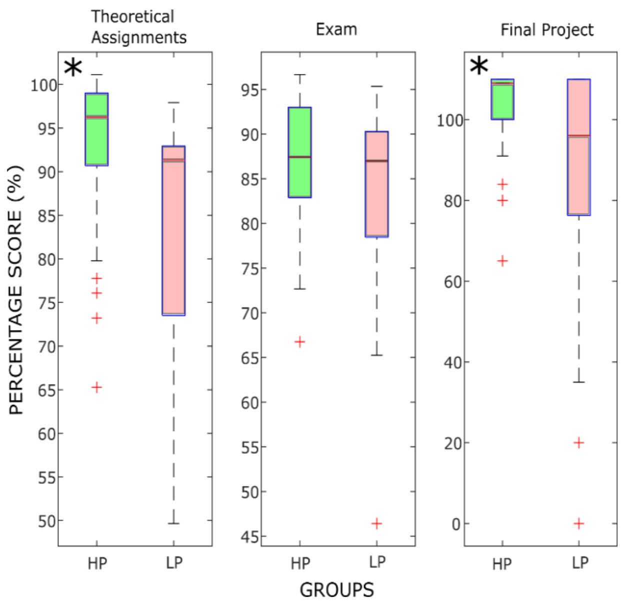

*Figure 5: Differences in the theoretical assignment, exam and final project scores between the high participation and low participation groups. * - significant differences between pre- and post-surveys (P<0.05).*

While these results may initially indicate that student self-efficacy with respect to the 3Cs increased for all students, further analysis revealed differences with respect to the two groups, see Figure 6. The LP group did not show any significant changes in Curiosity (z = 1.389, p = 0.16), Connections (z = 1.267, p = 0.21) or Creating Value (z = 1.652, p = 0.09) between the pre- and post-surveys. However, the HP group showed a significant increase across all 3Cs. The mean rating for Curiosity increased from 6.40 pre-survey to 6.92 post-survey (z = 4.5762, p < 0.001). Connections increased from 6.35 mean rating in the pre-survey to 6.86 mean rating in the post-survey (z = 4.692, p < 0.001). Creating Value increased from 6.14 mean rating in the pre-survey to 6.58 mean rating in the post-survey (z = 3.4352, p < 0.001).

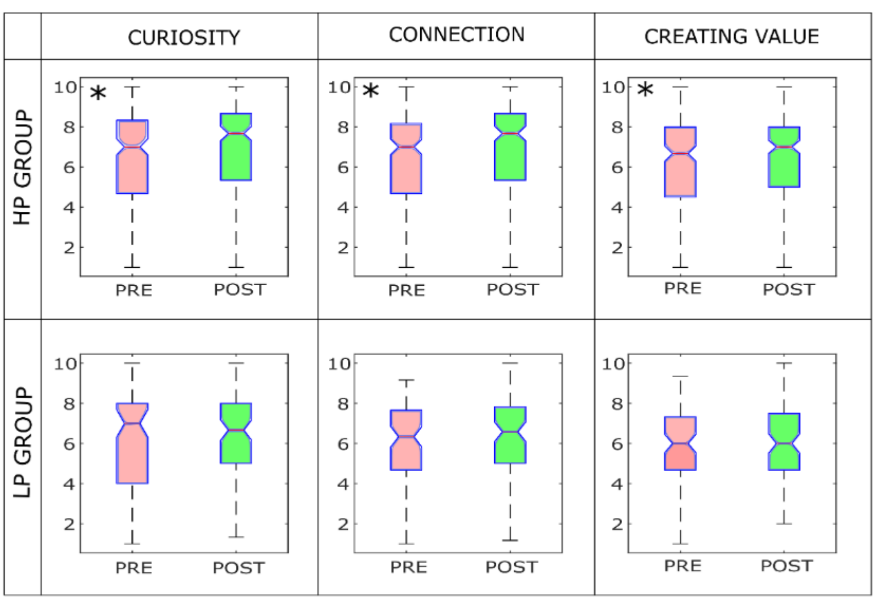

*Figure 6: Student self-perceived ratings of the entrepreneurial learning outcomes of curiosity, connection and creating value in the HP and LP groups. * - significant differences between pre- and post-surveys (P<0.05).*

Evaluating individual self-efficacy sections, there were no significant changes in Curiosity, Connections or Creating Value within the components related to Motivation or Anxiety.

Within the Confidence section, both the HP and LP groups showed significant increases in Curiosity, Connections and Creating Value. In the LP group, the average Curiosity rating significantly increased from 6.49 to 7.42 between the pre- and post-surveys ($z = 2.07$, $p = 0.038$), average Connections rating significantly increased from 6.35 in the pre-survey to 7.51 in the post-survey ($z = 2.77$, $p = 0.006$), and average Creating Value rating also significantly increased from 6.02 pre-survey to 7.10 post-survey ($z = 3.01$, $p = 0.003$). In the HP group, average Curiosity rating increased significantly from 6.97 to 7.94 between the pre- and post-surveys ($z = 4.8$, $p < 0.001$), average Connections rating increased significantly from 7.14 in the pre-survey to 8.09 in the post-survey ($z = 4.89$, $p < 0.001$), and average Creating Value rating also increased from 6.63 pre-survey to 7.54 post-survey ($z = 4.08$, $p < 0.001$) between the pre- and post-surveys.

Within the Success section, the LP group did not show any significant changes in the learning outcomes of the EM. However, the HP group showed significant increases in Curiosity, Connections and Creating Value. Curiosity increased from 6.83 mean rating pre-survey to 7.85 mean rating post-survey ($z = 4.89$, $p < 0.001$), Connections increased from 6.99 mean rating pre-survey to 7.95 mean rating post-survey ($z = 4.22$, $p < 0.001$), and Creating Value increased from 6.53 mean rating pre-survey to 7.32 mean rating post-survey ($z = 2.84$, $p < 0.001$).

Discussion

The HP group, the group of students that scored greater than 96% on the ‘making’ assignments, performed significantly better than the LP group in both the theoretical assignments and the final project. However, the HP group did not significantly outperform the LP group in the exams, although the trend did show a slightly higher mean score for the HP group. This could indicate that the students who put in the effort and time to successfully complete the ‘making’ assignments had acquired a level of mastery that allowed them to outperform the LP group. The insignificant differences in exam scores could be because of compounding factors like exam anxiety.

The difference in mean ratings between the pre- and post-surveys showed that the scaffolding ‘making’ approach improved the students’ self-perceived EM in the HP group. When considering the overall effects on the learning outcomes of the entrepreneurial mindset, across the 4 self-efficacy sections combined, Curiosity, Connections, and Creating Value all showed a significant improvement in the HP group, following the completion of the course. Nevertheless, this was not the case for the LP group. The LP group did not show any significant changes in their self-perceived EM between the pre- and post-surveys, when the 3Cs were evaluated across all the self-efficacy sections combined. This could be because the LP group did not get the full benefits of the ‘making’ assignments, as they spent less time and effort into these activities.

Separately analyzing the 3Cs within the 4 self-efficacy sections revealed that the scaffolding 'making' approach was effective at increasing the confidence of both groups in problems related to Mechatronics. However, only the HP group showed significant increase in the 3Cs within the Success section rating. This could be because the students in the LP group, who did not fully participate in all the 'making' assignments, did not acquire enough skills to perceive themselves as improved in successfully working through Mechatronics-related problems. On the corollary, the students who fully participated in the 'making' assignments rated themselves as perceiving to have greater success in working through Mechatronics-related problems as a result of this scaffolding 'making' approach to teaching Mechatronics.

Conclusions

Here we present the assessment of the three student learning outcomes of KEEN's definition for entrepreneurial mindset using a modified version of a validated tool for engineering design self-efficacy. In particular we show that within a scaffold learning approach to teaching the course Mechatronics, that high student participation levels within hands-on applied, or 'making', assignments not only increases summative performance in other assignments, sometimes significantly, but can also significantly increase student self-efficacy ratings across all three entrepreneurial student learning outcomes: curiosity, connections, and creating value. Further, if such activities are completely new to students, it does not necessarily mean that such advantages are lost if introduced via scaffolding techniques. Lastly, instructors must encourage ways to yield high participation, else the gains in entrepreneurial mindset may not transfer to some students.

References

[1] "Welcome to Engineering Unleased," *Engineering Unleashed*. [Online]. Available: http://www.engineeringunleashed.com/. [Accessed: 07-Feb-2022].

[2] S. R. Brunhaver, J. M. Bekki, A. R. Carberry, J. S. London, and A. F. McKenna, "Development of the Engineering Student Entrepreneurial Mindset Assessment (ESEMA).," *Advances in Engineering Education*, vol. 7, no. 1, p. n1, 2018.

[3] L. E. Rumreich, F. Logan, and A. D. Christy, "Comparison of Entrepreneurial Mindset Course Learning Objectives: Evaluating Consistency and Clarity."

[4] F. Guay, R. J. Vallerand, and C. Blanchard, "P1: vendor Motivation and Emotion [me] On the Assessment of Situational Intrinsic and Extrinsic Motivation: The Situational Motivation Scale (SIMS) 1," 2000.

[5] T. B. Kashdan *et al.*, "The five-dimensional curiosity scale: Capturing the bandwidth of curiosity and identifying four unique subgroups of curious people," *Journal of Research in Personality*, vol. 73, pp. 130–149, Apr. 2018, doi: 10.1016/j.jrp.2017.11.011.

[6] J. Turns, C. J. Atman, and R. Adams, “Concept maps for engineering education: A cognitively motivated tool supporting varied assessment functions,” *IEEE Transactions on Education*, vol. 43, no. 2, pp. 164–173, May 2000, doi: 10.1109/13.848069.

[7] A. R. Carberry, H. S. Lee, and M. W. Ohland, “Measuring engineering design self-efficacy,” *Journal of Engineering Education*, vol. 99, no. 1, pp. 71–79, 2010, doi: 10.1002/j.2168-9830.2010.tb01043.x.

[8] L. R. Roehler and D. J. Cantlon, “Scaffolding: A powerful tool in social constructivist classrooms.,” in *Scaffolding student learning: Instructional approaches and issues.*, Cambridge, MA, US: Brookline Books, 1997, pp. 6–42.

[9] T. Greening, “Scaffolding for Success in Problem-Based Learning,” *Medical Education Online*, vol. 3, no. 1, p. 4297, Dec. 1998, doi: 10.3402/meo.v3i.4297.

[10] K. D. Simons and J. D. Klein, “The impact of scaffolding and student achievement levels in a problem-based learning environment,” *Instructional Science*, vol. 35, no. 1, pp. 41–72, Jan. 2007, doi: 10.1007/s11251-006-9002-5.

[11] M. Reissman and T. Reissman, “Scaffold Approach to Teaching Experimentation,” *In 2017 ASEE Annual Conference and Exposition* 2017 Jun 24.

[12] N. Holstermann, D. Grube, and S. Bögeholz, “Hands-on Activities and Their Influence on Students’ Interest,” *Research in Science Education*, vol. 40, no. 5, pp. 743–757, Nov. 2010, doi: 10.1007/s11165-009-9142-0.

[13] T. J. Pfaff and A. Weinberg, “Do hands-on activities increase student understanding?: A case study,” *Journal of Statistics Education*, vol. 17, no. 3, 2009, doi: 10.1080/10691898.2009.11889536.