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Development of Engineering Component Curiosity Challenges (ECCCs)

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Abstract

Engineers have to adapt to rapidly changing technology throughout their careers, and this is especially the case for selecting engineering components which often evolve quickly. This paper describes the design and evaluation of *Engineering Component Curiosity Challenges* (ECCCs), a suite of self-directed laboratory modules intended to cultivate intrinsic motivation for lifelong learning among senior-level mechanical-engineering students. Each module juxtaposes two functionally similar components—e.g., a spring-powered versus a flywheel-powered toy car; DC versus stepper motors—and requires students first to articulate hypotheses regarding underlying mechanisms and performance trade-offs, then to verify or refine their conjectures through observation of disassembled components, measurement, and analysis. Implementation occurred during the first five weeks of a two-quarter capstone sequence with 82 students. Engagement was assessed with the Situational Motivation Scale after each module, yielding positive Self-Determination Index (SDI) values indicative of predominantly intrinsic motivation, with the highest values for a toy car module. Students reporting minimal prior shop experience exhibited significantly higher SDI scores than their more experienced peers in two of the three modules ($p < 0.01$). Analysis of "hidden discoveries" revealed that 34 %–74 % of students independently identified the intended non-obvious design principles; 74 % correctly explained the misalignment tolerance of an exactly-constrained linear-bearing system, whereas 34 % deduced the stepping mechanism of a stepper motor. Five weeks after completion of the ECCCs, 75 % of respondents reported increased interest in disassembling devices and in understanding the physics of component operation, and 68 % indicated that the ECCCs positively influenced the depth of research undertaken for their Individual Component Analysis within their capstone project. The findings demonstrate that carefully structured curiosity challenges can elicit robust intrinsic motivation, facilitate discovery learning, and exert a sustained influence on subsequent engineering projects.

Introduction

Engineers have to continually stay abreast of changing technology, and the importance of continued learning is evident by the ABET requirement that accreditation requires engineering programs to teach lifelong learning skills that can instill in our students an ability to acquire and apply new knowledge [Naimpally, 2011; ABET, 2024]. Thus, educators are tasked with more than teaching a set amount of content. We are asked to change students' attitude so that they are motivated to continue to learn long after their graduation, at which point learning must be motivated intrinsically. The approach we selected to promote lifelong learning is to provide activities that increase student curiosity about engineering components, and to demonstrate how learning improves an engineer's ability to make informed design decisions.

Our approach is focused on learning about engineering components such as bearings, gears, motors, and sensors. The technology of engineering components changes at a more rapid pace than engineering theory. Accordingly, engineers need to continually stay abreast of the engineering components that they work with. To foster creativity we provide self-guided activities for students to discover non-obvious aspects of engineering components. We also emphasize understanding the underlying principles and physics that govern component performance. This deeper understanding allows engineers to better interpret a manufacturer's specification sheet and evaluate the pros and cons of different technologies.

This paper describes the redesign of a senior-level mechanical engineering design class that incorporated activities to foster curiosity. An early implementation of this class had students build mechatronic devices, and then analyze the details of the components in their device [Delson and Lynch 2023]. However, building new devices each quarter required significant student time and significant Teaching Assistant (TA) guidance. The new implementation described here was developed to accommodate growing class sizes with reduced TA support. The course development was funded by a Course Development and Instructional Improvement Program grant from the University of California at San Diego. In this implementation, 3 modules of Engineering Component Curiosity Challenges (ECCCs) were developed. Each module had pairs of engineering components that achieved similar engineering functions, but with different pros and cons. The components selected for each ECCC module had "hidden discoveries" where the performance of the components had somewhat surprising results. The modules included disassembled components, to motivate hypotheses for how the components worked. There were also operational components where performance could be measured. The module hardware was built prior to the class and will be reused when the class is retaught. However, the student activities were self-guided with 7/24 access to a lab with door code access, thus reducing the amount of TA support needed. Each module had 2 assignments; the first one was a Hypothesis Assignment where students observed the components and made hypotheses of how they worked as well as their pros and cons, and the second was an Evaluation Assignment where students measured the performance of the engineering components and learned how they worked and how to analyze their performance. Students would receive full credit on their Hypothesis Assignment if their explanations were clear and sufficiently detailed, even if their hypotheses were incorrect. In the Evaluation Assignment students saw if their hypothesis were correct or not, and learned from engineering literature how those components worked. This study addressed the following Research Questions

RQ1 - Were the students engaged with the ECCC modules?

RQ2 - Were the hidden challenges at an appropriate level of difficulty where they were challenging, but still achievable?

RQ3 – Did completion of the ECCC modules impact student work moving forward?

RQ4 – Did subgroups of gender, first generation status, and prior hands-on experience, affect the engagement with the ECCC modules?

Background

As defined by Evans et al. [2022] "Curiosity occurs when a student encounters uncertainty and seeks to close a gap in knowledge [Loewenstein 1994], which can lead to deep and meaningful learning [Jirout et. al 2018]." Curiosity supports lifelong learning, one of the most desirable outcomes of higher education, by its role as an intrinsic reward [Kang et al. 2009], which is essential if we wish students to engage in life-long learning after graduation. Curiosity and conscientiousness have been shown to be correlated with student success [Leslie 2014]. Curiosity has also been linked with workplace learning and job performance [Reio et al. 2000].

Curiosity can be deliberately increased and interventions can measurably boost it [Schutte and Malouff 2023] .

The Kern Entrepreneurial Engineering Network (KEEN) organization has developed a framework for promoting Entrepreneurial Mindset [KEEN 2015]. They have identified 3 core factors; the 3 C's; Curiosity, Connections, and Creating Value. Many KEEN affiliated programs have implemented courses to promote an Entrepreneurial Mindset [Caplan et al. 2017; Estell et al, 2016; Gorlewicz and Jayaram 2020, LeMasney et al. 2020; Prince 2016; Vigeant et al.; Zhu 2021]. These courses include curiosity as a value for students to engage in, typically in the context of students working on real-world and often capstone design projects. However, to achieve the best performance in a real-world project it is often desirable to scaffold the instruction of foundational skills before the implementation in the larger scale project. The authors of this paper fully support the development of Entrepreneurial Mindset, but wish to add methods to teach curiosity in a more traditional design course, where all students can be working on the same prescribed assignments. In our implementation, the curiosity focused labs are followed by a 15 week real-world capstone design project. Our approach is to develop curiosity in a structured setting, and then apply the increased curiosity to real-world applications.

Methods

Course and Project Structure

The Mechanical Engineering capstone design project at UC San Diego is taught in a 2-quarter sequence, MAE 156A and MAE 156B. In the first five weeks of MAE 156A, students work in pairs to prepare them for their capstone design project that they complete in the remaining 5 weeks of 156A and the full 10 weeks of 156B. The ECCC modules were implemented as part of the first 5 weeks of 156A. The modules were built in the summer of 2024 and this study took place during the fall quarter of 2024 with 82 students enrolled in the course. Surveys were conducted at the beginning of the class, after each of the 3 ECCC modulus, and 5 weeks into the capstone design project. The study was reviewed by the institution IRB and deemed exempt status # 811195. Students could opt out of the study, but were by default considered enrolled in the study. Two of the students decided to opt-out and one other student had to leave mid course, and thus only 79 students were used in the analysis of the course.

ECCC Modules

Three ECCC modules were developed and the hardware was made accessible 7/24 in a code accessible room. Each module included a Hypotheses Assignment and Evaluation Assignment. The Hypotheses Assignments are a unique aspect of this course in which students are asked to use their observations to guess how a component may work and the pros and cons of its performance. Students are asked to not use the internet for the Hypotheses Assignment, and receive full credit if their opinions are clearly explained, even if their hypothesis was incorrect. The ECCC modules used are described below.

Toy Car Module

On the first day of classes each student was handed 2 toy cars (Fig. 1), simple hand tools for taking them apart, a caliper, and a multimeter. Both the toy cars were purely mechanical powered, but the mechanisms inside the cars were very different with many interesting design details. The small pull back car is operated by pulling it back and then releasing it. The larger push and go car is pushed forward and then released. The Hypotheses Assignment was for students to play with the intact cars, and hypothesize what propels the cars forward after they are released. Students were also assigned the task of drawing a freehand sketch of what they believe the inside of the cars would look like. The purpose of the sketching task was to support their description, and also to build up sketching skills which they would need for concept generation in their capstone project.

	
Small Pull Back Car	Larger Push and Go Car

Figure 1: Toy Car Module Components

The small pullback car is powered by a spring, which many students correctly hypothesized. However, the type of spring, a spiral clock/motor spring is not something most students have encountered. The car also had an interesting gear train. There is a 2:1 gear ratio between the wheel and spring when the car is pulled back to wind the spring. However, when the car is released one of the gear axles shifts in a slot so that the gear ratio changes to be a much higher ratio of 22:1, resulting in a much higher car speed. Another interesting feature is that only the rear wheels of the car had rubber on it for traction purposes. Slow motion video analysis of the car showed rear wheel slip at the moment of release, then a clear acceleration phase, and then a deceleration phase.

The large push and go car is powered by a flywheel. There is a 34:1 gear ratio between the car wheels and the flywheel. Since kinetic energy of the flywheel is a function of the rotational velocity squared, the flywheel has 1156 times the energy in it than if there was no gear train. Video analysis of the car showed almost no wheel slip at the moment of release, then constant velocity for a while and eventually a deceleration phase.

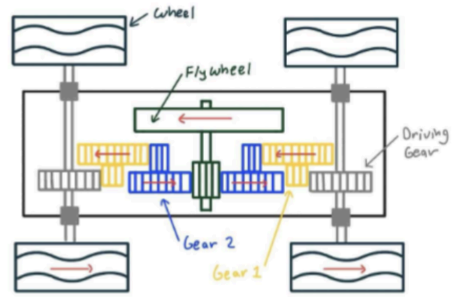
	
Small Pull Back Car Disassembled	Larger Push and Go Car Gear Train

Figure 2: Internals of Toy Cars

Since each pair of students had 2 large and small cars they could disassemble one (Fig. 2), while performing experiments with the other one. The students used Kenova motion analysis software to plot the velocity profile of the car from their video. The Evaluation Assignment included determining the purpose of the gear train,and calculating the gear ratio. The final task was to estimate the energy in Joules at the moment the cars were released.

<u>Bearing Module</u>

The Bearing Module evaluated bronze bushings, ball bearings, and linear bearings. The bushings and ball bearings where press fit into a set of pendulums as shown in Fig. 3. There were 3 bushing configurations, where the shaft diameters were ⅛", ¼", and ½". A similar pendulum setup was created for the ball bearings, where one ball bearing was packed with grease, one had all the grease removed, and one was a sealed bearing with factory installed grease.

Figure 3: Rotary Bearing/Bushing Setup

The Hypothesis Assignment for the rotary bearings configuration was to hypothesize which had the lowest friction. Then the students, in pairs, went to the lab and measured the duration of oscillation after starting the pendulum at a 30 degree angle. The Evaluation Assignment was to theoretically model the bushings in the pendulum which required solving a differential equation numerically. As an aside, we showed the students that ChatGPT gave the incorrect answer (as of

Oct. 3, 2024), since it mistakenly applied viscous friction instead of sliding friction. One of the hidden discoveries was that friction was proportional to the bushing diameter, and thus there was a factor of 4 difference in friction due to the ⅛” to ½” bushing sizes. A hidden discovery for the ball bearings was that the lowest friction in the group was the one without grease, because there is no viscous friction, but as the students learned would lead to quick wear.

The Bearing module also included linear bearings, since students had frequent challenges with linear bearings in capstone design projects. For the linear bearing setup, 2 different configurations of a cart sliding on shafts were built, as shown in Fig. 4. The shafts could be purposely misaligned using a micrometer so students could see the cart move smoothly when the shafts were aligned and then the cart would jam at a certain point of shaft misalignment. The configuration with a cart with 2 bronze bushing is over-constrained, so a small amount of misalignment will cause the cart to jam. The other configuration had a single bronze bushing and then 2 ball bearings used as rollers constrained against a second shaft. The design is motivated by Kamm [1993], and is exactly constrained; therefore the cart continues to move even with quite a bit of misalignment. The students hypothesized which design would work well despite part misalignment, and then measured the performance in the lab.

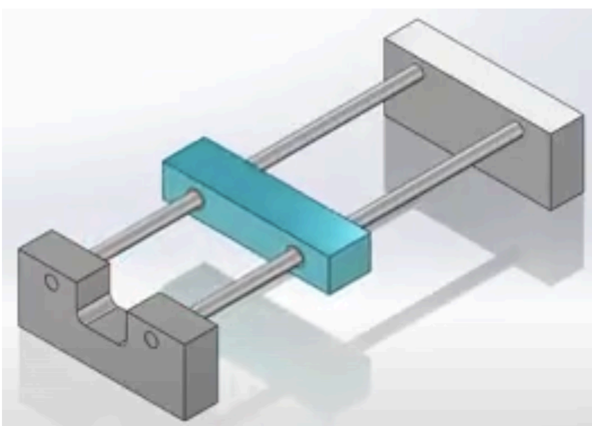
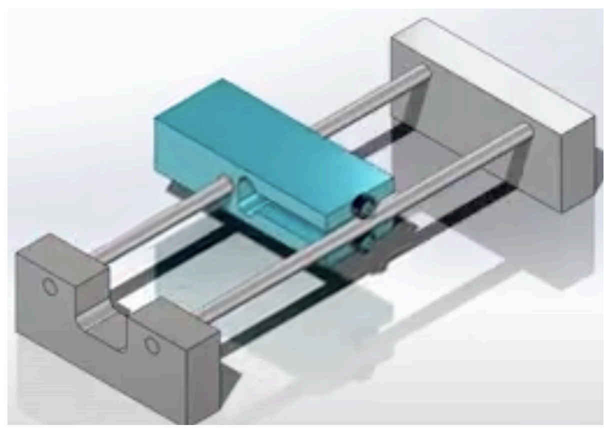
<table>
<tr><td></td><td></td></tr>
<tr><td>Cart on 2 Shafts (overconstrained)</td><td>Cart on 1 Shaft and Rollers
(exactly constrained)</td></tr>
</table>

Figure 4: Linear Bearing Setup

<u>Motor and Sensor Module</u>

A DC motor and stepper motor were disassembled and students were provided with a magnet polarity sensor to measure the permanent magnets in the motor. The students were asked to hypothesize how the motors operated as well as their pros and cons. This material was then covered in lecture and students went into the lab to measure torque and speed of the motors. This module also included a sensor component. There was a rotary potentiometer and an optical encoder. The students rotated these sensors by hand to feel the resistance, and observed the sensors disassembled.

These hardware choices were selected due to the differences between the components compared. A DC motor has an electromagnet as the rotor with brushes transferring the current to the coils.

In contrast, the stepper has electromagnets in the stator, no brushes, and permanent magnets in the rotor. Just from observation students could see that DC motors were more subject to wear due to their brushes. When measuring the torque and speed output, they calculated that the DC motor had higher power density, since it could rotate at much higher speeds. While the stepper motor had the benefit of being able to hold positions. The comparison of potentiometer to encoder also allowed for the observation that the encoder was a non-contact sensor and thus did not add friction to the shaft. In lecture we showed that the specification sheet for the potentiometer had a life rating, which was due to the wear of the wiper on the resistive element, while the encoder did not even have a life rating in its specification sheet. This example was highlighted as an example where understanding how a device works allows one to better understand the specifications sheet and pros and cons of that device.

Individual Component Analysis (ICA)

After the completion of the 5 week ECCC modules, students begin their capstone projects in teams of 4-5. Part of the capstone project is for each student to research an engineering component that is applicable to their capstone design project. This assignment is the Individual Component Analysis (ICA), and it is submitted 5 weeks after the completion of the ECCC modules. Students' attitude towards their ICA is used as part of the assessment of RQ3.

Assessment

Assessment included 5 surveys that included Likert scale and free response questions. The surveys were chronologically:

S1. Survey at the beginning of the class which included questions about familiarity with engineering components and hands-on experience.
S2. Survey after the Bearing Module.
S3. Survey after Toy Car Module.
S4. Survey after Motor and Sensor Module.
S5. Survey 5 weeks after the completion of the ECCC where students are asked if completing the ECCC experience impacted their approach for completing their ICA assignment.

To answer RQ1 (student engagement) we incorporated into surveys 2-4, the Situational Motivation Scale (SIMS) [Guay et. al 2000], which measured the student motivation in regards to the ECCC module they just completed. SIMS is a 16-item Likert scale survey that distinguishes between internal and extrinsic motivation. Questions ask about the reasons students were completing assignments and the value they see in the assignments, for example if the reason is because they have to do and if they find the activity interesting. The results from the SIMS survey was used to calculate a "Self-Determination Index" (SDI) where larger positive scores indicate greater intrinsic motion and larger negative scores indicate extrinsic motivation. To assess RQ4 (impact of sub-groups) intrinsic motion as measured by SDI was analyzed by group, and a statistical significance test was performed.

To answer RQ2 (hidden challenges) we asked students at the end of the ECCC Modules how they learned the answers to hidden discovery challenges, whether it be by themselves, with the help of classmates, or when it was disclosed in lecture. We felt that if almost all students identified the hidden discoveries on their own, then they may have been too easy. Conversely if very few students identified the hidden discoveries, then they may have been too difficult.

To answer RQ3 (impact on students after the ECCCs), we asked students 5 weeks after the completion of the ECCC modules whether it impacted their interest in learning about the physics of how things worked and impacted their ICA assignment in their capstone project.

Results

Characteristics of the incoming class was captured in the survey conducted in week 1, and is shown in Table 1. The gender and first generation status was received in a de-identified format from the School of Engineering. There was one student with a nonbinary gender which was not included in the gender comparison, but was included in the other analyses. In the week 1 S1 survey, students were asked how many times they have taken something apart to fix it or learn how it works, and were categorized in a group of greater than 4, and 3 or fewer. A question was asked about hands-on experience with the drill press (a tool used in a freshman design class), and were categorized in a group of very significant or significant, and some, very little, or none. The number of each group represents those that answered the corresponding question.

Table 1. Beginning of Course Survey S1

Gender		First Generation		S1 Taking Apart Experience		S1 Drill Press Experience	
Male (n=55)	Female (n=14)	Not First Gen. (n=45)	First Gen. (n=21)	4 or More (n=36)	3 or Less (n=35)	Very Significant or Sig. (n=47)	Some to None (n=24)
75%	19%	62%	29%	49%	48%	64%	33%

To answer RQ1 about student engagement, the SDI value was measured after each ECCC module. An SDI value greater than zero indicates that intrinsic motivation is higher than extrinsic motion, and the higher the value the higher the intrinsic motivation. To answer RQ4 about whether the effect of ECCC modules impacted different subgroups in the class differently, the SDI values were calculated for each group and are shown in Table 2. A two-sample t-test was used to determine if the grouping showed a statistically significant correlation, and cells with $p<0.05$ indicating statistical significance are highlighted.

Table 2. SDI Values After Each ECCC by Subgroup

SDI Scores per Module		Gender			First Generation Status			S1 Taking Apart Experience			S1 Drill Press Experience		
	Whole Class	Male	Female	p	Not First Gen.	First Gen.	p	4 or More	3 or Less	p	Significant or Very Sig.	None to Some	p
Bearings	11.3	13.4	6.8	0.307	14.6	8.8	0.298	8.9	14.4	0.309	6.6	21.3	0.008
Toy Car	15.9	18.3	11.1	0.293	14.9	21.4	0.279	12.3	19.8	0.191	10.2	27.7	0.003
Motor/Sensor	13.2	15.8	12.0	0.602	15.3	16.0	0.914	11.4	15.3	0.534	9.5	19.8	0.110

To answer RQ2 as to whether the hidden discoveries were at an appropriate level of difficulty, students were surveyed about when they learned about the answers to the challenges, which is shown in Table 3.

Table 3: Learning the Hidden Discoveries

Hypotheses Question	I figured it out by myself	I figured it out with my help from my lab partner	I figured it out with help of others	I figured it out after the hypothesis was discussed in lecture	Other
Were you able to hypothesize correctly why the rotary bushing with the smallest diameter had the lowest friction?	47%	37%	4%	10%	3%
Were you able to hypothesize correctly why the linear cart system with 1 bushing and 2 rollers had low friction even when the rods were misaligned?	74%	21%	4%	1%	0%
Were you able to hypothesize correctly that the brushes in the DC motor transmitted current to the rotor and would wear out over time due to the rubbing?	44%	25%	16%	15%	0%
Were you able to figure out how the stepper motor advanced and held its position?	34%	30%	15%	21%	0%
Were you able to hypothesize correctly that the encoder would last longer than the potentiometer because it was a non-contact sensor?	45%	16%	14%	23%	1%
Were you able to hypothesize correctly how the small pull back toy car stored energy and what the purpose of the gears were?	60%	25%	5%	10%	0%
Were you able to hypothesize correctly how the large push toy car stored energy and what the purpose of the gears were?	58%	22%	3%	18%	0%

To answer RQ3 regarding the impact of the ECCC modules on student work moving forward, students were asked 5 weeks after the completion of the course if the ECCC experience increased their interest in taking things apart, learning about the physics of how things work, and if it made them more inclined to perform research in their ICA for their capstone project. These results are shown in Table 4, where the last column shows the combined value of somewhat more inclined and much more inclined.

Table 4: S5 Survey - Impact of ECCC Modules During the Capstone Project

Motivations After ECCCs (whole class)	Much less inclined	Somewhat less inclined	Not changed in inclination	Somewhat more inclined	Much more inclined	Much OR Somewhat more inclined
How inclined are you to take things apart, since completing the ECCEs?	0%	0%	25%	37%	38%	75%
How interested are you in the physics of how things work, since completing the ECCCs Modules?	0%	0%	25%	36%	40%	75%
Did completing the ECCC modules make you more inclined to research how things work on the 156A Sponsored Project Individual Component Analysis?	0%	3%	29%	38%	30%	68%

A qualitative sense of the student experience can be seen by selected comments about the ECCC modules shown in Table 5 from the S5 survey.

Table 5:What were the best parts of the Engineering Component Curiosity Challenges?

"I really enjoyed the lab components as they allowed us to get hands on with the components and test them and see for ourselves their properties."
"Taking things apart was the most insightful and fun part. I always appreciate making a conjecture, then physically going through each part until I can confirm/deny whether or not I was correct."
"I liked having a hands on lab work experience where i am essential entrusted to be able to do so on my own and dont need a TA to guide me through it or have to do it during a class. It made me feel like i was doing my own research and had us rely on our own intuition more."
"The best parts of the Engineering Component Curiosity Challenges was the testing that we performed in the lab and writing a report about it. This helped bridge the gap between the information in the classroom and how the components actually work. I learned a lot while going through this process for each one."
"I think the best part was getting to work alongside people in the class and have all of us struggle, but then work together to understand how everything works."

Discussion

As shown in Table 2, the class as a whole had a positive SDI after each module which corresponds to a more intrinsic motivation than extrinsic, which is what we had hoped for. This supports RQ1 that the students were engaged in the projects for the intrinsic value of learning. The Toy Car module had the highest level of engagement. Interestingly this engagement level varied by group with males being more engaged with the Toy Car module than females (18.3 to 11.1), first generation students more engaged than not first generation students (21.4 to 14.9), and students who had less experience in taking things apart were more engaged than those that had more experience (19.8 to 12.3). Interestingly, the group that had the highest level of engagement was students who had less experience with using a drill press vs. those that had more experience (27.7 to 10.2). Indeed, the only statistically significant results were with these students who had less experience with the drill press, and this occurred in both the Toy Car and Bearings modules. This implies that students with less shop experience do not necessarily dislike hands-on work, and indeed valued the opportunity to engage with the modules even more. This group of students did use a drill press in their freshmen introduction to design course, but likely did not participate in further shop activity until their senior year. RQ4 was about differences between groups, and the results support that at least one subgroup in the class was more engaged at the level of statistical significance. If more students are included in a future study, it may be possible to see if differences noted between other groups become statistically significant.

When the idea of hidden discoveries was developed, we did not know how well the concept would work. We were pleased to see, as shown in Table 3, that there was a wide range of students discovering the hidden challenges. The hardest discovery was learning how the stepper motor advanced, with only 34 % of the students discovering it on their own, while the challenge of identifying the linear cart with the lowest friction was the easiest with 74% discovering it on their own. Accordingly, the RQ2 was supported with successful use of hidden discoveries. The selected comments in Table 5 illustrate how these students did indeed engage in discovery and overcoming challenges with comments describing engagement, learning, fun, self guided discovery, and overcoming challenges.

The impact of the ECCC modules on students' future activity was a key objective of the curriculum. Survey 5 was conducted 5 weeks after the students completed the ECCC, and was when they had completed their ICA reports for their capstone project. Accordingly, survey 5 reflects students' actual experience in a real-world project and not just a general sense of what they thought they might do in the future. Table 4 shows that for 68% of the students completing the ECCC modules made them somewhat or much more inclined to perform research on engineering components for their capstone project. The results rise to 75% for somewhat or much more interest in taking things apart and learning the physics of how things work. Accordingly, RQ3 was answered in the affirmative indicating that the ECCC models did have an impact on student work moving forward.

Conclusion

Lifelong learning is an explicit goal of ABET, and an important skill for career success. Lifelong learning in engineering is built on a foundation of intrinsic motivation and curiosity. The Engineering Component Curiosity Challenges introduced in this study were explicitly designed to nurture these qualities by giving students a chance to explore engineering components in a hands-on, self-directed manner. A number of outcomes of our implementation support the effectiveness of this approach. Across three ECCC modules, students expressed consistently positive SDI values, confirming that their primary impetus was the inherent satisfaction of inquiry rather than external rewards. The statistically higher SDI scores observed among students with limited prior hands-on experience suggest that the activities were especially impactful for those that needed the skills most in preparation for a real-world design project.

Beyond the immediate excitement of discovery, the lasting influence of the ECCCs on student learning habits is an encouraging sign that this approach meets its long-term goal. When surveyed 5 weeks after completing the ECCC modules, a significant portion of students reported enduring changes in their attitude towards learning. Approximately 75% expressed a greater inclination to disassemble gadgets and a heightened interest in understanding the physics behind how things work, directly attributing these changes to their ECCC experience. About two-thirds of the class (68%) were more inclined to conduct independent research into an engineering component they had completed during their subsequent capstone design project. In other words, the curiosity sparked by the ECCCs carried forward, with students internalizing an inquisitive mindset that persisted to a following project.

The hidden discovery framework functioned as intended: a substantial proportion of students identified the concealed design principle without explicit instruction, yet the challenges were sufficiently demanding to preserve a meaningful investigative experience. This student experience was evident in student comments and the statistics that in the different modules between 34% and 74% of the students were able to identify the hidden discoveries on their own and that the large remainder of students figured it out with the help of other students in the class.

From an instructional design perspective, the modules required a one-time capital investment and low teaching assistant oversight because the hardware was reusable and the laboratory remained accessible on a flexible schedule for self-guided exploration. Consequently, the ECCC approach offers a scalable model for embedding curiosity driven learning in the curriculum. Future research could examine longer term retention of curiosity driven exploration. In addition, with a larger number of students in the study, further research on statistically significant impact on more subgroups could be explored. Nonetheless, the present study provides evidence that strategically organised, self guided exploration of engineering components can serve as an effective and efficient mechanism for promoting intrinsic motivation and lifelong learning among undergraduate engineers.

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