2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #37233

Capturing First-Year Engineering Students' Situational and Individual Interest via a Formal Makerspace Course

Dr. Brian Scott Robinson, University of Louisville

Brian Robinson is an Associate Professor with the Department of Engineering Fundamentals at the University of Louisville. His primary research focus is in Engineering Education, with highest interest in first-year (and beyond) engineering retention & the effects of value-expectancy theory on student persistence.

Dr. Thomas Tretter, University of Louisville

Thomas Tretter is professor of science education and director of the Gheens Science Hall & Rauch Planetarium at the University of Louisville. His scholarship includes collaborative efforts with science and engineering faculty targeting retention of STEM majors in entry-level STEM courses.

Dr. James E. Lewis, University of Louisville

James E. Lewis, Ph.D. is an Associate Professor in the Department of Engineering Fundamentals in the J. B. Speed School of Engineering at the University of Louisville. is research interests include parallel and distributed computer systems, cryptography, engineering education, undergraduate retention and technology used in the classroom.

Mr. Nicholas Hawkins, University of Louisville

Nick Hawkins is an Assistant Professor in the Engineering Fundamentals Department at the University of Louisville. He received his B.S. (2016), M.Eng. (2017), and Ph.D. (2020) in Electrical and Computer Engineering at the University of Louisville. His res

Capturing First-Year Engineering Students' Interest and Retention via a Formal Makerspace Course

Abstract

This complete research paper explores two different research questions associated with a larger, more comprehensive research study ultimately aimed at formal makerspace course characterization in conjunction with student interest in engineering and its associated impact on engineering retention. More specifically, this paper is predominantly focused on student perceptions in personal levels of interest triggered by varying fundamental engineering topics and associated activities, in addition to investigating the effectiveness of a formal makerspace course in increasing students' maintained interest in engineering through the promotion of the various (triggered) situational interests among first-year engineering students. Situational interest refers to environmentally triggered responses, such as focused attention and affective reactions, that are predominantly short-term. Maintained interest refers to beliefs related to the enjoyment and/or usefulness of engineering that are relatively stable across pedagogical settings, which have been shown to be more effective at positively influencing longer-term engineering student retention. While makerspaces have excited considerable interest, much of the research on makerspace impacts and practices have focused on K-12 and informal educational settings. Little is known about how a well-designed makerspace-based engineering course can contribute to first-year students' persistence in engineering.

The platform for this study is an introductory engineering makerspace course at a Southeastern, public university. The course's objective is to facilitate the application and integration of fundamental engineering skills. Six course features were identified by course instructors as potential pedagogical features that can activate students' situational interest: technical writing, hand tool usage, 3D modelling, 3D printing, circuitry, and programming. Other course-related factors were also considered with respect to impact on situational interest, such as, engineering design sub-features, personal satisfaction in proficiency, and teamwork. Participants were 314 first-year, undergraduate students enrolled in the makerspace course during Spring of 2022. From January 2022 to April 2022, students completed a series of surveys that prompted them to reflect on their interest regarding specific course-related experiences and activities. Situational interest surveys were administered immediately following the completion of the feature modules identified above, whereas the maintained interest survey was administered at the end of the course. Surveys regarding other course-related factors were administered throughout the semester at appropriate times. Findings suggested that hand tool usage elicited the highest situational interest among students, whereas technical writing was the lowest. In this sample, maintained interest in engineering did not differ based on student demographic (i.e., age, gender, and race). Additionally, situational interest in all feature modules, with the exception of programming, significantly and positively explained the variance of students' maintained interest in engineering. The majority of students reported an increase in interest in engineering for all course-related factors. Lastly, implications of these findings and limitations of the study are discussed.

1. Introduction

1.1 Overview and Scope of the Interest in Engineering Study

Researchers in Engineering Education at J. B. Speed School of Engineering at the University of Louisville (UofL) are in the preliminary stages of a multi-year study aimed at exploring the effectiveness of a formal, makerspace-based course in increasing engineering retention among first-year undergraduate, engineering students. Specifically, the study explores the impact of the *interest-in-engineering* (IIE) construct on engineering student retention by examining how students' experiences in a formal makerspace-based course can influence their interests in course features and engineering in general. The aforementioned makerspace course is titled *Engineering Methods, Tools, and Practice II* (ENGR 111) [1-7], and centers around a suite of hands-on, active learning-based activities focused on multiple institutionally identified fundamental engineering skills. Preliminary results show that ENGR 111 has a positive influence on student interest [4]; however, more research is needed to understand the impact and the causal mechanisms of this intervention.

The conceptual framework for our multi-year study is shown in Figure 1. While the latter phase focuses on the more desirable long-term student retention in the J. B. Speed School of Engineering program, the focus of this paper is predominantly on the first research question (RQ1A) shown in the project's first phase focused on interest and first-year retention: *What features of the makerspace course promote students' situational interest in engineering?* This paper also includes some additional discussion related to partial assessment specific to RQ4 (Figure 1): *How does triggered interest stimulated by ENGR 111 contribute to maintained interest in engineering?*

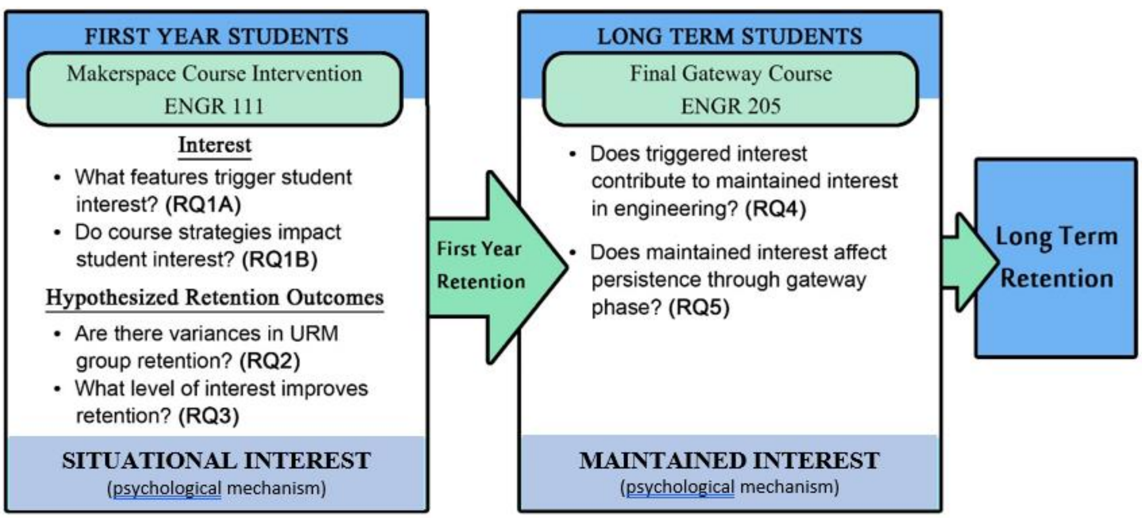

Figure 1. The overall conceptual framework has two phases. The first phase focuses on interest triggered by the first-year makerspace course. The second phase focuses on maintained interest further into academic career(s).

1.2 Interest in Engineering and Potential Significance in Student Retention

Increasing the quantity of graduating engineers is challenging because factors associated with engineering student retention are multifaceted and not thoroughly understood [8-9]. In addition to individual aptitude and work ethics, researchers have identified other individual psychological constructs that play an influential role in retention rates among engineers [e.g., 10]. One of the psychological constructs that have been identified as a key factor in student persistence in engineering is motivation.

Researchers have identified several types of motivational factors (e.g., sense of belonging) initiated via the expectancy-value theory of motivation [11-13]. In its simplest form, the theory postulates that decisions to continue in activities, such as earning an engineering degree, are formed by beliefs in competency and value. Competency beliefs are defined as individual expectations of success, and encompass one's belief as to how well one will perform in a given activity or task [11]. Competency beliefs are frequently grounded in self-efficacy theory [14], which mediates the connection between positive feedback and better academic achievement [15]. While competency beliefs focus on a person's ability to do a task or engage in an activity, value beliefs focus on an individual's desire to engage (or the relevance of engaging) in an activity or task. Key retention barriers associated with value beliefs include perceptions of attainment value, utility value, and interest value, which is the motivational construct under investigation in this study. In the current study, interest refers to "student beliefs related to the enjoyability, significance and/or usefulness of engineering". This definition of interest includes student perception(s) related to the level of pleasure experienced in conducting engineering-related tasks or activities, and/or the level of pride associated with becoming a professional engineer.

There are several reasons why the authors have chosen the interest motivational factor as the focal point of this study. One investigation at UofL identified interest as the primary barrier for J. B. Speed School of Engineering students [16]. In that study, it was found that magnitude of interest is a critical predictor for J. B. Speed School of Engineering first-year retention. In another study conducted with J. B. Speed School of Engineering students [17], first-year engineering students were instructed to respond to nine different motivational factors and rank the top three they considered when deciding on what career to pursue. The interest factor was ranked first by the majority of the students, and was present in the top three for the highest percentage of students. Another J. B. Speed School of Engineering study [18], focused exclusively on the effects of interest in engineering on first-year retention, found that out of the top three factors influencing students' decisions to study engineering (i.e., interest in engineering, job availability, and good pay), interest in engineering was the only construct specified as a reason students drop-out of the school of engineering. In addition, first-year J. B. Speed School of Engineering students were categorically grouped to inform a 2x2 matrix: first-year students with below-average versus above-average GPA, and first-year students with low versus high (mean-split) engineering interest. For students with above-average GPAs, there was a 27% increase in retention for those with high interest (versus low interest), while for students with below-average GPAs, there was a 40% increase in retention for students with high interest (versus low interest) in engineering. While these studies focused on J. B. Speed School of Engineering students, the significance of the interest construct extends to engineering programs nationwide [10, 13, 19-24].

Many theorists have historically separated the construct of interest into two separate domains: ***situational interest*** and ***maintained interest***. Situational interest is specific to an immediate response(s) and is *triggered* directly via an immediate pedagogical feature [25-28]. In contrast, maintained interest is *sustained and long-term interest* within the individual across pedagogical settings [29-32], and is consequently a more effective indicator for predicting longer-term engineering student retention. We recognize that others use labels such as "individual interest" rather than "maintained interest" in reference to the same construct, or "triggered interest" rather than "situational interest" to refer to interest immediately generated or triggered by a specific experience. For this paper, we will use the terms ***situational interest*** for short-term, context-dependent triggered interest and ***maintained interest*** for long-term individual interest (as highlighted in Figure 1).

1.3 A Formal Makerspace Course

While makerspaces have excited considerable attention within academia, much of the research on makerspace impacts and practices has focused on K-12 and informal education. Makerspaces represent ideal sites for active learning pedagogy, and studies have shown that an active learning environment produces strong indications of success and increased retention rates in engineering [33-35]. However, little is known about how a ***well-designed, makerspace-based, undergraduate engineering course*** can address barriers to first-year students' persistence in engineering. Institutions that do not have the advantage of makerspace resource(s) could still benefit from such studies by an increased understanding of the impact that interest in engineering has on student retention.

The makerspace movement provides an excellent opportunity for students to develop their interests and identities [36]. Dougherty [37] declares that the term "maker" is universal and essential to human identity, "describing each one of us, no matter how we live our lives or what our goals might be". Informal makerspaces offer opportunities for participants to engage in engineering practices and knowledge in creative ways [38], and they have been found to be widely effective [39]. Not only do makerspaces offer opportunities for young people to engage in engineering practices and knowledge in creative ways [38], but makerspaces also offer great potential in serving broader goals of education [36, 40-42], such as the critical goal of augmenting first-year engineering retention. Some institutions utilize makerspaces as a means to offer training and/or teaching new skills and/or knowledge [43]. For quite some time now, many colleges have provided makerspace-analogous functionalities, including assembly/testing areas, machine shops, Computer Aided Design laboratories, and/or classrooms. What universities often lack is the inclusion of all of these elements in one location [44]. For campuses that do implement such centralized accommodations, the majority of these makerspaces are utilized predominantly for *informal* settings rather than as a required program course.

However, in contrast to informal makerspaces for the public or K-12 students, little is known about formal makerspace experiences for undergraduates. A common reason students pursue engineering is because they enjoy the process of creation and the ability to work with their hands [45]. A formal makerspace experience would systematically allow *all* students to engage in those activities, with the potential to address motivational barriers in a way that traditional courses and labs cannot do, where the emphasis tends to be on GPA. Likewise, makerspaces provide students a tangible means of visualizing how problems can be solved in a way they would not see on paper, when the critical engineering skill of problem-solving can get lost amid memorization and anxiety. While research in college retention has focused on integration into the university, research in engineering retention has focused more on integration into the engineering culture [14]; thereby making a formal makerspace environment an ideal means of intervention for addressing first-year engineering retention barriers. Utilizing a makerspace for housing an introductory course in engineering, such as ENGR 111, fosters a *formal* setting that systematically can impact the entire range of engineering students.

Several years ago, J. B. Speed School of Engineering redesigned the school's existing courses focused on introducing first-year students to the profession and fundamentals of engineering [1-3], resulting in a two-course sequence that all first-year J. B. Speed School of Engineering students (approx. 350-450 students per year) are required to take. The first course in this sequence, *Engineering Methods, Tools, & Practice I* (ENGR 110), is a classroom-based course and is primarily focused on introduction to, and practice with, fundamental engineering skills. The second course, *Engineering Methods, Tools, and Practice II* (ENGR 111), is taught in a 15,000 ft^2, well-equipped makerspace. This course is primarily focused on application and integration of the fundamental skills, many of which are introduced in ENGR 110, through active participation in a structured team around salient engineering challenges. Course instruction, activities, and deliverables have been designed to augment student practice of essential engineering skills while at the same time scaffolding progression towards a comprehensive Cornerstone Project(s) that all students present at the end of the semester. ENGR 111 features a high level of faculty interaction with students during class time, with a minimum of five personnel (a combination of faculty and teaching assistants) manning six different course sections of 60-90 students per section. ENGR 111 exclusively employs various forms of active learning, including collaborative, cooperative, problem-based, project-based, and discovery-based learning [46-54]. The course includes numerous features that have the potential to increase student interest in engineering.

1.4 The Current Study

Taken together, we hypothesize that course features studied in J. B. Speed School of Engineering's ENGR 111 (see Table 1) will be positively associated with students' maintained interest in engineering (RQ4), and that some features (and associated instructional methodology) may have more impact on engineering interest than others (RQ 1A). Specific course features under investigation are specified below in Table 1.

2. Methods

2.1 Participants

The sample included 314 first-year, undergraduate students who were enrolled in the ENGR 111 course in the Spring of 2022. Participants' age ranged from 18 to 36 (M = 19.99; SD = 2.46), Among the 314 participants, 67 (21.3%) identified as female, 223 (71.0%) male, and 24 (7.6%) did not specify. Regarding racial identity, 16 (5.1%) participants identified as Latinx/Hispanic, 10 (3.2%) Black/African American, 19 (6.1%) Asian, 17 (5.4%) multiracial, 223 (71.0%) white, and 29 (9.2%) did not specify.

2.2 Measures

2.2.1 Maintained Interest

The 8-item Individual Interest Scale [55] was adapted in the current study by modifying "math" to "engineering". Sample item include "It is important for me to be a person who reasons as an engineer." Items are measured on a 5-point Likert-type scale ranging from 1 (*not true at all*) to 5 (*completely true*). Mean scores were created for the scale and higher scores indicate greater overall interest in engineering. In the current study, Cronbach's alpha for the scale was 0.91.

2.2.2 Situational Interest

The 12-item Situational Interest Survey [55] is a three-factor scale that assesses an individual's situational interest across various academic settings. The Situational Interest Survey was adapted in the current study by using two items from each factor (i.e., triggered, maintained-feeling, and maintained-value) to develop a brief six-item scale for each specific course feature being assessed. A sample item for the technical writing feature includes "Class work on technical writing makes engineering more exciting." Items are measured on a 5-point Likert-type scale ranging from 1 (*not true at all*) to 5 (*completely true*). Mean scores were created for each scale and higher scores indicate greater situational interest in that specific course feature. In the current study, Cronbach's alpha was 0.86 for technical writing, 0.82 hand tool usage, 0.92 for 3D modeling, 0.94 for 3D printing, 0.92 for circuitry, and 0.94 for programming.

To explore course-related features and experiences that extend across the entire course rather than being constrained to a relatively short window (week or two) within the course, participants also responded at the end of the course to items assessing: (a) engineering design features (i.e., open nature, iterative nature, problem-solving nature); (b) personal satisfaction in proficiency (for applicable course features technical writing, 3D modeling, circuitry, programming); and (c) teamwork. Items for each of these 3 cross-course measures are structured on a 5-point Likert-type scale ranging from 1 *(interest greatly decreased)* to 5 (*interest greatly increased*).

2.3 Procedure

Undergraduate students enrolled in ENGR 111 during the spring semester of 2022 were invited to participate in the study at the beginning of the semester. Potential participants who wished to participate in the study conveyed their consent by signing and returning the consent form. If students chose to not participate in study dissemination inclusion, their data were not included in the final dataset for analysis and publishing purposes. At times throughout the semester (January 2022 to April 2022) immediately after students concluded practice and/or activities related to a specific course feature, they completed a short feature-specific survey aligned with that feature as discussed in the previous subsection (2.2.2). Surveys were electronically administered via online course modules. More specifically, in an attempt to alleviate potential student survey fatigue and to capture specific situational interest in a given feature, these short surveys (6 items) about each course feature were administered immediately after practice and engagement in that task. For those course experiences that spanned the entire course, surveys pertaining to those features were administered closer to the end of the course. The survey concerning maintained interest was administered upon completion of the course.

Table 1 provides further detail for each course feature under investigation, and when (situational interest) survey(s) for respective features were administered. Specific survey items related to maintained interest and situational interest (for course features shown in Table 1) are shown in Appendices A and B, respectively. Although introduction and practice in Engineering Design (ED) commenced relatively earlier in the semester, related situational interest surveys in ED subfactors were not administered until immediately after the final iteration for the final course design challenge was due (several weeks later closer to the end of the semester); in order to procure student perceptions upon experience engaging in each of the ED subfactors (specified in Table 3) while practicing the ED process during the aforementioned timeframe. Surveys related to personal satisfaction (Table 4) were also administered late in the semester, allotting maximum time for students to develop proficiency before providing related feedback. Finally, the same situational interest survey pertaining to teamwork was administered twice during the semester. This is because the ENGR 111 course was designed in a scaffolded manner with respect to teamwork dynamics; that is, effective teamwork dynamics become more critical with progression through the semester. Accordingly, and thusly providing a more nuanced assessment of the potential impact of teamwork on interest in engineering, the first survey related to teamwork was presented during the early course stages while the second was given during the latter stages.

Table 1. Details on respective course features for which situational interest surveys were administered, including the semester week when surveys were taken in addition to respective course survey item reference locations.

<table>
<tr><th>Course Feature</th><th>Survey Week</th><th>Survey Items</th></tr>
<tr><td>Technical Writing</td><td>1</td><td rowspan="7">See Appendix B</td></tr>
<tr><td>Hand Tool Usage</td><td>3</td></tr>
<tr><td>Circuitry</td><td>6</td></tr>
<tr><td>3D Modeling</td><td>7</td></tr>
<tr><td>Circuitry</td><td>6</td></tr>
<tr><td>3D Printing</td><td>8</td></tr>
<tr><td>Programming</td><td>10</td></tr>
<tr><td>Teamwork #1</td><td>7</td><td rowspan="2">See Table 5</td></tr>
<tr><td>Teamwork #2</td><td>12</td></tr>
<tr><td>Engineering Design: Open-Ended Nature</td><td rowspan="3">11</td><td rowspan="3">See Table 3</td></tr>
<tr><td>Engineering Design: Iterative Nature</td></tr>
<tr><td>Engineering Design: Problem Solving Nature</td></tr>
<tr><td>Personal Satisfaction: Technical Writing</td><td rowspan="4">14</td><td rowspan="4">See Table 4</td></tr>
<tr><td>Personal Satisfaction: 3D Modeling</td></tr>
<tr><td>Personal Satisfaction: Circuitry</td></tr>
<tr><td>Personal Satisfaction: Programming</td></tr>
</table>

3. Results

3.1 Data Management

A total of 366 students completed the surveys. After removing cases for non-consent (*N* = 12; 3.28%), low response rate[1] (*N* = 39; 10.66%), and inconsistent responding[2] (*N* = 1; 0.27%), the final dataset consisted of 314 cases. Due to a significant number of participants not responding to the situational interest 3D printing survey items (*N* = 87; 27.8%), the 3D printing variable was removed from analyses. A Little's MCAR test was conducted on the final dataset to test for the randomness of missing data. Results suggest that missing data were missing at random; χ^2 (4449) = 4386.39, $p = .745$. Thus, imputation was not necessary.

[1] A 75% benchmark was used to determine low response rate. Only cases with 47 or more completed items (out of a total of 63 items) were retained in the final dataset.
[2] e.g. All survey items were rated 5.

3.2 Descriptive Statistics

The means, standard deviations, intercorrelations, and reliability coefficients for maintained interest and situational interest features are shown in Table 2. A visual check of histograms showed that all maintained interest and situational interest features appear normally distributed with no significant outliers present. The mean score for hand tool usage was the highest (M = 4.44, SD = 0.56), whereas technical writing was the lowest (M = 3.40, SD = 0.77). All situational interest features are shown to be significantly correlated to maintained interest in engineering. 3D modelling was most strongly and positively correlated with maintained interest in engineering (r = .41, p <.05). Cronbach's alpha of all continuous variables ranged between .82 and .94, which suggests an acceptable level of reliability for the purpose of our exploratory study.

Table 2. Descriptive Statistics and Intercorrelations for Maintained Interest and Situational Interest Variables.

Features	*N*	*M*	*SD*	1	2	3	4	5	6
1. MI – Engineering	312	4.09	0.67	(.91)					
2. SI – Technical Writing	297	3.40	0.77	.29*	(.86)				
3. SI – Hand Tool Usage	302	4.44	0.56	.35*	.28*	(.82)			
4. SI – 3D Modeling	283	4.17	0.80	.41*	.33*	.43*	(.92)		
5. SI – Circuitry	305	4.05	0.82	.37*	.20*	.34*	.35*	(.92)	
6. SI – Programming	284	3.77	1.01	.23*	.15*	.10	.23*	.39*	(.94)

Note. Reliability coefficients are represented in the diagonals in parentheses. MI = Maintained Interest; SI = Situational Interest.

*p < .05.

3.3 Effects of Gender, Race, and Age on Maintained Interest in Engineering

Prior to running the analysis, gender was recoded into female = 1 and male = 2 and race was recoded into racially marginalized identity (i.e., Asian, Black/African American, Latinx, multiracial) = 1 and white = 2. One-way analysis of variance was conducted to check for potential differences in maintained interest based on gender and race. Using Levene's Test, the assumption of homogeneity of variances was met for both gender (F (1, 284) = 2.61, p = 0.107) and race (F (1, 283) = 0.10, p = 0.755). Results showed that the effect of gender (F(1, 284) = 0.57, p = 0.451) and race (F(1, 283) = 0.885, p = 0.348) were not statistically significant for maintained interest in engineering. Next, a bivariate correlation was conducted to test the relation between age and maintained interest. Results demonstrated that there is no statistical significance between age and maintained interest; r = 0.08, p = 0.185.

3.4 Effects of Situational Interest on Maintained Interest in Engineering

Multiple linear regression was conducted to examine the effects of situational interest of makerspace features on maintained interest in engineering. Prior to running the analysis, all variables were converted from raw scores into z-scores (standardized). In this regression, maintained interest in engineering was assigned as the dependent variable, and situational interest variables (i.e., technical writing, hand tool usage, 3D modelling, circuitry, programming) as predictor variables.

A visual inspection of the histograms showed a relatively normal distribution of data for all predictor variables, indicating that the assumption of normality was met. Next, a visual inspection of the histogram of residuals and P-P plot showed that the residuals were normally distributed, and the observed values hover close to the regression line (between +/-3) respectively, indicating that the assumption of normality of residuals was met. The scatterplot of standardized predicted values showed random variation, with no indication of highly influential cases or observations that are not well accounted for in this particular regression model, indicating that the assumption of homoscedasticity and linearity were met. The Durbin-Watson value of 1.97 fell between Field's [56] recommended range of 1.5 and 2.5, which indicates that the assumption of autocollinearity was met. The VIF of all predictor variables fell below Johnston and colleagues [57] recommended value of 2.5, which indicates that the assumption of multicollinearity was met. Lastly, two cases were identified as outliers and removed from the regression analysis due to standard residuals falling outside 3 standard deviations [58].

The overall regression model was statistically significant, F (5, 223) = 20.87, p = <0.001, and accounted for 32% of the variation in maintained interest. The results showed that technical writing (β = 0.15, p = 0.013), hand tool usage (β = 0.15, p = 0.012), 3D modeling (β = 0.23, p = <0.001), and circuitry (β = 0.21, p = 0.002) significantly explained the variance in engineering maintained interest, with 3D modeling having the strongest effect on maintained interest. Programming, however, did not significantly predict maintained interest in engineering (β = 0.10, p = 0.097).

3.5 Effects of Course-Related Factors on Interest in Engineering

Tables 3 to 5 show the number of participants who endorsed negative, positive, or no changes in engineering interest for the following course-related factors: engineering design features, personal satisfaction in proficiency, and teamwork. Negative change consisted of response ratings 1 (interest greatly decreased) and 2 (interest somewhat decreased); no change consisted of response rating 3 (no change in interest); and positive change consisted of response ratings 4 (interest somewhat increased) and 5 (interest greatly increased).

Taken together, the majority of participants reported an increase in their engineering interest for all course-related factors. The problem-solving nature of engineering design (Table 3) and personal satisfaction in 3D modeling proficiency (Table 4), received the highest report of positive change in engineering interest in their respective factor. Trends related to endorsement of negative, positive, or no changes in interest due to teamwork were analogous despite these respective surveys being conducted at times during the semester when variance in teamwork dependence were significant.

Table 3. My interest in the engineering profession was strengthened by my ENGR 111 experience in engineering design because of the following related features ($N = 294$).

	Negative Change	No Change	Positive Change
Open-ended nature	8	42	244
Iterative nature	9	62	222
Problem-solving nature	4	34	256

Table 4. My interest in the engineering profession was strengthened in ENGR 111 because of personal satisfaction in becoming more proficient in ($N = 298$).

	Negative Change	No Change	Positive Change
Technical Writing	36	110	152
3D Modelling	14	39	245
Circuitry	22	53	223
Programming	48	80	170

Table 5. My interest in the engineering profession is being strengthened in ENGR 111 because of personal satisfaction in working with my team (teamwork).

	N	Negative Change	No Change	Positive Change
Time 1	303	10	43	250
Time 2	307	8	53	243

4. Further Discussion & Concluding Thoughts

The current study explores the extent to which situational interest, elicited by certain pedagogical features and other course-related factors in a formal makerspace course, contributed to individual interest in engineering. We focused on an introductory engineering course at the J. B. Speed School of Engineering at the University Louisville, titled Engineering Methods, Tools, and Practice II (ENGR 111). ENGR111's course objective is to facilitate the application and integration of fundamental engineering skills. Six feature modules were identified by the course instructors as potential pedagogical features that can activate students' situational interest: technical writing, hand tool usage, 3D modelling, 3D printing, circuitry, and programming. Other course-related factors were also considered, such as, engineering design features, personal satisfaction in proficiency, and teamwork.

The conjecture that situational interest related to course features studied would be positively associated with students' maintained interest in engineering (RQ4) was relatively supported. Most of the course features were statistically significantly associated with maintained interest in engineering, and these results suggest interest triggered by certain course features play a significant role in promoting engineering interest among first-year engineering students.

Course administrators predicted that the technical writing feature would have the lowest mean in interest, which is supported by the current study's results, but not due to confusion and/or frustration resulting from practice in the feature as some may expect. Instead, numerous years of collective experience observing first-year engineering students at J. B. Speed School of Engineering has shown that the technical writing feature is one that the highest percentage of incoming students have had the most prior experience in. Consequently and potentially resulting in scenarios where there is little potential for triggering interest in a feature that one is already quite comfortable and familiar with. Generally, course administrators have observed that incoming students broadly fall into two different categories with respect to potential interest in a respective feature: 1) those that have prior experience/proficiency in a given feature that may find ENGR 111 pedagogy too elementary, and 2) those intimidated by the prospect of tackling a new feature that they personally feel they can never become proficient in, and frustration in practice can further exacerbate the intimidation.

The highest correlation coefficients shown in Table 2 (3D Modeling in conjunction with Hand Tool Usage at 0.43, and Programming in conjunction with Circuitry at 0.39) can also be explained by the interrelated nature of these paired features. Tasks involving 3D modeling, such as dimensioning, are dependent on various tool usage, such as dial calipers. Similarly, the more challenging tasks related to programming in the course could not be executed without effectively integrated circuitry.

The higher mean in interest for 3D Modeling (4.17) versus Programming (3.77) was collectively surprising for the authors, as equivalent levels of struggles, frustrations, or the like with these skills have been historically observed (thus expectation was that these means would be closer in value). Table 4 further reinforces the difference in interest for these two features (3D Modeling had the highest reported *positive* change in interest, while Programming had the highest *negative* change in interest). Several related postulates have been presented in response to these results. One possibility involves the timing of when respective situational interest surveys are administered. There is considerably more practice in 3D modeling prior to survey conduction versus programming, and it is possible this results, as mentioned above, in a higher level of comfort in turn a higher level of interest. Alternately, in consideration of potential confidence/frustration in proficiency, challenges associated with 3D modeling can be more tangibly realized – that is, there is an associated visual element that augments error identification. Errors in programming algorithms, on the other hand, are more often much more difficult to troubleshoot and/or resolve. Yet a standard deviation in the Programming interest mean of 1.01 suggests polarized levels of interest, and the authors are hopeful that qualitative responses (discussed below) to these surveys will shed light on potential future pedagogical strategies that can be employed to further enhance collective interest in programming.
The results shown in Table 3 related to the subfactors of engineering design and their associated situational interest for students are encouraging in that a high level of positive change in interest was attributed to each. This provides further confirmation that inclusion of open-ended, iterative, and problem-solving components in engineering design challenges has value in further enhancing student interest in this particular feature. Course administrators are also pleased that the implementation of more challenging team dynamics in conjunction with semester progression appears to have no deleterious impact on student situational interest in teamwork itself (Table 5).

It is pertinent to mention that a second year (Spring 2023 ENGR 111 cohort) of data collection identical to the methods laid out in this paper is currently ongoing. Upon completion of associated data collection, related analysis will be similarly and separately assessed and compared to the initial results shared in this paper; followed by a combination of all data from both years and reassessment. Qualitative queries were also included amongst respective quantitative for all situational interest surveys discussed above. Associated qualitative response analysis is still ongoing and thus did not fall within the scope of the study results reported in this paper, yet it is certainly expected that completion of this analysis will further highlight and/or confirm conclusions related to the quantitative results shown in this paper. One final note is that the methods and results shown related to RQ4 are only partially representative of the full research design developed for this question. Specifically, the maintained interest survey discussed above and administered at the end of the ENGR 111 experience is also taken by students at the end of the previous semester, effectively providing pre- and post-measures in maintained interest (with respect to ENGR 111). This will allow creation of a new variable that will account for any student-level change relative to the growth proportional available from the starting "pre" level (proportional increase will be the dependent variable), and is expected to provide an even more nuanced assessment of this research question.

Appendix A

Scale: Individual Interest Scale [55]
Response Rating: 5-point Likert Scale (5 = Completely True, 4 = Very True, 3 = Somewhat True, 2 = Slightly True, 1 = Not True at All)

1. Engineering is practical for me to know.
2. Engineering helps me in my daily life outside of school.
3. It is important for me to be a person who reasons as an engineer.
4. Thinking as an engineer is an important part of who I am.
5. I enjoy the subject of engineering.
6. I like engineering.
7. I enjoy doing engineering.
8. Engineering is exciting to me.

Appendix B

Scale: Situational Interest Scale [55]
Response Rating: 5-point Likert Scale (5 = Completely True, 4 = Very True, 3 = Somewhat True, 2 = Slightly True, 1 = Not True at All)

TI1. When we learn about ____ in ENGR 111, related instruction and activities grabbed my attention.
TI2. Class work on ____ makes engineering more exciting.
MF1. I look forward to continuing practice with ____ because I find it engaging.
MF2. I found the tasks I did in ENGR 111 related to ____ to be interesting.
MV3. ____ is a worthwhile topic to me because it is useful for the engineering profession.
MV4. ENGR 111 was effective in conveying the value of ____ skills in engineering.

References

[1] Robinson, B., Thompson, A., Eisenmenger, G., Hieb, J., Lewis, J. E., & Ralston, P. (2015). Redesigning the First-Year Experience for Engineering Undergraduates. In *Proceedings of the 7th First Year Engineering Experience (FYEE) Conference*.

[2] Robinson, B. S., McNeil, J., Thompson, A., & Ralston, P. (2016, July). Continued Development and Implementation of a Two-Course Sequence Designed to Transform the First-Year Experience for Engineering Undergraduates. In *FYEE Annual Conference The Ohio State University Columbus, Ohio*.

[3] Robinson, B. S., & Hawkins, N., & Lewis, J. E., & Foreman, J. C. (2019, June), *Creation, Development, and Delivery of a New Interactive First-Year Introduction to Engineering Course* Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida. https://peer.asee.org/32564

[4] Robinson BS**,** Lewis JE, Hawkins, NA, & Tinnell, TL. "Addressing First-Year Interest in Engineering via a Makerspace-Based Introduction to Engineering Course," ASEE 127th Annual Conference & Exposition, Virtual, June 21-25, 2020.

[5] Hawkins, NA, Robinson BS, & Lewis JE. "Employment of Active Learning Pedagogy Throughout a Makerspace-Based, First-Year Introduction to Engineering Course," ASEE 127th Annual Conference & Exposition, Virtual, June 21-25, 2020.

[6] Lewis JE, Robinson BS, & Hawkins, NA. "First-Year Engineering Student Perceptions in Programming Self-Efficacy and the Effectiveness of Associated Pedagogy Delivered via an Introductory, Two-Course Sequence in Engineering," ASEE 127th Annual Conference & Exposition, Virtual, June 21-25, 2020.

[7] Robinson, B., Lewis, J., & Hawkins, N., & Tretter, T., & Chan, F. B. (2022, August), *Converting a First-Year Engineering, Makerspace Course into COVID-Necessitated Fully-Online Synchronous Delivery and Related Student Perceptions* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/41024

[8] Eris, O., Chachra, D., Chen, H., Rosca, C., Ludlow, L., Sheppard, S., & Donaldson, K. (2007, June). A preliminary analysis of correlates of engineering persistence: Results from a longitudinal study. In *Proceedings of the American society for engineering education annual conference* (pp. 24-27).

[9] Lichtenstein, G., Loshbaugh, H., Claar, B., Bailey, T., & Sheppard, S. (2007, June). Should I stay or should I go? Engineering students' persistence is based on little experience or data. In *Proceedings of the American Society for Engineering Education Annual Conference* (pp. 24-27).

[10] Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving* (p. 134). Westview Press, Boulder, CO.

[11] Eccles, J. (1983). Expectancies, values and academic behaviors. *Achievement and achievement motives*.

[12] Eccles, J. S. (2005). Subjective task value and the Eccles et al. model of achievement-related choices. *Handbook of competence and motivation*, 105-121.

[13] Eccles, J. S. (2007). Families, schools, and developing achievement-related motivations and engagement.

[14] Matusovich, H. M., Streveler, R. A., & Miller, R. L. (2010). Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values. *Journal of Engineering Education*, *99*(4), 289-303.

[15] Alias, M., & Hafir, N. A. H. M. (2009). The relationship between academic self-confidence and cognitive performance among engineering students. In *Proceedings of the Research in Engineering Education Symposium* (pp. 1-6).

[16] Tinnell, T. L., & Bego, C. R., & Ralston, P. A., & Hieb, J. L. (2019, June), *An Interdisciplinary Research Group's Collaboration to Understand First-Year Engineering Retention* Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. https://peer.asee.org/32073

[17] Honken, N. B., & Ralston, P. (2013). Freshman engineering retention: A holistic look. *Journal of STEM Education: Innovations and Research*, *14*(2).

[18] Honken, N., Ralston, P.A., & Tretter, T.R. (2016). Step-Outs to Stars: Engineering Retention Framework.

[19] Jones, B. D., Paretti, M. C., Hein, S. F., & Knott, T. W. (2010). An analysis of motivation constructs with first-year engineering students: Relationships among expectancies, values, achievement, and career plans. *Journal of engineering education*, *99*(4), 319-336.

[20] Eccles, J. (1984a). Sex differences in achievement patterns. In *Nebraska symposium on motivation*. University of Nebraska Press.

[21] Eccles, J. S. (1984b). Sex differences in mathematics participation. *Advances in motivation and achievement*, *2*, 93-137.

[22] Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of educational psychology*, *82*(1), 60.

[23] Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child development*, *78*(1), 246-263.

[24] Shuman, L. J., Delaney, C., Wolfe, H., Scalise, A., & Besterfield-Sacre, M. (1999). Engineering attrition: Student characteristics and educational initiatives. In *Proceedings of the American Society of Engineering Education* (pp. 1-12).

[25] Hidi, S., & Baird, W. (1986). Interestingness—A neglected variable in discourse processing. *Cognitive science*, *10*(2), 179-194.

[26] Hidi, S., & Anderson, V. (1992). Situational interest and its impact on reading and expository writing. *The role of interest in learning and development*, *11*, 213-214.

[27] Krapp, A. (2004). 18: An Educational-Psychological Theory of Interest and Its Relation to SDT. *Handbook of self-determination research*, 405.

[28] Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational psychologist*, *41*(2), 111-127.

[29] Schiefele, U. (1991). Interest, learning, and motivation. *Educational psychologist*, *26*(3-4), 299-323.

[30] Renninger, K. A., Hidi, S., Krapp, A., & Renninger, A. (Eds.). (2014). *The role of interest in learning and development*. Psychology Press.

[31] Rathunde, K. (1993). The experience of interest: A theoretical and empirical look at its role in adolescent talent development. *Advances in motivation and achievement*, *8*, 59-98.

[32] Renninger, K. A. (2000). Individual interest and its implications for understanding intrinsic motivation. In *Intrinsic and extrinsic motivation* (pp. 373-404). Academic Press.

[33] Tinto, V. (1993). Leaving college rethinking the causes and cures of student attrition.: The University of Chicago. *Chicago, IL*.

[34] Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1998). Engineering student attitudes assessment. *Journal of Engineering Education*, *87*(2), 133-141.

[35] Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. (2000). The future of engineering education II. Teaching methods that work. *Chemical engineering education*, *34*(1), 26-39.

[36] Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *5*(1), 4.

[37] Dougherty, D. (2012). The maker movement. *Innovations: Technology, governance, globalization*, *7*(3), 11-14.

[38] Barton, A. C., Tan, E., & Greenberg, D. (2016). The makerspace movement: Sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. *Teachers College Record*, *119*(6), 11-44.

[39] Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2017). Empirical studies on the Maker Movement, a promising approach to learning: A literature review. *Entertainment Computing*, *18*, 57-78.

[40] Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard educational review*, *84*(4), 495-504.

[41] Vossoughi, S., & Bevan, B. (2014). Making and tinkering: A review of the literature. *National Research Council Committee on Out of School Time STEM*, 1-55.

[42] Martin, L., Dixon, C., & Betser, S. (2018). Iterative design toward equity: Youth repertoires of practice in a high school maker space. *Equity & Excellence in Education*, *51*(1), 36-47.

[43] Hsu, Y. C., Baldwin, S., & Ching, Y. H. (2017). Learning through making and maker education. *TechTrends*, *61*(6), 589-594.

[44] Wilczynski, V. (2015). Academic maker spaces and engineering design. In *American Society for Engineering Education* (Vol. 26, p. 1).

[45] Bucks, G. W., Ossman, K. A., Kastner, J., & Boerio, F. J. (2015, June). First-year engineering courses effect on retention and workplace performance. In *Proceedings of the 122nd ASEE Annual Conference and Exposition, Seattle, WA.*

[46] Millis, B. J., & Cottell Jr, P. G. (1997). *Cooperative Learning for Higher Education Faculty. Series on Higher Education*. Oryx Press, PO Box 33889, Phoenix, AZ 85067-3889.

[47] Feden, P. D., & Vogel, R. M. (2003). *Methods of teaching: Applying cognitive science to promote student learning*. McGraw-Hill Humanities, Social Sciences & World Languages.

[48] Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of engineering education*, *94*(1), 87-101.

[49] Prince, M. (2004). Does active learning work? A review of the research. *Journal of engineering education*, *93*(3), 223-231.

[50] Aglan, H. A., & Ali, S. F. (1996). Hands-on experiences: An integral part of engineering curriculum reform. *Journal of Engineering Education*, *85*(4), 327-330.

[51] Giralt, F., Herrero, J., Grau, F. X., Alabart, J. R., & Medir, M. (2000). Two way integration of engineering education through a design project. *Journal of Engineering Education*, *89*(2), 219-229.

[52] Cronk, S., Hall, D., & Nelson, J. (2009, March). Living with the Lab: A Project-Based Curriculum for First-Year Engineering Students. In *Proceedings of the 2009 ASEE Gulf-Southwest Annual Conference*.

[53] Etkina, E., & Van Heuvelen, A. (2001). Investigative Science Learning Environment: Using the processes of science and cognitive strategies to learn physics. In *Proceedings of the 2001 physics education research conference* (pp. 17-21). Rochester, NY.

[54] Etkina, E., & Van Heuvelen, A. (2007). Investigative science learning environment–A science process approach to learning physics. *Research-based reform of university physics*, *1*(1), 1-48.

[55] Linnenbrink-Garcia, L., Durik, A. M., Conley, A. M., Barron, K. E., Tauer, J. M., Karabenick, S. A., & Harackiewicz, J. M. (2010). Measuring situational interest in academic domains. *Educational and psychological measurement*, *70*(4), 647-671.

[56] Field, A. (2009). Discovering statistics using SPSS, third edition. Sage Publications.

[57] Johnston, R., Jones, K., & Manley, D. (2018). Confounding and collinearity in regression analysis: a cautionary tale and an alternative procedure, illustrated by studies of British voting behaviour. *Quality & quantity*, *52*(4), 1957-1976.

[58] Montgomery, D. C., Peck, E. A., & Vining, G. G. (2013). *Introduction to linear regression analysis, fifth edition*. John Wiley & Sons.