Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #47039

Impact of an Introductory, Makerspace-Based Engineering Course on First-Year Retention

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Abstract

This complete evidence-based practice paper focuses on the impact an introductory, makerspace course has on engineering student retention. The course, titled *Engineering Methods, Tools, & Practice II* (ENGR 111), is a requisite for all J.B. Speed School of Engineering first-year engineering students, features integration and application of institutionally-identified fundamental engineering topics (first introduced and practiced in prerequisite *Engineering Methods, Tools, & Practice I*), and takes place in a 15,000 square foot facility located on the University of Louisville's campus. ENGR 111 was inaugurated in the Spring 2017 semester, and primary course iterations have occurred during every spring semester since.

One research-cited reason that collegiate students leave engineering is a lack of engineering-related experiences during the first year of the program. Conventional first-year engineering curricula require students to complete multiple gateway courses prior to beginning disciplinary coursework. These courses oftentimes deal with abstract material with little perceived engineering context. As a result, students end up believing that all engineering courses will be similar, and some ultimately leave for other professional arenas where applications can be understood much earlier in academic career(s). A key motivating factor in developing ENGR 111 was to augment student desire to persist in engineering degree pursuit, by providing support and context for many of the requisite gateway courses and to provide a more substantial engineering-related experience.

Starting in the Spring 2019 semester and included in every subsequent course semester up to present day (thus providing a large sample size of thousands of responses), ENGR 111 students were surveyed on this topic at the end of the semester(s). Specifically, students were asked: *To what extent do you intend to keep pursuing an engineering major?*, via a 10-point Likert scale (10 = *definitely* will and 1 = definitely will *NOT*). This question was then followed up with the following query: *Please indicate below how much (if any) impact your ENGR 111 experience had on the answer you provided on the previous question related to your intent to keep pursuing an engineering major*. Possible responses to this question were ENGR 111 had *no* impact, *somewhat* of an impact, or *significant* impact on the response to the first question on engineering retention.

For each of the five different semesters of ENGR 111 in which data was collected, over 80% of the student body specified high intent (Likert values of 8-10) to continue pursuing an engineering degree. Associated results show evidence for optimism that ENGR 111 is having a positive impact on this aforementioned high desire to persist. Out of nearly 2000 ENGR 111 students over a 6-year period, 78.8% of the students who specified a high intent to continue pursuing their engineering degree also specified ENGR 111 to have *at least* somewhat of an impact on that intent, while nearly one quarter specified their ENGR 111 experience to have a significant impact on their strong desire to persist to earning an engineering degree.

Challenges in First-Year Engineering Retention

For several decades now, there has been a decrease in the number of collegiate students persisting in engineering degree programs [1-2]. Increasing the quantity of graduating engineers is challenging because factors associated with engineering student retention are multifaceted and not thoroughly understood [3-4]. Increasing first-year engineering retention increases the number of engineering students earning undergraduate degrees, yet the first year of engineering undergraduate education presents several hurdles for students [5]. While aptitude and work ethic play a role in effecting retention, research has shown that other individual constructs not only play a very influential role in retention, but are even more meaningful than aptitude and/or work ethic. A large-scale study by Seymour and Hewitt [6], for example, found that students' choices to leave STEM majors were usually not due to poor aptitude or work ethic, but instead were more related to diminished motivation and perspectives on the reason(s) they chose that field in the first place.

One particular factor contributing to this attrition is the nature (e.g., the student feels the course is very difficult, or the course appears unrelated to the student's choice of major) of many first- and second-year gateway courses (such as foundational mathematics and/or science courses) [7], resulting in an undesirably large number of students that fail or drop out [8]. This is certainly true at the University of Louisville's J.B. Speed School of Engineering (SSoE) college, in which engineering-based mathematics courses are taught "in-house" during the first two years of undergraduate engineering programs. Several studies [e.g. 2] have shown that the challenges faced within this math sequence are driving factors in SSoE attrition. While SSoE has made considerable effort to improve these courses to enhance student success, the fact remains that many students find them quite difficult and, on occasion, overwhelmingly challenging. A potential remedy for this issue is the provision of applied engineering-related experiences for first-year students, potentially counteracting the discouragement resulting from some early courses such as the math sequence, making students more likely to persevere through these courses and persist in engineering.

Another key postulate on why first-year engineering students leave their programs is the lack of engineering related experiences in the first year [9]. A large portion of first-year engineering curricula require students to complete various gateway courses prior to beginning discipline-specific studies later in their academic career(s). These courses oftentimes focus on theoretical foundations, with little perceived engineering context for aspiring engineers with limited knowledgebase and/or experience in the field. As a result, students end up believing that all engineering courses will be similar, and some ultimately leave for other professional arenas where applications can be understood much earlier in academic career(s) [10]. One approach in addressing this issue is to send students out into the workforce early in their academic career(s), providing them the benefits of experiencing direct engineering applications in a real-world context. This strategy is often denoted as cooperative education (co-op). Co-op has been shown to improve both student performance and retention [11-12]. The co-op experience is mandated as part of the degree requirements at SSoE.

A Formal, First-Year Makerspace Course in Introductory Engineering

Another proposed strategy in addressing potential first-year engineering student disenchantment, is integration of first-year student curricula that provides support and context for many of the requisite gateway courses. Makerspaces are ideal facilities for fostering pedagogy in active learning and applied engineering, thus resulting in a more substantial engineering-related experience for students early in their academic studies. The makerspace movement furthermore provides an excellent opportunity for students to develop their interests and identities [13]. Not only do makerspaces offer effective opportunities for young people to engage in engineering practices and knowledge in creative ways [14-15], but makerspaces also offer great potential in serving broader goals of education [13, 16-18], 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 [19]. 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.

A common reason students pursue engineering is because they enjoy the process of creation and the ability to work with their hands [20]. A formal, first-year makerspace experience could 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. For example, through a makerspace experience, engineering students could learn that "failure" is not something to be feared. The makerspace environment gives students an outlet to learn that failure is a part of the learning process rather than an indication of lack of ability. Perceived failure should not be considered an obvious sign that engineering isn't a good fit, thus resulting in leaving the program. 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 [21]; thereby making a formal makerspace environment an ideal means of intervention for addressing first-year engineering retention barriers.

In the fall of 2014, SSoE redesigned the school's existing courses focused on introducing first-year students to the profession and fundamentals of engineering [22-24], resulting in a two-course sequence (2 credit-hours each) that all first-year SSoE students (approx. 350-450 students per year) are required to take. Motivating factors for this programmatic restructure included desire to improve the first-year experience via a newly opened makerspace on the university campus, to provide a common first year experience for all SSoE students, to boost student potential for success in subsequent courses, and to deliver a more substantial, realistic first-year exposure to the engineering design process. 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 called the Engineering Garage (EG). ENGR 111 is primarily focused on application and integration of the fundamental skills introduced in ENGR 110 through active participation in a structured team around salient engineering challenges. The only prerequisite for

ENGR 111 is ENGR 110. Although students start SSoE under a variety of math level preparation (SSoE does have criteria pertaining to minimum ACT/SAT/Accuplacer mathematical requirements for admission), ENGR 111 has been intentionally structured to accommodate the full range of student possible math level preparation. Utilizing a makerspace for housing an introductory course in engineering, such as ENGR 111, fosters a formal setting that can systematically impact the entire range of first-year SSoE engineering students. The first iteration of ENGR 111 was launch in Spring 2017.

As previously stated, co-op rotations are an integrated component of the degree requirements at SSoE, yet all SSoE coops don't start until *after* the first year. Thus ENGR 111 is an ideal first-year supplement to impending coop experience(s). Accordingly, course development, implementation, maintenance, and modification have continuously been conducted with a primary objective to provide support and context for the aforementioned requisite gateway courses and to provide more substantial engineering-related experiences [10]. Use of these strategies has been shown to improve retention of students in engineering fields [25], and ENGR 111 employs such methodology. ENGR 111 also employs various forms of active learning, including collaborative, cooperative, problem-based, project-based, and discovery-based learning. Studies have shown that an active learning environment produces strong indications of success and increased retention rates in engineering [26-28]. Furthermore, the nature of ENGR 111 has provided an excellent platform for various institutional faculty to conduct research in engineering education. Since course inception, numerous related research have been disseminated, including studies in teamwork pedagogy [29], active learning [30], value-expectancy theory [31-33], programming [34-36], circuitry [38], and articles (SSoE best paper awardee) on the challenges and successes of conducting the course via remote delivery at the height of the COVID-19 pandemic [38-39].

ENGR 111 course instruction, activities, and deliverables have been designed to augment student practice of essential engineering skills while at the same time scaffolding progression towards Cornerstone Projects that all students present at the end of the semester. ENGR 111 features a high volume of faculty and teaching assistant interaction with students during class time(s). The course is also heavily team-based, which adds a level of complexity that enhances the experience [28, 40-41]. ENGR 111 student feedback pertaining to the teamwork experience has been overwhelmingly positive thus far [58]. As discussed above, ENGR 111 was designed with numerous features that, based on educational research, have potential to increase student interest and motivation in engineering, in turn, augmenting likelihood of respective students persisting to degree achievement. Table 1 provides a summary, listing these key features in addition to 1) associated sample citations for referencing validity of each feature with respect to feature potential in addressing student interest/motivation, and 2) notes that include examples further detailing the listed features. The purpose of this paper is to share and discuss results from data collected in foundational efforts to determine the impact ENGR 111 may or may not have on engineering student retention.

Table 1. Pedagogical features and description for the ENGR 111 course.

Feature	Ref. [e.g.]	Notes
Hand tool usage	[42-44]	➢ Course instruction & lesson plan(s) directly related to hand tool usage ➢ Continuing need to utilize had tools during construction (making), experimentation, and/or design
Engineering workforce association	[44-46]	➢ Course pedagogy represents more tangible connection to the world of engineering ➢ The Cornerstone project will always model an actual, real-world engineered system
Teamwork	[47-50]	➢ Students work in small (3-4 person) teams for vast majority of semester ➢ Course is intentionally structured so that teamwork skills become more critical as course progresses
Interdisciplinary nature of engineering	[51-52]	➢ All teams are intentionally created as interdisciplinary, with 3-4 person teams consisting of differing discipline majors ➢ Course pedagogies encompass basics of various disciplinary skills
Problem-solving nature of engineering	[43, 53-54]	➢ Vast majority of course lesson plans present content that requires student problem-solving application
Engineering Design: 3D Modeling	[43-44]	➢ Students learn & develop 3D modelling basics early in the semester ➢ Course design challenges are developed to be integrated within the existing Cornerstone system
Engineering Design: 3D Printing	[43, 55]	➢ Students learn & develop 3D printing basics early in the semester ➢ Student models are printed for testing various design challenges
Engineering Design: Iterative Nature	[56-57]	➢ Students are given multiple chances to refine design(s) throughout the semester
Engineering Design: Open-ended nature	[58-59]	➢ Students are only provided the problem statement and criteria/constraints for design challenges; the rest is up to them
Practice-based engineering	[60-68]	➢ Hands-on, active student participation throughout semester ➢ At least one experimentation experience involves student comparison of experimental (actual) vs. theoretical results
Satisfaction in success: • 3D Modeling • Circuitry • Programming • Cornerstone Project	[43, 69-71]	➢ Course presents advantageous opportunity to teach students that failure in engineering practices is often a step on the “road” to success in engineering ➢ Often, the initial frustration that results in achieving proficiency in these skills results in *greater* satisfaction once the proficiency is finally achieved

Methods

Starting with the Spring 2019 iteration of ENGR 111, individual students were surveyed at the end of the semester as follows: 1) *To what extent do you intend to keep pursuing an engineering* *major?* And 2) *Please indicate below how much (if any) impact your ENGR 111 experience had on the answer you provided on the previous question related to your intent to keep pursuing an engineering major*. Potential responses for the first query were provided via a 10-point Likert scale (10 = *definitely* will and 1 = definitely will *NOT*); while potential responses to the latter query included specifying significant, somewhat, and/or no impact from the ENGR 111 impact. These same two questions have been delivered to subsequent ENGR 111 cohorts each and every (Spring) semester since, with the exception of 2020 (the course was significantly altered midway through the semester due to the onset of the COVID-19 pandemic). Upon data collection and compilation, the varying Likert degrees of intent in continuing pursuit of an engineering degree were further organized into 3 different subcategories: *high* intent for Likert responses ranging from 8-10, *medium* intent for Likert responses ranging from 4-7, and *low* intent for Likert responses ranging from 1-3.

Results & Discussion

Results associated with the first survey question (*To what extent do you intend to keep pursuing an engineering major?*) for each of the five (Spring 2019 & 2021-2024) semesters are shown in Table 2.

Table 2. Respective semester response data pertaining to survey question #1.

ENGR 111 Cohort	N (# responses)	High Intent (%)	Medium Intent (%)	Low Intent (%)
2019	440	83.4	12.7	3.9
2021	456	86.2	9.0	4.8
2022	365	85.2	10.7	4.1
2023	340	87.6	10.3	2.1
2024	370	88.4	8.4	3.2

As shown in Table 2, the varying reported intents to pursue an engineering degree are quite analogous across respective semesters. Accordingly, associated trends can be effectively represented via consolidation of each of the five semesters shown in Table 2. This is shown in Figure 1, which represents a total of 1971 different ENGR 111 student responses.

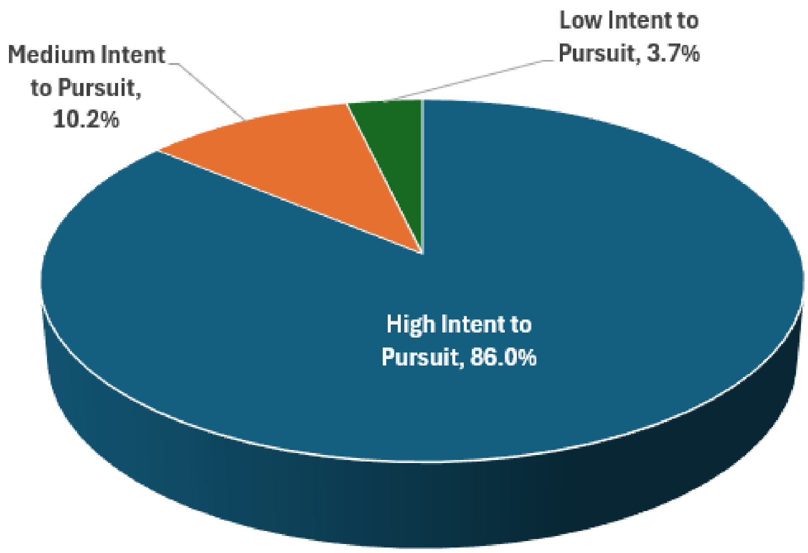

Figure 1. Consolidated (Spring 2019 & 2021-2024; N=1973) student responses to the (10-point Likert) survey question: ***To what extent do you intend to keep pursuing an engineering major?***

The impact of the ENGR 111 experience on each of the three different subcategories of Spring 2019 student intent to pursue an engineering degree is shown in Figures 2. Figure 2a shows a raw data distribution of the reported ENGR 111 impact across each subcategory. While Figure 2b shows the data normalized to 100% of the total responses for each respective subcategory.

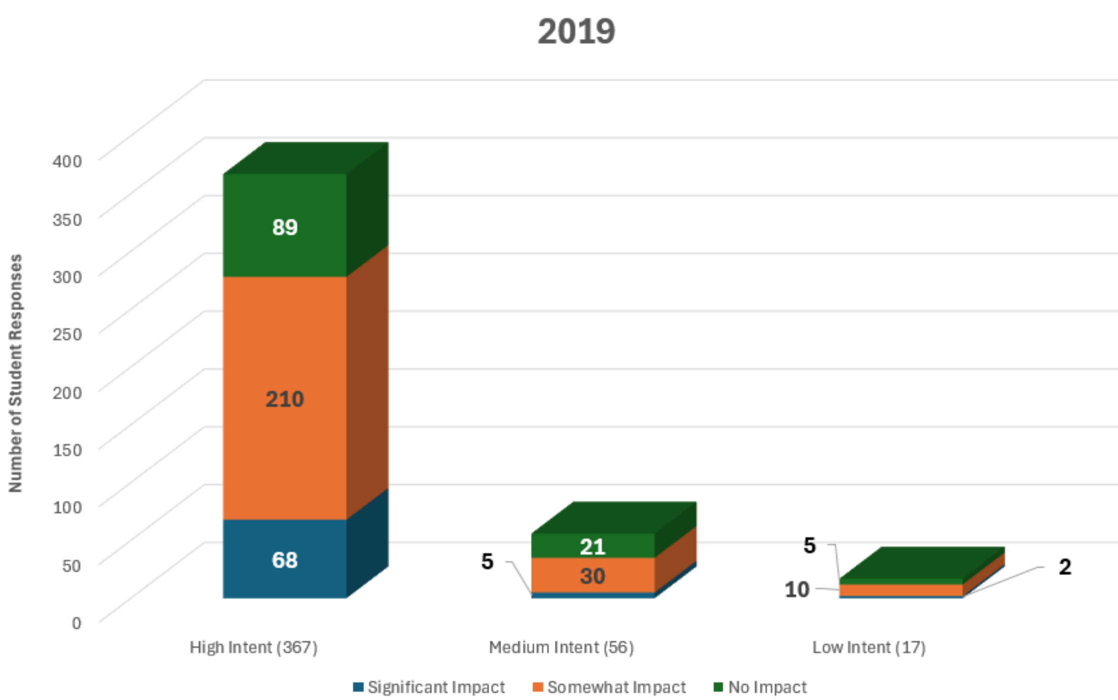

Figure 2a. Raw data distribution of the reported ENGR 111 impact across each intent to pursue subcategory for 2019.

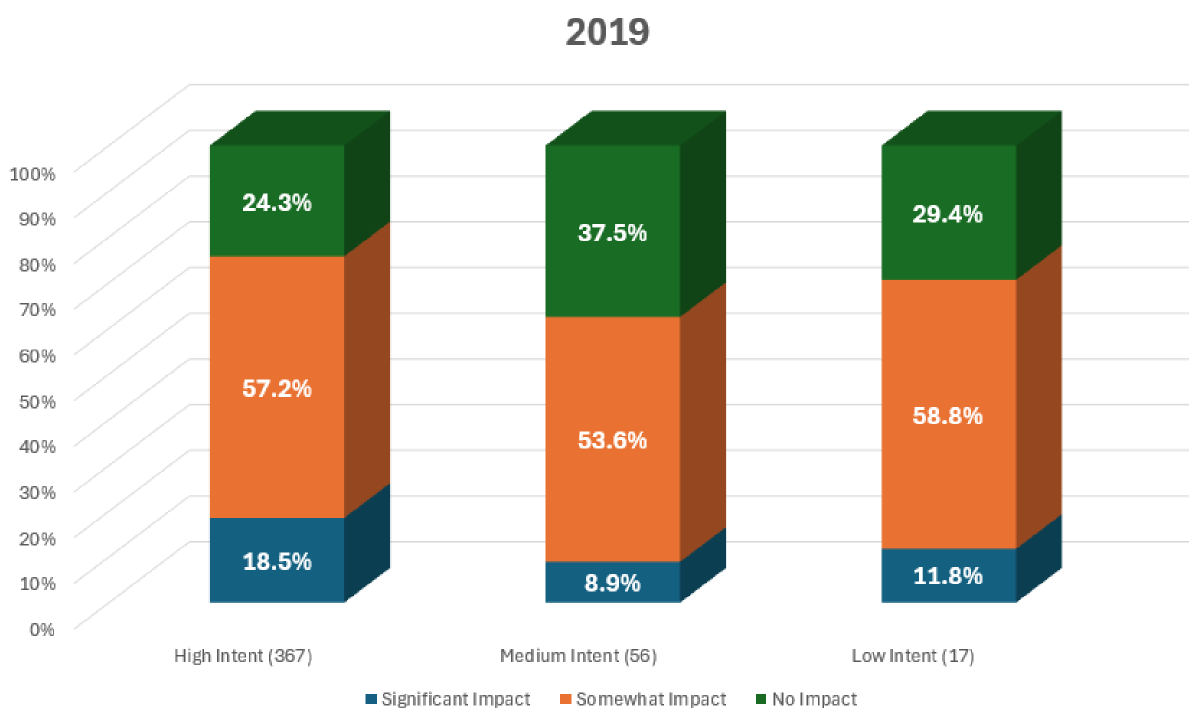

Figure 2b. Normalized data distribution of the reported ENGR 111 impact across each intent to pursue subcategory for 2019 (note nominal values associated with x-axis labels represent total *N* value of student responses instead of normalized percent distribution).

The normalized data, as shown in Figure 2b, provides easier visualization of the ENGR 111 impact on each respective subcategory of degree pursuit intent. To elaborate, when comparing figures 2a versus 2b, overall percentages of ENGR 111 impact are more apparent in Figure 2b. For 2019, ENGR 111 had *significant* impact on 18.5% of the students who expressed high intent to degree pursuit, 8.9% with medium intent, and 11.8% (2 out of 17) with low intent. When this data is normalized as in Figure 2b, the overall ENGR 111 impact on each level of intent is easier to determine and compare since it is associated with respective color heights/volumes (blue fill = significant impact, orange fill = somewhat impact, and green fill = no impact). The normalized data for the 2021-2024 cohorts are shown in Figures 3.

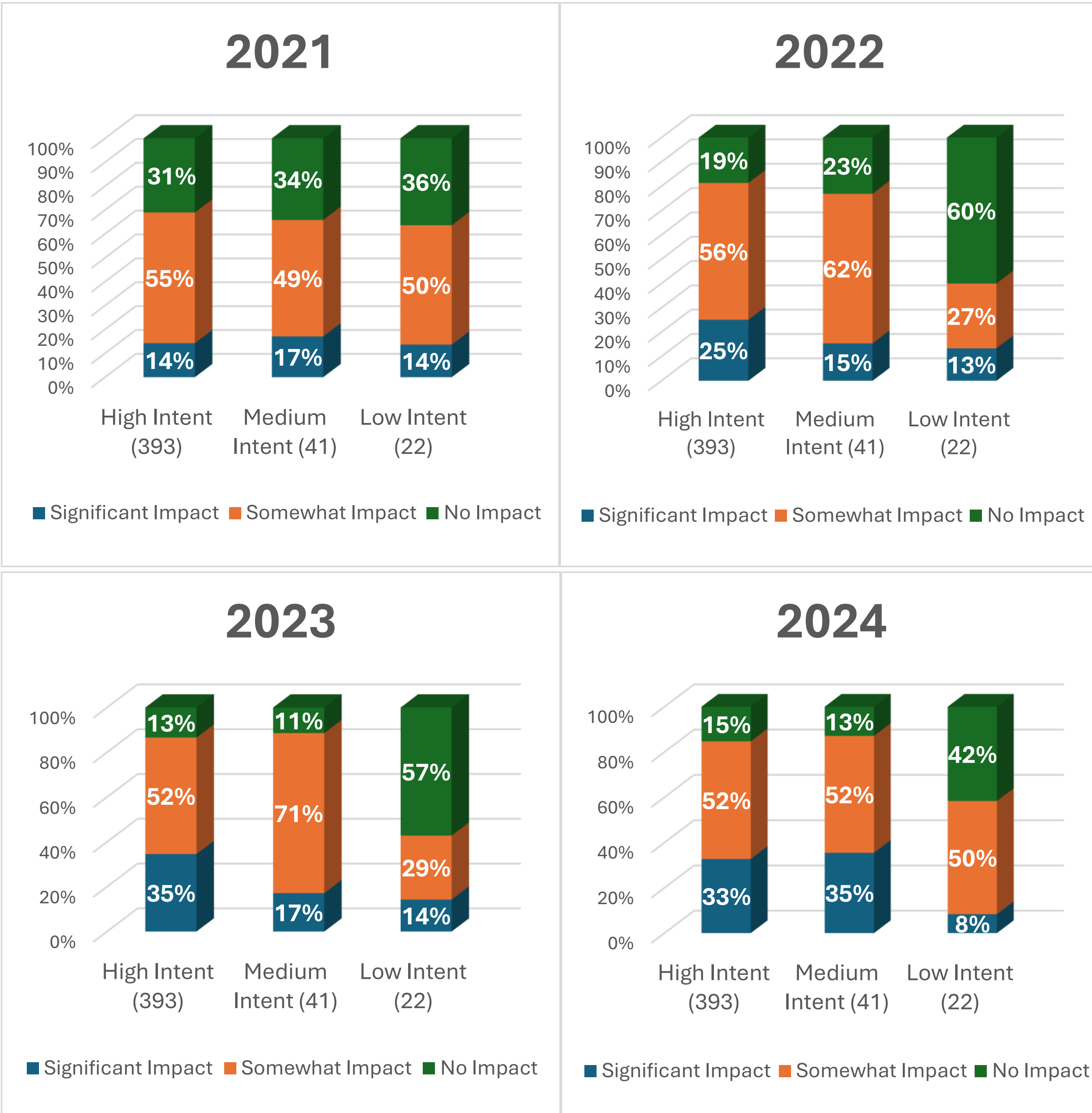

Figure 3. Normalized data distribution of the reported ENGR 111 impact across each intent to pursue subcategory for 2021, 2022, 2023, & 2024, respectively.

Table 3 displays the distribution of ENGR 111 impact across each cohort for those that reported high intent only (as over 80% for each and every cohort fell into this intent to pursuit subcategory).

Table 3. Distribution of ENGR 111 impact across each cohort for student reporting high intent to continue pursuit of an engineering degree.

ENGR 111 Cohort	N (# of student reporting high intent)	*Significant* ENGR 111 Impact (%)	*Somewhat* ENGR 111 Impact (%)	*No* ENGR 111 Impact (%)
2019	367	18.5	57.2	24.3
2021	393	14.3	54.7	31.0
2022	311	25.1	56.3	18.6
2023	298	34.6	52.0	13.4
2024	327	32.7	52.0	15.3

Discussion, Conclusions & Future Work

Student intent to pursue an engineering degree after their first year in the engineering program remains relatively high across all semesters in which they were surveyed; with no less than 83.4% specifying high intent (2019), and no higher than 4.8% specifying low intent (2021) across each semester. It is worth noting that the 2019 cohort, which as stated directly above specified the lowest percentage of high intent to pursuit, was the one and only semester of associated data collected prior to the pandemic. For the four semesters of collected data since the pandemic, the next lowest percentage of high intent to pursuit (2022) was nearly 2% higher (85.2%) than the 2019 cohort, and as much as 5% higher (2024). Associated author theories are varying, and not shared in this report since the 2019 cohort represents the only pre-pandemic data point (this result, for instance, could simply be a coincidental outlier versus being a result directly related to the pre- and post- pandemic conditions itself).

Ultimately, the results show promising evidence that ENGR 111 is indeed having a positive impact on engineering retention. In summary, when consolidating each of the five cohorts shown in Table 3 (N=1973), a total of 78.8% of the students who specified a high intent to continue pursuing their engineering degree also specified ENGR 111 to have *at least* somewhat of an impact on that intent; with nearly one quarter (24.3%) of the nearly 2000 students surveyed stating that ENGR 111 had a significant impact on their high intent to continue pursuing an engineering degree. It is also obviously desirable for the ENGR 111 experience to have a minimal negative impact on student intent to degree pursuit. For the (77 out of 1973) students that reported low intent to degree pursuit, course administrators are satisfied that only 0.5% of the entire consolidated cohort – that is 9 out of 1973 students – reported that ENGR 111 had a significant impact on their low intent to continue pursuing an engineering degree.

When considering the plots shown in Figure 3, there are a couple of trends that are particularly noteworthy. Specifically, there is a notable increase in students with *high intent* to degree pursuit that specified *significant* ENGR 111 impact between the 2021 & 2022 cohorts, in addition to another increase between the 2022 & 2023 cohorts. The 2021 cohort had consisted of 14.3% of the students specifying high intent that credited the ENGR 111 impact as significant. This percentage increased (10.8%) to 25.1% in 2022, followed by an additional (9.5%) increase in 2023 to 34.6%. It is highly probable that the first increase (2021 vs. 2022) is due to the 2021 iteration of ENGR 111 being delivered under remote instruction (due to COVID-19 pandemic). Although course leaders are overall pleased with their efforts in developing and delivering a remote version of a course that is in no way conducive to such a setting [38], the positive benefits, and in turn, positive impacts, for students that receive the ENGR 111 experience while physically present in the makerspace is intuitive and has been documented [39]. Explanation for the second significant increase (2022 vs. 2023) is a bit less concrete, with two predominant theories as follows. The first possible explanation for this increase is a different Cornerstone system was utilized for each cohort. That is, the 2022 cohort Cornerstone was a bench-scale windmill system, while the 2023 Cornerstone was a water filtration/treatment system (WFS), developed in conjunction with local Metropolitan Sewer District (MSD) industry. Partnership with MSD provided more opportunity for the 2023 cohort to make more direct connections with industry and thus may have further enhanced student desire to persist in earning an engineering degree. Perhaps a more likely cause of the 2022-2023 increase is related to the fact that SSoE admission criteria were modified between the 2022 & 2023 academic years. Essentially, this change in criteria resulted in larger percentage of the 2023 student body (in comparison to the 2022 student body) that had less exposure to the engineering profession prior to attending SSoE. In other words, it's possible that the smaller percentage of 2023 students coming into ENGR 111 with a lower level of engineering familiarity resulted in a greater impact on individual desire to become an engineer.

Some additional analyses related to the study presented in this paper remain, including a more in-depth statistical analysis that wasn't able to be completed prior to submission. An institutional IRB process is currently underway for authorization to further separate the data into sub-groups (e.g. race, gender, starting level of math preparation) to assess any potential change in trends versus those for the entire consolidated cohort seen and shared in this report. Furthermore, since students have been responding to the research questions reported on in this paper since the Spring 2019 semester, collected data has officially become longitudinal, with these past students currently much further along in their academic careers – and many already expected to have graduated. Accordingly, researchers are in the process of cross-referencing student responses on intent to pursuit against *actual* persistence to degree (since the ENGR 111 experience) in order to determine how effective a predictor the first-year question is on intent to pursue an engineering degree.

References

[1] Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1997). Characteristics of freshman engineering students: Models for determining student attrition in engineering. *Journal of Engineering Education*, 86(2), 139-149.

[2] Grose, T. K. (2012). "The 10,000 Challenge." *ASEE Prism*, 32-35.

[3] 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. *Proceedings of the American Society for Engineering Education Annual Conference*, 24-27.

[4] 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. *Proceedings of the American Society for Engineering Education Annual Conference*, 24-27.

[5] Miller, M. J., Lent, R. W., Lim, R. H., Hui, K., Martin, H. M., Jezzi, M. M., ... & Wilkins, G. (2015). Pursuing and adjusting to engineering majors: A qualitative analysis. *Journal of Career Assessment*, 23(1), 48-63.

[6] Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving* (p. 134). Westview Press, Boulder, CO.
[7] Bego, C., Young Barrow, I., & Ralston, P. (2017). "Identifying Bottlenecks in Undergraduate Engineering Mathematics: Calculus I through Differential Equations." *124th Annual American Society for Engineering Education Conference*, Columbus, OH, June 25-28.
[8] Chen, X. (2013). *STEM Attrition: College Students' Paths Into and Out of STEM Fields*, National Council for Education Statistics, Editor, Institute of Education Sciences, U.S. Department of Education: Washington, D.C.
[9] Olds, B. M., & Miller, R. L. (2004). The effect of a first-year integrated engineering curriculum on graduation rates and student satisfaction: A longitudinal study. *Journal of Engineering Education*, 93(1), 23-36.
[10] Froyd, J., & Ohland, M. W. (2005). Integrated engineering curricula. *Journal of Engineering Education*, 94(1), 147-164.
[11] Blair, B. F., Millea, M., & Hammer, J. (2004). The impact of cooperative education on academic performance and compensation of engineering majors. *Journal of Engineering Education*, 93(4), 333–338.
[12] Raelin, J. A., Bailey, M. B., Hamann, J., Pendleton, L. K., Reisberg, R., & Whitman, D. L. (2014). The gendered effect of cooperative education, contextual support, and self-efficacy on undergraduate retention. *Journal of Engineering Education*, 103(4), 599–624.
[13] Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research (J-PEER)*, 5(1), 4.
[14] 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.
[15] 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.
[16] Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, 84(4), 495-504.
[17] 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.
[18] 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.
[19] Hsu, Y. C., Baldwin, S., & Ching, Y. H. (2017). Learning through making and maker education. *TechTrends*, 61(6), 589-594.
[20] Bucks, G. W., Ossman, K. A., Kastner, J., & Boerio, F. J. (2015, June). First-year engineering courses effect on retention and workplace performance. *Proceedings of the 122nd ASEE Annual Conference and Exposition*, Seattle, WA.
[21] 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.
[22] 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*.
[23] 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*.

[24] 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

[25] Pendergrass, N. A., Kowalczyk, R. E., Dowd, J. P., Laoulache, R. N., Nelles, W., et al. (1999). Improving first-year engineering education. *Frontiers in Education*.

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

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

[28] 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.

[29] Robinson, Brian & Hawkins, Nicholas & Lewis, James & Foreman, James. (2019). Creation, Development, and Delivery of a New Interactive First-Year Introduction to Engineering Course. 10.18260/1-2--32564.

[30] Hawkins, Nicholas & Lewis, James & Robinson, Brian. (2020). Employment of Active Learning Pedagogy Throughout a Maker-Space-Based, First-Year Introduction to Engineering Course. 10.18260/1-2--34526.

[31] Robinson, Brian & Lewis, James & Hawkins, Nicholas & Tinnell, Teresa. (2020). Addressing First-Year Interest in Engineering via a Maker-Space-Based Introduction to Engineering Course. 10.18260/1-2--34093.

[32] Robinson, Brian & Tretter, Tom & Lewis, James & Hawkins, Nicholas. (2021). Measuring First-Year Engineering Majors' Interest in Engineering. 10.18260/1-2--37493.

[33] Robinson, Brian & Tretter, Thomas & Lewis, James & Hawkins, Nicholas. (2023). Capturing First-Year Engineering Students' Situational and Individual Interest via a Formal Makerspace Course. 10.18260/1-2--43120.

[34] Lewis, James & Robinson, Brian & Hawkins, Nicholas. (2020). First-Year Engineering Student Perceptions in Programming Self-Efficacy and the Effectiveness of Associated Pedagogy Delivered via an Introductory, Two-Course Sequence in Engineering. 10.18260/1-2--34676.

[35] Lewis, James & Hawkins, Nicholas & Robinson, Brian. (2022). Student Perceptions of Programming Instruction in a Makerspace vs Synchronous Remote Environment. 10.18260/1-2--41022.

[36] Lewis, James & Hawkins, Nicholas & Robinson, Brian. (2023). Comparing First-Year Student Programming Confidence Perceptions Between Different Hands-On Projects. 10.18260/1-2--43274.

[37] Hawkins, Nicholas & Lewis, James & Robinson, Brian & Thompson, Angela. (2024). Comparing Circuitry Interest in Engineering Between Different Hands-On Projects. 10.18260/1-2--48481.

[38] Robinson, Brian & Lewis, James & Hawkins, Nicholas & Tretter, Thomas & Chan, Fei. (2022). Converting a First-Year Engineering, Makerspace Course into COVID-Necessitated Fully-Online Synchronous Delivery and Related Student Perceptions. 10.18260/1-2--41024.

[39] Robinson, Brian & Tretter, Thomas & Hawkins, Nicholas & Lewis, James. (2023). Assessing Various Pedagogical Features of Remote Versus In-Person Iterations of a First-Year Engineering, Makerspace Course. 10.18260/1-2--42316.

[40] Vygotsky, L. (1997). *Educational psychology: Problems of general psychology, Volume I.*

[41] Felder, R. M., & Brent, R. (2001). Effective strategies for cooperative learning. *Journal of Cooperation & Collaboration in College Teaching*, 10(2), 69-75.

[42] Wilczynski, V., & Adrezin, R. (2016, November). Higher education makerspaces and engineering education. In *ASME International Mechanical Engineering Congress and Exposition* (Vol. 50571, p. V005T06A013). American Society of Mechanical Engineers.

[43] Taheri, P., Robbins, P., & Maalej, S. (2020). Makerspaces in first-year engineering education. *Education Sciences*, 10(1), 8.

[44] Kemp, A. (2013). *The makerspace workbench: Tools, technologies, and techniques for making*. Maker Media, Inc.

[45] Feisel, L. D., & Rosa, A. J. (2005). The role of the laboratory in undergraduate engineering education. *Journal of Engineering Education*, 94(1), 121-130.

[46] Strobel, J., Wang, J., Weber, N. R., & Dyehouse, M. (2013). The role of authenticity in design-based learning environments: The case of engineering education. *Computers & Education*, 64, 143-152.

[47] Alves, A. C., Mesquita, D., Moreira, F., & Fernandes, S. (2012). Teamwork in Project-Based Learning: Engineering students' perceptions of strengths and weaknesses. In *Proceedings of the Fourth International Symposium on Project Approaches in Engineering Education (PAEE'2012)* (pp. 23-32). Paee'2012.

[48] Lamm, M. H., Dorneich, M., & Rover, D. T. (2014). Team-based learning in engineering classrooms: Feedback form and content adds value to the learning experience.

[49] Borrego, M., Karlin, J., McNair, L. D., & Beddoes, K. (2013). Team effectiveness theory from industrial and organizational psychology applied to engineering student project teams: A research review. *Journal of Engineering Education*, 102(4), 472-512.

[50] Giannakos, M. N., Divitini, M., & Iversen, O. S. (2017). Entertainment, engagement, and education: Foundations and developments in digital and physical spaces to support learning through making. *Entertainment Computing*, 21, 77-81.

[51] Passehl-Stoddart, E., Velte, A., Henrich, K. J., & Gaines, M. L. I. S., A. M. (2018). History in the making: Outreach and collaboration between special collections and makerspaces. *Collaborative Librarianship*, 10(2), 8.

[52] Wilczynski, V., & Adrezin, R. (2016, November). Higher education makerspaces and engineering education. In *ASME International Mechanical Engineering Congress and Exposition* (Vol. 50571, p. V005T06A013). American Society of Mechanical Engineers.

[53] Van Holm, E. J. (2015). Makerspaces and contributions to entrepreneurship. *Procedia-Social and Behavioral Sciences*, 195, 24-31.

[54] Paganelli, A., Cribbs, J. D., Huang, X., Pereira, N., Huss, J., Chandler, W., & Paganelli, A. (2017). The makerspace experience and teacher professional development. *Professional Development in Education*, 43(2), 232-235.

[55] Saorín, J. L., Melian-Diaz, D., Bonnet, A., Carrera, C. C., Meier, C., & De La Torre-Cantero, J. (2017). Makerspace teaching-learning environment to enhance creative competence in engineering students. *Thinking Skills and Creativity*, 23, 188-198.
[56] Lottero-Perdue, P. S., & Parry, E. A. (2017). Elementary teachers' reflections on design failures and use of fail words after teaching engineering for two years. *Journal of Pre-College Engineering Education Research (J-PEER)*, 7(1), 1.
[57] Johnson, M. M. (2016). Failure is an option: Reactions to failure in elementary engineering design projects.
[58] Forest, C. R., Moore, R. A., Jariwala, A. S., Fasse, B. B., Linsey, J., Newstetter, W., ... & Quintero, C. (2014). The Invention Studio: A university maker space and culture. *Advances in Engineering Education*, 4(2), n2.
[59] 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.
[60] 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.
[61] Feden, P. D., & Vogel, R. M. (2003). *Methods of teaching: Applying cognitive science to promote student learning*. McGraw-Hill Humanities, Social Sciences & World Languages.
[62] 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.
[63] Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223-231.
[64] 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.
[65] 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.
[66] 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*.
[67] 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.
[68] 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.
[69] 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.
[70] Galaleldin, M., Bouchard, F., Anis, H., & Lague, C. (2016). The impact of makerspaces on engineering education. *Proceedings of the Canadian Engineering Education Association (CEEA)*.
[71] Han, S. Y., Yoo, J., Zo, H., & Ciganek, A. P. (2017). Understanding makerspace continuance: A self-determination perspective. *Telematics and Informatics*, 34(4), 184-195.