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# Assessing Various Pedagogical Features of Remote Versus In-Person Iterations of a First-Year Engineering, Makerspace Course

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# Assessing Various Pedagogical Features of Remote Versus In-Person Iterations of a First-Year Engineering Makerspace Course


## Abstract

This evidence-based practice paper is a follow-up to an ASEE 2022 conference proceeding that was focused on the challenges in development, in addition to resulting student perceptions upon delivery, of a remote iteration (Spring 2021, due to the COVID-19 pandemic) of a conventionally hands-on, active learning-based makerspace course; of which employs integration and application of fundamental engineering skills and all institutional first-year engineering students are required to take. Specifically, this paper is focused on the ensuing iteration of the course (Spring 2022) in which students resumed in-person course execution, and aims to disseminate comparative resulting student perceptions on course features between the remote iteration versus the in-person iteration and, in some cases, the course iteration *prior* to the pandemic.

At the conclusion of the 2022 (post-COVID) semester, more than 300 student participants were surveyed on respective perceptions in Perceived Belonging Uncertainty and Interest in Engineering. Resultant responses were then compared to responses to the same surveys conducted by pre-pandemic students in addition to students that experienced the course during the pandemic (in which students experienced the course under a remote environment). Student participants during the 2022 course iteration were further surveyed with a quantitative forced-choice ranking. Specifically, students were asked to rank pedagogical effectiveness of six select course features – 3D modeling, circuitry, engineering design, programming, teamwork, and technical writing – and these six features were predominantly determined by qualitative identification of effective and/or ineffective features by the (2021) remote cohort. Respective responses from the during-COVID cohort versus the post-COVID cohort were compared and assessed. Resultant implications, limitations, and revelations of these findings conclude this paper.


## 1. The Formal Makerspace Course

### *1.1 Course Overview*

During the first-year at the J. B. Speed School of Engineering at the University of Louisville (UofL), all engineering students are required to take a course titled *Engineering Methods, Tools, and Practice II* (ENGR 111) [1-7]. The ultimate goal of ENGR 111 is to instruct students in application and integration of institutionally-identified fundamental engineering skills that are introduced and practiced in the prerequisite *Engineering Methods, Tools, and Practice I* (ENGR 110) course. Other notable general features of ENGR 111 include a formal (15,000 $ft^2$) makerspace setting that exclusively employs active learning pedagogy [5], and the course houses the J. B. Speed School of Engineering Cornerstone project. A final relevant staple of ENGR 111 is the presence of quantitative and qualitative student surveys framed around the expectancy-value theory of motivation [8-10]; specifically, student surveys pertaining to Perceived Belonging Uncertainty (PBU, often called “sense of belonging”) and (maintained) interest in engineering (IIE) have been a component of the ENGR 111 course culture since its inception.

*1.2 The Remote Iteration of ENGR 111*

For the Spring 2021 iteration of ENGR 111, following the peak period of the COVID-19 pandemic and although UofL allowed in-person instruction to resume on campus, course administrators made the difficult and challenging decision to redesign the course for remote delivery (the 2020 iteration of the course was canceled halfway through completion when the pandemic started). Although a course based in active-learning, makerspace-based pedagogy is intuitively counter to remote implementation, the close vicinity of student team-based activities in addition to numerous shared tools, materials, supplies, and the like across various course sections fostered agreement amongst course leaders that a remote redesign of ENGR 111 was in the best overall interest of all personnel involved. Accordingly, a report focused on logistics involved in the ENGR 111 remote restructure, detailing modifications for some of the most challenging curriculum and/or features of remote accommodation (including teamwork, experimentation, design challenges, programming & circuitry, and the Cornerstone Project), was disseminated upon completion of the remote course iteration [7]. Given the unique circumstances, efforts in remote redesign were deemed overall satisfactory; supporting details are included in the following text.

Since student perceptions related to PBU [11] and IIE [12] have been collected from students since ENGR 111 inauguration, responses from the 2019 (pre-COVID, in-person) cohort versus the 2021 (during COVID, remote) cohort were compared. Specific details pertaining to survey items for PBU and IIE are shown in Tables 1 and 2, respectively. As discussed in the Robinson et al. study [7], the IIE survey items can be further grouped into a 2-subfactor structure consisting of pragmatic (useful, important) and/or affective (enjoyable) features. The results suggested that the remote iteration of ENGR 111 was overall effective in retaining similar student *affective* interest in engineering (versus the pre-COVID cohort). Alternately, the results further suggested that the remote makerspace instruction had an adverse impact on students' *pragmatic* interest and PBU (also when compared to the pre-COVID cohort).

For the remote (2021) cohort, in addition to the aforementioned quantitative surveys related to PBU and IIE, students responded to two additional qualitative queries designed to collect open-ended perceptions related to the remote ENGR 111 experience: 1) "*Due to the COVID-19 pandemic, the Spring 2021 ENGR 111 experience was converted to remote delivery and instruction. As a student, which ENGR 111 course features and/or topics do you think was still effective (and why)*", and 2) "*Which course features and/or topics do you think would have been more effective if your ENGR 111 experience could have been the normal, hands-on, makerspace-based delivery and instruction (and why)?*". Several clear trends were discovered upon coding these qualitative responses, and results showing course features specifically identified by students as "effective" versus "ineffective" have been reproduced in Figure 1 for convenience.

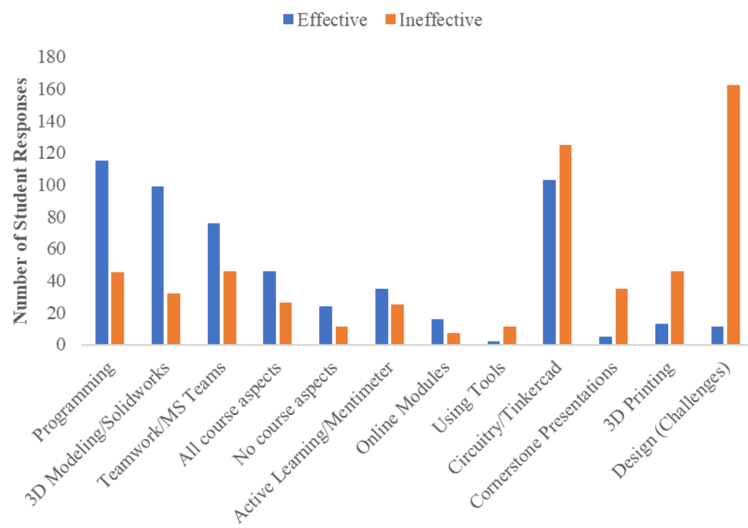


**Figure 1: Coded responses to qualitative survey questions regarding effective and ineffective course aspects for the 2021 remote iteration of ENGR 111.**

The programming course feature received the highest percentage of effective identification, while engineering design was identified by the highest percentage as ineffective. Perceptions related to circuitry effectiveness were rather polarized ($2^{nd}$ highest percentage for *both* effective and ineffective). The set of course features were furthermore grouped into two general categories: 1) course features that were more *software-based*, such as programming, 3D Modeling, and circuitry (using the online Tinkercad platform [7]), and 2) course features, that typically involve more physical material interaction, which required more extensive modification for remote delivery, identified as *build replacements* and including 3D printing, experimentation, tool usage, and engineering design. Related trends were even more clear when grouped in this manner, with only 39% of students identifying the *software-based* category as ineffective (versus 62% identifying as effective), and 89% identifying the *build replacements* category as ineffective (with less than 10% identifying this category as effective). It is worth noting, as it may be intuited via Figure 1, that the vast majority of "ineffective" responses for the *build replacements* category specifically pertained to engineering design.

The primary focus of this paper is on the Spring 2022 iteration of ENGR 111 in which students officially returned to in-class participation back on campus, and serves as a follow-up to the aforementioned previous ENGR 111 iteration when the course was delivered remotely. Survey responses related to student PBU and IIE were again collected, this time from the 2022 cohort, thus providing comparative assessment of student perceptions in these constructs for pre- (2019), during (2021), and post-pandemic (2022) experiences. The topic of effective course features was also reexamined, this time with the 2022 cohort, using the qualitative results from the 2021 cohort to create quantitative surveys designed to provide a basis for comparing perceived course feature effectiveness between the remote and in-person student cohorts. It is pertinent to note an unanticipated (and pleasantly surprising) outcome of the COVID-forced, remote redesign was the realization that several of the resultant newly-implemented and/or significantly-modified course delivery mechanisms, if retained, could further enhance the normal iteration course experience. Specifically, four course delivery mechanisms that were developed and/or augmented for remote delivery [7] – Classroom Response Systems, MS Teams, Tinkercad, and supplemental videos –

remained as is for students returning to in-class instruction in the Spring 2022 semester. Additionally, a rocket launcher engineering design challenge created and implemented for the remote cohort [7] was kept as a second design challenge (in addition to the original pre-pandemic design challenge) for the 2022 cohort. ENGR 111 course delivery for the returning 2022 cohort was otherwise analogous to that prior to the pandemic.

## 3. Methodology

### *3.1 Participants and Procedures*

The pre-COVID cohort (2019) consisted of 443 students who enrolled in ENGR111 in the Spring semester of 2019; the COVID cohort (2021) consisted of 456 students who enrolled in ENGR111 in the Spring semester of 2021; and the post-COVID cohort (2022) consisted of 342 students who enrolled in ENGR111 in the Spring semester of 2022. Students from all cohorts completed an online survey near the end of their respective semesters. These surveys included items related to Perceived Belonging Uncertainty (PBU) and Interest in Engineering (IIE), which are shown below in Tables 1 and 2, respectively, and have been regular features built into ENGR 111 since its inauguration.

### *3.2 Instruments*

Surveys related to PBU, as defined by Strayhorn [11], were presented as an existing 4-item scale measured on a 5-point Likert-type scale ranging from 1 (*not true at all*) to 5 (*completely true*). Negatively worded items (#1, 2, 4 in Table 1) were recoded so that higher scores indicated greater sense of belonging in engineering. Survey items specific to PBU are shown in Table 1.

**Table 1. Perceived Belonging Uncertainty Survey Items.**

| Item |
|---|
| 1. Sometimes I worry I do not belong in engineering. |
| 2. I am anxious about whether I fit in the engineering profession. |
| 3. I feel confident that I belong in engineering. |
| 4. When I face difficulties in engineering, I wonder if I really fit in. |

For measuring (maintained) IIE, an 8-item interest survey, developed and validated by Linnenbrink-Garcia et al. [12], was adapted by modifying the item wordings to “engineering” versus “mathematics”, which was the subject under investigation in the original study. The interest items were measured on a 5-point Likert-type scale ranging from 1 (*not true at all*) to 5 (*completely true*) in which higher scores indicate greater IIE. The 2-subfactor nature of the IIE instrument, as discussed in Section 1.2, was derived from Pintrick’s [13] 3-part characterization of interest (useful, important, and enjoyable), which was also the basis for the Linnenbrink-Garcia et al. study. A previous study conducted by the authors of this paper [14] showed that Pintrick’s three latent factors hold up well when grouped into a 2-subfactor model, in which the Pintrick factors “useful: and “important” relate to *pragmatic* features of IIE, and the third factor “enjoyable” relates to an *affective* feature of IIE. Survey items and associated factors specific to IIE are shown in Table 2.

**Table 2. Interest in Engineering Survey Items and Hypothesized Factor Structure.**

| Item code | Item | Hypothesized Factor Structure | |
|---|---|---|---|
| use1 | Engineering is practical for me to know. | useful | pragmatic |
| use2 | Engineering helps me in my daily life outside of school. | useful | pragmatic |
| imp1 | It is important to me to be a person who reasons as an engineer. | important | pragmatic |
| imp2 | Thinking as an engineer is an important part of who I am. | important | pragmatic |
| enj1 | I enjoy the subject of Engineering. | enjoyable | affective |
| enj2 | I like Engineering. | enjoyable | affective |
| enj3 | I enjoy doing Engineering. | enjoyable | affective |
| enj4 | Engineering is exciting to me. | enjoyable | affective |

To provide a basis of comparison of student perceptions in key course feature effectiveness, between the remote (COVID) cohort (2021) and in-person cohort (2022), an additional quantitative survey was developed and presented to the 2021 cohort. For this particular survey, force-choice ranking was employed, asking students to rank six different course features in perceived effectiveness, whereas a ranking of 1 was given to the most effective feature and, accordingly, a ranking of 6 represented the least effective course feature. The item for this survey was specifically stated as follows: *Rank the following ENGR 111 fetures that you feel were most EFFECTIVE in helping you deepen your understanding of the fundamental skills, knowledge, and qualities of an engineer (1 = MOST EFFECTIVE, 6 = LEAST EFFECTIVE)*.

The six different course features included in this survey were predominantly determined via the results of student perceptions in effectiveness from the remote cohort (Figure 1) including features with the highest level of identified effectiveness (programming and 3D modeling) and the feature with the (recall overwhelmingly) highest level of identified ineffectiveness (engineering design). The survey further included choices for two high-priority course topics that received the most mention (effective and/or ineffective) from the remote survey: circuitry and teamwork. The final course feature included in the force-choice ranking survey was technical writing; although there was very minimal mention of this feature from the remote cohort qualitative responses, it nevertheless remains a high enough course priority that it was included as a sixth option for ranking in the survey.

## 4. Results and Discussion

### *4.1 Analytic Strategy*

Statistical comparisons on IIE and PBU were computed for three groups of students: (a) pre-COVID (in-person, spring 2019); (b) COVID (remote, spring 2021); and (c) post-COVID (in-person, spring 2022). Interest is compared in three ways: the first two (see Table 3) compare the two interest factors *pragmatic interest*, and *affective interest*, each consisting of 4 items on a 5-point Likert scale. Then the entire 8-item interest scale is compared as one construct between the three groups.

A one-way analysis of variance (ANOVA) was conducted to check for potential differences in (1) pragmatic interest factor, (2) affective interest factor, (3) overall interest, and (4) belonging between cohorts. Table X2 reports on the internal consistency reliability (Cronbach's alpha, α), the ANOVA *F*-statistic, the statistical significance of the ANOVA test (*p*-value), and the omega squared *(*$\omega^2$, an ANOVA effect size parallel to Cohen's *d* for t-tests with two groups). All constructs were computed by summing the Likert-scale responses to items in that construct.

**Table 3. Comparison Between Pre-COVID, COVID, and Post-COVID Cohorts Ratings of Interest in Engineering and Sense of Belonging**

| | PRE-COVID | | COVID | | POST-COVID | | *F* | *p* | $\omega^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | M(SD) | α | M(SD) | α | M(SD) | α | | | |
| Interest (pragmatic) | 15.1(3.6) | .80 | 14.8(3.2) | .67 | 15.9(2.9) | .82 | 24.34 | <.001 | .03 |
| Interest (affective) | 15.9(3.7) | .89 | 15.8(3.6) | .89 | 16.8(3.0) | .92 | 11.45 | <.001 | .01 |
| Interest (whole) | 30.9(6.7) | .89 | 30.1(5.9) | .84 | 32.7(5.4) | .90 | 20.63 | <.001 | .03 |
| Belonging | 13.8(3.2) | .57 | 13.0(3.8) | .80 | 15.2(3.7) | .88 | 33.02 | <.001 | .05 |

*M*=mean, *SD*=standard deviation

### *4.2 Preliminary Analyses*

Missing data for the study variables ranged between 0.1% and 1.6%. Little's MCAR test indicated that data were missing completely at random, $\chi^2(154) = 172.99$, $p = .14$. Therefore, imputation was not necessary. The final sample consisted of 1241 valid responses. Univariate normality was examined by inspecting skewness, kurtosis, and histograms of the study variables. All scales were approximately and normally distributed. The two-factor interest scale and the overall 8-item interest scale showed good internal consistency (see Table 3), with the exception of the during-COVID cohort pragmatic interest factor (α = .67). For the belonging scale, the pre-COVID showed weak internal consistency (α = .57), whereas adequate internal consistency was demonstrated in the during-COVID (α = .80) and post-COVID (α = .88) cohorts.

### *4.3 Primary Analyses*

The assumption of homogeneity was not met for all ANOVAs conducted. As such, the Welch's ANOVA, an ANOVA that is robust against the violation of homogeneity, was conducted. The results of the Welch's ANOVA revealed that there was a statistically significant difference in (1) pragmatic interest factor, (2) affective interest factor, (3) overall interest, and (4) belonging between at least two cohorts (see Table 3). It is noteworthy to mention that although the ANOVA results showed statistical significance, the effect sizes indicated small practical significance.

A Tukey's HSD Test for multiple comparisons revealed that the post-COVID cohort reported significantly higher pragmatic interest (*M* = 15.9, *SD* = 2.9) than the pre-COVID cohort (*M* = 15.1, *SD* = 3.6) and the during-COVID cohort (*M* = 14.8, *SD* = 3.2). There was also a statistically significant difference between the pre-COVID and during-COVID cohorts, with the pre-COVID cohort reporting higher pragmatic interest. The post-COVID cohort reported significantly higher affective interest (*M* = 16.8, *SD* = 3.0) than the pre-COVID cohort (*M* = 15.9, *SD* = 3.7) and the during-COVID cohort (*M* = 15.8, *SD* = 3.6). There was no statistically significant difference between the pre-COVID and during-COVID cohorts (*p* = .774). The post-COVID cohort reported significantly higher overall interest (*M* = 32.7, *SD* = 5.4) than the pre-COVID cohort (*M* = 30.9, *SD* = 6.7) and the during-COVID cohort (*M* = 30.1, *SD* = 5.9). There was no statistically significant difference between the pre-COVID and during-COVID cohorts (*p* = .144). The post-COVID cohort reported significantly higher sense of belonging (*M* = 15.2, *SD* = 3.7) than the pre-COVID cohort (*M* = 13.8, *SD* = 3.2) and the during-COVID cohort (*M* = 13.0, *SD* = 3.8). There was also a statistically significant difference between the pre-COVID and during-COVID cohorts, with the pre-COVID cohort reporting higher belonging.

These results suggest that the cohort who returned to an in-person makerspace instruction after COVID reported statistically higher interest, both two-factor and overall, and belonging when compared to the pre-COVID (in-person instruction before COVID) and during-COVID (remote instruction) cohorts.

Table 4 shows the results of the during-COVID cohort's qualitative responses about course feature effectiveness/ineffectiveness compared to the results of the forced choice rankings on course feature effectiveness form the post-COVID cohort. Because the during-COVID cohort were not asked to provide a ranking but instead an open-ended response, instead of an average ranking in Table 4 the during-COVID cohort responses per feature are shown in terms of percentage of responses mentioning a particular feature that were characterized as 'effective' (as opposed to ineffective). Not all during-COVID cohort students' responses mentioned each feature shown in Table 4.

**Table 4. Comparing COVID and POST-COVID Student Judgements of Most and Least Effective Course Features.**

| **Rankings** | **DURING-COVID cohort** (% effective among comments on this feature) | | **POST-COVID cohort** (Mean ranking; 1=Most & 6=Least) | |
|---|---|---|---|---|
| Most Effective (rank = 1) | 3D Modeling | (77%) | Engineering Design | (2.70) |
| | Programming | (72%) | Teamwork | (2.73) |
| | Teamwork | (63%) | 3D Modeling | (3.14) |
| | Circuitry | (47%) | Circuitry | (3.76) |
| | Technical Writing | (---)[a] | Programming | (4.22) |
| Least Effective (rank = 6) | Engineering Design | (6%) | Technical Writing | (4.44) |

[a] *Technical Writing* was very rarely mentioned in open-ended responses from COVID cohort as either effective or ineffective, and thus unable to compute a reliable percentage for effectiveness ratings.

## Conclusions

It is not surprising that the experience for the post-COVID (2022) cohort, returning to the makerspace classroom for a course explicitly designed to augment active learning and student interaction, reported statistically higher IIE, both two-factor and overall, and belonging when compared to the remote, during-COVID cohort; yet it is interesting that the post-COVID cohort also conveyed statistically higher for each of these constructs versus the pre-COVID cohort, which had the same benefit of in-person pedagogy. Accordingly, two possible theories have resulted in explaining this difference, and it's certainly feasible that both theories had a collective impact. The first assumption is that the aforementioned course delivery mechanisms (Section 1.2, last paragraph), that were developed for remote instructions yet retained for the return to in-person delivery, were significant enough augmentations to further improve collective gains in the PBU and IIE constructs. A second probable factor is a heightened level in student enthusiasm upon returning from the isolated conditions during the peak of the pandemic; that is, remote instruction perhaps provided many students a greater appreciation in being back together in turn fostering a higher level of interest and belonging.

It is important to mention that qualitative queries were also included amongst the forced-choice ranking related to the post-COVID cohort. 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 forced-choice ranking results shown in this paper. Another relevant point to consider is the possibility that some students may have personally felt that all six of the features were effective, yet the forced-choice nature of the survey meant that something had to be ranked last even if still thought of as effective.

Perhaps the most striking result from the data shown in Table 4 related to course feature effectiveness is the complete "flip" in engineering design effectiveness. Particularly, engineering design for the during-COVID cohort was by far identified as "least effective", while the post-COVID cohort rated this feature as "most effective" - **a very dramatic shift**. Based on this result, one can conclude that teaching engineering design skills, including the iterative and tentative nature of any proposed design and the need to frequently revisit and refine (iterate) select design elements, may be very difficult or even impossible to effectively teach beginning engineering students in a remote environment. By contrast, in a traditional face-face, in-person environment, utilizing a well-supplied engineering makerspace lab and engaging students with pedagogically-informed instruction, engineering design tasks and challenges may be among the most effective features for strengthening student understanding of core engineering practices.

Another noteworthy difference between the two columns (i.e. during-COVID vs. post-COVID) shown in Table 4 is the noticeable "drop" in ranking for the programming feature. Keeping in mind that the programming feature is the most software-intensive (versus the other five included features), this feature typically tends to be practiced more individually regardless of the environment. While there are certainly interactive elements within practice in programming, such as checking in with course leaders and/or teammates on programming-related questions, struggles, and/or verifications, such interactions can be executed about as well in a remote environment – which is likely why the programming feature was so highly rated during the remote iteration. Thus for the in-person cohort, it isn't necessarily that programming instruction was less effective, only that the other course features tended to be rated higher when in-person, thus forcing programming to fall down in relative rankings. Although, another legitimate potential factor (in the difference in programming) worth highlighting is the difference in programming pedagogy between the during- and post-COVID cohorts. Under the remote environment, programming curriculum consisted of more direct "do this" type of instruction, while curriculum associated with the cohort returning to the makerspace included a heavier dose of dependency on team dynamics and independent problem-solving. Furthermore, the course-culminating Cornerstone project requires more involved, higher level programming competency in comparison to the necessarily and significantly more scaled down Cornerstone requirements for the remote cohort.

Finally, course leaders predicted that technical writing would be the course feature with the lowest ranking in effectiveness (which it indeed was). Yet we postulate that the lowest ranking of this feature does not necessarily reflect a lack in technical writing instructional effectiveness. Collective years of experience in interacting with and observing ENGR 111 students have led to the realization that technical writing is the feature that the highest percentage of incoming students have had the most prior experience in. Student-interacting experience has also shed light on the fact that students often interchange lack of instructional *effectiveness* with lack of feature *interest*. This theoretical possibility is further supported by the lack of qualitative responses for technical writing – for either effective or ineffective – from the during-COVID cohort, which suggests more a lack of interest in the feature versus strong feelings related to the effectiveness/ineffectiveness of associated pedagogical strategies.

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