Evaluating the effectiveness of implementing active learning opportunities for first year engineering students who are taking math, physics, and chemistry

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Introduction

Undergraduate engineering students are typically required to take introductory math, chemistry, and physics concurrently with their first-year engineering curriculum. According to previous studies, success in these core courses is an integral part of a successful engineer's training and development, both in their pure content as well as the introduction to a variety of problem solving techniques.\(^1\)\(^2\) These subjects are studied in order to provide the groundwork necessary to develop an effective engineer. However, one theory behind low undergraduate retention in engineering is disinterest in these core courses.\(^3\)\(^4\) With this as the basis of this study, we suggest that students who enroll in engineering are most looking forward to the engineering aspect of the coursework, and are thus surprised at the high volume of what they perceive to be non-engineering (and therefore irrelevant) content from core courses in their first semester of their undergraduate degree. This is what we take to be a major contributor to disinterest in, and potentially departure from, the engineering discipline as a whole for first-year engineering students.

In order to combat this disinterest, a new program implemented by the College of Engineering at Colorado State University (CSU) employed select high-achieving engineering graduate students interested in teaching (named Graduate Teaching Fellows or GTFs) to serve as learning assistants within these core classes in order to help connect concepts from core subjects to those covered in various engineering disciplines. This is done using a combination of lecture review, active learning techniques, and open question-and-answer in optional one-and-a-half-hour sessions called Learning Labs (LLs) twice a week for each subject. Each LL is designed to be specific to its related core course, and looks at these math, chemistry, or physics concepts in the context of engineering topics. This work aims to preliminarily assess the effectiveness of this new undergraduate engineering retention program recently implemented at CSU, under the hypothesis that LLs will improve retention of engineering students between their first- and second-semester courses. The results of this study are expected to inform and improve future iterations of this program, as this model is not expected to be without flaws in its first implementation.

More specifically, this study examines the effectiveness of this Learning Lab model by looking at a combination of (1) Learning Lab attendance data, (2) first-year engineering student feedback (taking introductory course in Mechanical Engineering (MECH 103), Civil Engineering (CIVE 102), and Chemical and Biological Engineering (CBE 101)), (3) feedback from the GTFs holding LLs, and (4) enrollment in the second semester engineering course for first-year students as a means of gauging initial retention after implementation of the LL model. The student and GTF feedback were collected in the form of surveys which asked for perceived effectiveness and as convenience of the LLs,
among other questions surrounding retention. A major aim is to gain an understanding of engineering student retention at the end of the semester and compare it to previous cohorts of first-year engineering students. We quantify this through a combination of first-year course data as well as survey responses in regards to intentions to stay or leave students’ chosen programs, and reasons behind these intentions. This preliminary study evaluates effectiveness of the new retention effort and simultaneously elucidates limitations and area of improvement for its future implementations.

**Methods**

*Implementation of Learning Labs using Graduate Teaching Fellows*

It is relevant to discuss how LLs were advertised to the first-year engineering students in their respective courses to more thoroughly evaluate attendance to the LLs. The GTF assigned to each engineering course made a brief presentation at the beginning of the semester outlining the goals of the LLs, stressing that they are a resource designed to connect engineering to topics in core math and science courses. The LL schedule was presented and made available for the entirety of the semester, categorized by the math or science course it corresponded to (e.g. CHEM 111 Engineering Learning Lab from 5-7pm in ENGR Room B6). Throughout the semester, the schedule was adjusted slightly in order to accommodate student availability and changes in LL activities, and was therefore sent out to students intermittently throughout the semester, simultaneous serving as a reminder of the resource.

The LLs themselves were to be laid out in the following way, designed and administered by GTFs assigned to both the core course and an engineering course to bridge the subjects. A sign-in sheet was available to record attendance, with their major and student ID indicated. Students were first given an overview of their LL activities for the day in the context of the core science or math subject matter. Students then worked with one another through the worksheet designed by the GTFs to cover topics relevant to the core and engineering courses (see Appendix A for example). The worksheets generally required some explicitly non-traditional learning medium, such as a hands-on physical model, online video, or Physics Education Technology (PhET) simulations designed to illustrate concepts in a more visual and/or physical way. After the hands-on portion, the worksheets had a series of questions designed to elicit deeper thinking, therefore encouraging a more thorough understanding of the topic at hand. Students were allowed, and often encouraged, to do their own research to answer the sometimes difficult questions which required higher-level understanding than simple regurgitation. This involved use of their textbooks, course notes, lecture slides, and internet searches. The purpose behind this was to not only give the engineering applications of the topics covered in the core courses, but also to develop conscientious students and engineers able to think outside of the box, and investigate problems in more interesting and comprehensive ways.

*Course progression data collection and analysis*
To assess retention of first-year students after implementation of the LLs, “progression,” defined here as movement of a student between their first and second engineering courses, is examined. Progression was assessed by comparing the rosters of two compulsory courses offered in two consecutive semesters (e.g. MECH 103 in the Fall semester and MECH 105 in the subsequent Spring semester; and CIVE 102 in the Fall and CIVE 103 in the Spring). The rosters and grade information of the relevant courses were collected from an instructor-accessible CSU database called ARIESweb. Due to differences in curriculum across departments, this method applies only to CIVE and MECH. For CBE, a 2015 curriculum change which combined the first-and-second semester courses required “progression” to be defined somewhat differently, as self-reported from survey responses as opposed to ARIESweb data. More general ways to look at the progression will be developed for future studies in order to avoid these inconsistencies.

Personal identifiers were removed with the exception of student ID number to match progression with grades received. “Progressed” students were defined as those individuals registered for both consecutive required courses examined. Non-progressed students were defined as those registered for the first course of the year, but not the second. Other possible cases were not taken into consideration at this stage. The effects of grades on student’s progression were then examined using the following two methods.

In the first method, the grades of progressed and non-progressed students were plotted in histograms separately. Based on these two histograms of grades, we tested the statistical significances of the differences in the grade distributions of the two categories using Wilcoxon rank sum tests. The Wilcoxon rank sum test is a nonparametric alternative of Student’s t-test to test the null hypothesis that the two samples are from continuous distributions with equal means. Unlike the Student’s t-test, the Wilcoxon rank sum test does not assume the two distributions tested are normally distributed and is generally insensitive to the actual distribution of the data.\(^5,6\) Differences between two populations are deemed as statistically significant for p-values smaller than 0.05. The MATLAB function \texttt{ranksum()} was used to perform all the Wilcoxon rank sum tests in this study and to assign a p-value.

In the second method, the percentage of students who progressed was examined as a function of their received grades, and was calculated based on the two histograms obtained in the first method. The percentage of progression is defined as the ratio of number of progressed students over the total number of students (progressed and non-progressed).

Due to the lack of grade identifiers reported for CBE students in the survey data, the effects of grades were not evaluated for these students. As a result, here we report the percent progressed as a function of grades of CBE students for the previous years (2013-2015) only, omitting the Fall 2016 grade correlation plotted for MECH and CIVE.

\textit{Survey feedback collection and analysis}
As discussed before, in order to assess the effectiveness of LLs on retention of first-year engineering students a comprehensive survey was designed. This survey (see Appendix B) was conducted for first-year engineering students at CSU during Fall 2016. Our case study consists of three different engineering majors: MECH, CIVE, and CBE. Electrical and Computer Engineering (ECE) and Open Option Engineering (ENGR) were initially considered and surveyed, but later omitted due to the departments’ course pre-requisite structure being incompatible with our progression analysis method using the ARIESweb database.

A total of 132 of the 412 potential participants of all four majors completed the survey (32% participation). The sample population for each major was as follows: MECH (n=73 of 145, 50%), CIVE (n=10 of 196, 5%), and CBE (n=49 of 71, 69%), where n represents the number of respondents. Based on the demographic information, 61% of participants were male, 31% of participants were female, and 8% of participants had non-heterosexual orientations or did not report. Of these participants, 81.7% were White, 8.5% were Hispanic or Latino, 1.2% were Black, 5.5% were Asian or Pacific Islander, and 3.1% did not report. Finally, 18.4% of participants were first-generation college students and 5.5% of participants identified as non-traditional.

The surveys were distributed in two forms: (1) printed on paper, passed out and collected in the respective engineering classes, or (2) in an online Google Form advertised to be available through the CSU teaching and learning portal (Canvas) for one week. The paper format had been shown to yield highest response rates, but based on instructors’ preferences, online format was applied for the MECH and CIVE classes. The survey consists of three different sections: gauging the students’ retention, evaluating LL effectiveness, and demographic reporting. The participants could select more than one option in some questions, and could choose to skip any section or question. The time required to complete the survey was estimated to be 10 minutes.

**Results and Discussion**

The purpose of this study was to gauge the effectiveness of Learning Labs on retention of first-year engineering students in first semester MECH, CIVE, and CBE department courses. This was done using the combined metrics of semester-to-semester retention and grade data, LL attendance data, LL attendance/non-attendance feedback, and progression intention feedback.

**First-year engineering course progression**

To have a preliminary estimation of the response of engineering departmental retention to implementation of LLs, we developed a measurement of retention referred to here as “progression,” as stated before. For our purposes, progression is defined as enrollment in the typical 2nd semester engineering course of the specific engineering discipline after completion of the typical 1st semester introductory engineering course. First, semester-to-semester progression in three previous years was analyzed. This progression data was then compared to that of the semester that LLs were first implemented, Fall 2016,
progression being enrollment in the typical subsequent course in Spring 2017. The results of these comparisons are shown in Fig. 1a. No consistent trend before and after implementation of the LLs is found, with MECH showing better progression than previous years, CIVE the reverse and CBE no significant difference. There are also several additional points to be noted. First, active learning was incorporated into MECH 103 beginning in the Fall 2016 semester along with the efforts of LLs. Evaluation of the active learning activities covered in a separate study shows statistically significant improvements over the past years. Therefore, such an improvement in progression of Mechanical Engineering first-years is also expected. Secondly, CIVE 102 saw a significant increase in class size from the Fall 2016 semester compared to the Fall semesters of the three previous years (from an average of ~93 to 196 students). The observed decrease in progression may reflect the increase in class size.

Then, we looked at the effects of grades on students’ progression. Firstly, we tested the statistical significances of the differences in the grade distributions of progressed and non-progressed students using the Wilcoxon rank sum test. The corresponding p-values are shown in Table 1. We found that the two distributions are statistically significantly different except for MECH in Fall 2016 and CBE in Fall 2014. This finding preliminarily shows the significant effects of grades achieved for a student’s decision on progression. We further looked at the details of how grade is influencing the progression as detailed in the Methods section. As shown in Fig.1b-d, a nearly monotonically decreasing trend of progression as a function of grades was observed for all three departments. We compared the grade data of Fall 2016 to those of the three Fall semesters (color-coded red and blue respectively in Fig. 1). Varied results were observed for all departments covered in this analysis. Consistent with the results shown in Fig. 1a, the trend in progression of MECH in Fall 2016 is significantly higher than that of previous years. Several possible factors could be contributing to this improvement, including the implementation of LLs or the change in pre-requisite grade of a C to a D. In contrast, the trend of progression of CIVE in Fall 2016 seems to be completely consistent with that of previous years, despite an overall lower percentage of progression as shown in Fig. 1a. This data shows no consistent improvement on progression of the three departments covered by the implementation of LL program.

Even though this method analyzing progression reveals the differences and consistencies across different years based on an objective dataset, there are several limitations to it. First, personal identifiers were not considered here, but could be used to determine more personal factors driving the decision-making process to stay in or leave the program. Second, we are not able identify personal reasons behind the decisions of students to progress in the same program or not, due to the nature of the dataset. For instance, we cannot distinguish between a student leaving just their major but staying in the College of Engineering, or leaving the discipline completely, therefore limiting our direction following this analysis alone. Lastly, the definition of progression in the current method is an oversimplification of real-world cases. Given these limitations, this study called for the incorporation of more insights collected by surveys. Such surveys were issued and discussed further herein.
Figure 1. (a) Comparison of first semester-to-second semester retention in past three years (2013-2015) vs. during and after semester that LLs were implemented (Fall 2016). Also shown are progression trends as correlated to achieved grades in the first semester for each major’s first semester engineering class, broken down into first-year engineering courses for (b) MECH, (c) CIVE, and (d) CBE.

Table 1. Overview of p-values of Wilcoxon rank sum tests on the grade distributions of progressed and non-progressed students. Except for MECH in 2016 Fall and CBE in 2014 Fall (shown in red text), p-values smaller than 0.01 are observed.

<table>
<thead>
<tr>
<th>Program</th>
<th>2016</th>
<th>Averaged Plotted Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2013</td>
</tr>
<tr>
<td>MECH</td>
<td>0.093</td>
<td>0.002</td>
</tr>
<tr>
<td>CIVE</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>CBE</td>
<td>N.A.</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Learning Lab feedback and correlation with progression
Following the above analysis, it was necessary to also examine progression in the context of LL attendance in order to determine whether LLs may have had any effect on progression between courses in Fall 2016 and Spring 2017. Reasons behind attendance and non-attendance were also examined using survey response data in order to inform and adjust future applications of the LL program.

As reported in the Methods section, the overall response was about 32% participation across all four engineering majors included in this study. The lowest response rate was in CIVE, with 5% of the first year class responding. This may be explained by fact that the Civil Engineering department at CSU tends to survey their students regularly throughout the semester collecting some similar data, and when given the option to take an additional survey that was only advertised online with no grade incentive, the motivation to respond was low. In contrast, the CBE course had the highest response rate (69%), likely due to paper survey distribution and collection within the same course period. These differences in surveying methods may have affected the survey response rates and thus outcome of data presented, but seem to reflect relative surveying conditions.

MECH and CIVE had low LL attendance (1.4% and 0.5% of their total class sizes, respectively), while CBE had higher attendance (42.3%) (Fig. 2a). A few weeks into the semester, the GTF cohort noticed that attendance was not improving despite attempts to advertise the resource. Instructors of engineering courses were requested to add an incentive for LL attendance, but CBE was the only one to gain one in the form of extra-credit incentive. Based on survey responses, students from MECH largely did not attend due to either never hearing about them or not knowing exactly what they involved. This latter reason held similarly true with CIVE, though the other highly cited reason was that LLs were held at inconvenient times. Those who did attend LLs tended to find the sessions generally helpful.

At the end of the semester, LL attendance data was tallied and the overall attendance of the LLs was low, with only 33 students attending of a possible total population of 412 (8% attendance) (Fig. 2a). The number of LLs a student attended was broken down into whether those students progressed or did not progress (Fig. 2b). From this data, it appears that the highest percentage of students who were able to progress to the second semester of their first year came from the group of students who did not attend any LLs. For groups of students who attended one or more LLs, a majority is observed to not progress. In order to explain these unexpected findings, timing of attendance was deemed important to take into consideration. Given that most LL attendance (from any student) occurred towards the end of the semester, it may be that students who attended LLs were more often than not looking for an additional resource due to struggling in their courses, who were then unable to progress in the field due to the lateness of their reaching out. At this later point of the LLs, students doing favorably in their courses may not have seen the need for an extra obligation, or relatedly, potential extra credit as offered in the CBE 101 course. In summary, students most likely saw LLs as an opportunity for extra help in areas they were weak in, rather than a way to expand their existing understanding of a topic to a deeper level to encourage growth and understanding in the long term.
Conversely, the students who did not attend and did progress likely did not deem it necessary to seek additional help with their work in the form of LLs.

While LLs were on the surface somewhat ineffective in attracting students based on attendance data, GTFs made several observations based on those students who did participate, which may be valuable for future iterations of the GTF/LL program. First, attending students did not seem to be aware of the fact that resources are available to them outside of their textbooks and lecture materials. This led to adjustments of the LL design to point them towards outside resources and encourage personal research on topics they required or desired additional information and perspectives on. With some attendees, this led to exploration and discovery of their personal learning styles. As a result, LLs began to be even more emphasized as less of an additional office hour, and more of a way to point students towards outside resources and a forum to encourage students to do their own research on topics that they required or desired additional information and perspectives on. This response was not atypical, as studies have shown that self-motivated research generally led to exploration of student interests and learning styles.8, 9

A second observation was made in retrospect and in reflection to poor attendance. For those students given extra credit incentive to attend within their engineering course, they came without specific issues and were uninterested or unmotivated to delve into the content presented in LLs. Based on the design of the LLs, it seems apparent that some level of self-motivation is necessary for the activities to be effective since there is no requirement tied to the LLs. The basis behind this program was to discover the connection between fundamentals taught in core math science courses and their application to engineering content, and while LLs aimed to do this it seems that the purpose was overlooked by most. Students did not appear to be actively thinking about the reasons behind their learning, therefore somewhat undermining the purpose of the LLs. This could suggest that the fundamental assumption of a disconnect between core and engineering subject matter is either incorrect, or simply an unconscious phenomenon rather than a conscious disinterest of students who end up leaving engineering.

Another observation was that students were more interested in asking questions related explicitly to their homework or examples from class, rather than becoming acquainted with concepts designed by GTFs to encourage deeper thinking in an engineering context. This suggests while response to the LLs was ultimately tested, the intended effect of the LLs was not successfully tested and the experiment was incomplete as a result of its design. LLs must be made attractive to those students experiencing it, possibly on an even more fundamental level than extra credit in order for them to feel the full effects of this active learning and core-engineering course integration attempt. On the plus side, engineering applications not mentioned in their core courses ended up appealing to many attendees, though whether this deepened their understanding or excitement past a fleeting interest is inconclusive at this point.

Another explanation as to low attendance and somewhat disappointing results of the LL model is simply a failure in the way LLs were advertised (see Methods for details). Due to their being categorized and tailored by the core math and science course (e.g. PHYS
141 Learning Lab) rather than an engineering course, students may not have perceived them to be useful for their engineering courses, and being that our initial assumption was less interest in core vs. engineering courses, there was little motivation to attend. Future implementations of the program in response to this observation may then require categorization of LLs based on their engineering course (e.g. MECH 103 Learning Lab), offering help in all core math and science courses in the context of that specific engineering course.

In order to help narrow down the potential causes of low attendance, students were asked the following questions in surveys deployed in the first-year engineering courses. First, if they attended, in what ways was the LL helpful or not helpful (Fig. 2c); second, their reason for not attending if they did not attend LLs (Fig. 2d). The most prominent reasons for non-attendance for both students who progressed and did not progress were (1) that the LLs were at an inconvenient time, and (2) that they were unsure of the content of the LLs.

Regarding reason (1) behind non-attendance, LL times were chosen based on estimates of undergraduate student free-time and cross reference to corresponding course times in order to minimize conflicts with class. They were generally held from 12-2pm and 5-7pm. Based on this survey response, it may be useful in future implementations to survey undergraduates on times they would be most likely to attend. However, this is additionally constrained by Graduate Teaching Fellows’ own schedules and limitations which may limit flexibility to schedule sessions. Regarding reason (2) behind non-attendance, LLs were advertised by an in-class announcement by the GTF involved in that classroom on the first day of the engineering courses. Additionally, first-years were intermittently reminded throughout the semester by either more in-class announcements or online reminders by email or class forum. After discussion among GTFs, it may be useful in future semesters to give a sample lesson or sample worksheet in core courses to demonstrate how LLs will be run, and all the possibilities for how LL sessions might go. Perhaps a description of the benefits of active learning, and the intended benefits of the LL program may be worth going explaining to first-year students the program is being advertised to.
Figure 2. LL attendance and feedback across engineering disciplines. (a) Shows a breakdown of overall LL attendance across first-year engineering courses. (b) Quantifies overall LL attendance of students who progressed and did not progress between semesters. (c) Quantifies survey responses of whether or not the LLs were helpful while (d) summarizes the reasons for non-attendance in LLs of first-year engineering students.

Feedback on progression from first-year engineering students

Finally, the reasons behind progression or non-progression after the first semester of LL implementation were examined based on the survey. This was done in order to determine whether there was any correlation, as well as to elucidate reasons behind the progression statistics reported earlier in this study.

Fig. 3a reports on student survey responses to the question of why they were remaining within their major and continuing on to the next course. The first most popular response was due to their confidence in their success at their chosen major. This corresponds well to the results shown in Fig. 1 indicating that achieved grade in a course is a strong factor in determining a student’s progression or non-progression to the subsequent course. The second most common response indicated perceived importance of the degree for their desired future career. The third most popular answer was that they found their program of study enjoyable. It is important to note that students were able to make multiple selections for this particular survey question. That said, while a large majority of
progressing students were confident in their success in the program, only one student reported the coursework being easy. Therefore, this confidence is likely not a product of ease of training but of something else internal, the most likely reason being good work ethic. In addition, it may also be surmised that the programs are enjoyable despite not being particularly easy.

**Fig. 3b** addresses reasons for reported non-progression via the distributed surveys. The reason (1) “engineering is uninteresting” constituted the highest percentage of responses of any of the options given, followed by both (2) students having had different expectations for what engineering was and (3), difficulty of the coursework.

![Survey results on reasons behind progression into the 2nd semester and non-progression into the 2nd semester, during semester that LLs were implemented.](image)

**Figure 3.** Survey results on reasons behind (a) progression into the 2nd semester and (b) non-progression into the 2nd semester, during semester that LLs were implemented.

Reason (1) may have some overlap with reason (2), in that disinterest was related to different expectations of the program. Reasons (2) and (3) were part of original motivation behind the LL/GTF program. Regarding reason (2), it was implemented under the assumption that students expected much more “engineering” and less focus on core math and science coursework, consequently neglecting to put more work and effort into their core courses. However, this survey result suggests that the engineering courses themselves are not what students expected to enter into, which may still relate to the unexpectedness of much more math and science within their courses. This result prompts the question, what exactly do students expect engineering coursework to involve, and how this can be reconciled with actual courses? This is a topic to be explored in a future study.

Reason (3) had also been considered a main deterrent to remaining in engineering, assumed, as mentioned, to be due to large amounts of focus in courses outside of the “pure” engineering courses of math and science, and the integration of multiple areas of study into one that is typically considered difficult. Almost any fundamental course in the field of engineering requires knowledge of math, science, coding, and ethical restraints, proper handling of which in turn begs a deeper understanding than the surface-level, simplified “sum of its parts.” The LL program’s intended design was to adjoin these seemingly separate modes of thinking, and present math and science in the context of
engineering, and vice versa. Integrating active learning as well as shifted contexts of the standard topics in core and first-year engineering courses was designed to allow students to gain an understanding of engineering through multiple lenses, in an attempt to enrich the learning environment and produce skilled and knowledgeable engineers.

Upon completion of this preliminary study, it is worth noting that the true effects of the program could not be fully analyzed due to low attendance of LLs, revealing a possible flaw in the way LLs were advertised to students. Details of the LLs appeared to not have been adequately defined and promoted. By recommendation of members of the GTF cohort, future LLs should be advertised in such a way to distinguish them from other resources such as office hours and subject-specific tutoring. In this way, we can more confidently determine whether it was the content of the LLs that was ineffective, or simply the way it was deployed. Relatedly, there seemed to be a lack of extrinsic motivation for most students to attend, with the one example of extra credit being offered in the introductory CBE course having increased attendance. The focus of those few who did attend was not necessarily on the deeper understanding intended for the LLs, but instead simple answers to homework questions and more tangibility in relation to their final grades in the course.

Importantly, the LL model did result in exposure of undergraduate students to a number of engineering-related problems that they may not have been aware of before. Additionally, the program ended up being highly necessary in bringing awareness to possible incorrect assumptions of reasons behind retention. This resulted in GTFs as well as College of Engineering retention program coordinators to more deeply probe causes of non-progression and overall retention at CSU by careful study of this Spring 2016 semester, including summarizing and publishing of data resulting from it. We also discovered the need for attention to how programs like these are advertised, and revealed that there may have to be an official incentive for students to attend. Extra credit, while effective at increasing attendance, does not seem to be a sufficient motivator towards the goal of improved learning and fundamental understanding of the subject matter. This has led to discussion of an extra course credit for future implementation of active learning activities and engineering applications to core coursework.

It is worth noting that the data reported are influenced by several factors which were not taken into account due to limited time and resources. For instance, the effect of class size on retention was not examined explicitly in this study even though it has been shown to be a major influencer of the student learning experience. Therefore future studies plan to include a dissemination of variables such as class size, educational background, teaching/learning styles, and reported study habits on progression and retention. These studies would also require “progression” to be more explicitly and consistently defined than was in this study, perhaps after a full year of progression data after implementation of retention programs like the LL model. It may also be interesting for topics such as the effect of advertisement method on optional resources (such as LLs) to be explored in order to have a better understanding of how we may collect complete data in the future. Additionally, it may be interesting to look at the effect of LLs on core math and science
grades of engineering students since LL activities were designed with respect to these subjects.

Conclusions

This study evaluates the effect of implementing a first-year engineering student retention program in the form of Learning Labs. This LL program was deployed for the first time in the Fall 2016 semester and advertised as an additional optional resource for first-year engineering students taking traditional core math and science courses concurrently. A combination of semester-to-semester progression data from the ARIESweb database, student survey responses, and observations from the GTF cohort tasked with leading these LL sessions has revealed many strengths and weaknesses of the LL model.

The introduction of LLs to the first-year engineering experience was intended to be a helpful resource to deepen understanding of both engineering and math/science concepts. However, due to a variety of factors, its implementation fell short to some extent due to factors such as time constraints of first-year engineering students as well as ineffective communication regarding their utility. Future implementations of retention programs such as this will work to simultaneously address and correct weakness uncovered by this study, as well as augment its perceived and proven strengths.

Acknowledgements

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References


Appendix A: Example Learning Lab worksheet

Mars Climate Orbiter
Chemistry 111: Learning Lab 2
September 12-16, 2016

The Mars Climate Orbiter was launched on its 669 million mile journey towards Mars on December 11, 1998, to help with communication for the Mars Planetary Lander. Together, the Mars Orbiter and Mars Planetary Lander were to map Mars’ surface, profile the structure of the atmosphere, try to detect surface ice reservoirs, and dig for traces of water beneath the surface—to understand its history and its potential to sustain, or to have sustained, life.

On September 23, 1999, the final rocket fired to adjust the Orbiter’s trajectory to reach Mars’ orbit. The spacecraft suddenly went out of radio contact, and communication with the Orbiter was never reestablished. An investigation concluded that NASA engineers failed to convert the rocket’s thrust from pounds force (lb) to newtons (N). The spacecraft expected newtons, while the computer worked in pound forces (1lb = 4.448 N). As a result, the spacecraft missed its intended 140-150 km altitude above Mars when going into orbit, entering below the 80 km minimum required for the spacecraft’s safety. Entry at such a low altitude resulted in high atmospheric stresses and friction, completely destroying the spacecraft.

**Problem 1.** A solid rocket booster like the one used on Mars Orbiter is ordered with the specification that it is to produce a total of 10 million pounds (or lb) of thrust. If this number is mistaken for the thrust in Newtons, by how much, in lb, will the thrust be in error?

**Problem 2.** The Mars Climate Orbiter was meant to stop about 160 km away from the surface of Mars, but it ended up within 36 miles of the surface. How far off was it from its target distance (in km)? If the Orbiter is able to function as long as it stays at least 85 km away from the surface, will it still be functional despite the mistake?
The Mars Climate Orbiter was outfitted with a two-camera color imaging system called MARCI. Under good conditions, resolutions up to 1 kilometer away are possible. Its objectives:

- Observe martian atmospheric processes at global scale
- Study details of the interaction of the atmosphere with the surface at a variety of scales in both space and time.
- Examine surface features characteristic of the evolution of the martian climate over time.

**Problem 3.** The MARCI takes an image of the soil immediately in front of it. Considering the planet's nickname, what wavelength might the camera filter pick up? What frequency does this wavelength correlate to?

**Problem 4.** There are interesting mountain-like features 1.4 miles from the Mars Climate Orbiter. Will its camera be able to capture these? What is the MARCI’s resolution capability in miles?

**Think about it:** How do you think this problem relates to working in groups as an engineer? If you were chief NASA engineer on the mission, what would you do to prevent this from happening again?

**References:**
http://chem.libretexts.org/Core/Analytical_Chemistry/Quantifying_Nature/Case_Studies/%3A_Metric%2F%2FEnglish_Conversion_Errors
Appendix B: Engineering Student Survey

Engineering Student Survey

Note to participants: This is a survey aimed at researching learning and retention in engineering. Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty. Your instructor will not have access to the collated survey data until after the grades are posted for the semester, and this report will be a summary of results with no personal identifiers. Should results of this survey be reported in any way, data from all participants will be combined. The researchers have taken reasonable safeguards to minimize any known risks. Completing the survey and turning it in is your consent to participate in the study.

- This survey is expected to take 5-10 minutes to complete, and consists of 12 questions (see both sides of paper).
- You may select multiple options unless explicitly asked to choose one.
- All questions are optional, but full completion of the survey is highly encouraged.
- Feel free to attach extra pages if more space is needed for comments.

1. Select your major(s)
   a. Biomedical Engineering
   b. Chemical and Biological Engineering
   c. Civil and Environmental Engineering
   d. Electrical and Computer Engineering
   e. Mechanical Engineering
   f. Other: ____________________________

2. Are you continuing in your major(s)? Choose one.
   a. Yes
   b. No
   c. Both – explain (e.g. if changing 1 of 2 majors, please state which one you are dropping):

            ____________________________

3. If yes, why?
   a. Confidence in my future success in this major
   b. Interesting/enjoyable
   c. Easy
   d. Important to career path
   e. External pressures (familial, societal, etc.)
   f. Sense of community/friendship
   g. Other:

            ____________________________

4. If no, why not?
   a. The coursework is too difficult
   b. The basic science and mathematics courses I have to take don’t relate to my engineering course(s)
   c. The class sizes are too large
   d. The required homework and study hours are too many
   e. The teaching in my engineering courses is not engaging
   f. The teaching in my chemistry course is not engaging
   g. The teaching in my physics course is not engaging
   h. The teaching in my math course is not engaging
   i. I don’t like engineering; I find the coursework uninteresting
   j. Engineering is not what I expected
   k. There is not enough student support
   l. I feel isolated from other students
   m. The instructor is not approachable
   n. Financial issues
   o. Other:

            ____________________________

More questions on reverse
5. If no, what are you moving on to do?
   a. Leave major for another within the CSU College of Engineering – which one?
   b. Leave major for another outside the CSU College of Engineering – which one?
   c. Transfer from CSU to another university/college
   d. Leave university/college completely
   e. Other:

6. About how many learning labs did you attend?

7. Were the learning labs helpful?
   a. Yes, for both core and first-year engineering class concepts – name course(s): 
   b. Yes, for core class (chemistry/math/physics) concepts only: name course(s):
   c. Yes, for first-year engineering class concepts only
   d. No
   e. N/A

8. If you did NOT attend any learning labs, why not?
   a. Inconvenient time
   b. Too time-consuming
   c. Didn’t need/want help
   d. Heard they were unhelpful
   e. Hadn’t heard about them
   f. Didn’t know what they involved
   g. N/A
   h. Other:

9. On a scale of 1-5, how helpful were your Learning Lab-connected TAs in your ENGINEERING courses? Circle one.
   
<table>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<td>Not at all</td>
<td>Extremely</td>
<td></td>
<td></td>
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</table>

10. Gender identification
    a. Male
    b. Female
    c. Transgender
    d. Prefer not to say
    e. Other:

11. Ethnic identification
    a. White
    b. Hispanic or Latino
    c. Black
    d. Native American
    e. Asian or Pacific Islander
    f. Other:

12. Educational identification
    a. First generation college student
    b. Non-traditional student
    c. None of the above
    d. Other: