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Living-Learning Communities Improve First-Year Engineering Student Academic Performance and Retention at a Small Private University

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Abstract

Living-Learning Communities (LLCs), in which students share a residence, one or more classes, and extracurricular activities, have been shown to improve first-year student engagement, academic performance, and retention in non-engineering fields. Research on Engineering LLCs has focused primarily on student engagement. Two studies to examine performance and retention found that LLCs had little effect on first-semester grades but increased first-year retention in engineering by 2 to 12%. Unfortunately, one of these studies did not control for differences in incoming student characteristics, and another used a comparison group that differed little from the LLC group, possibly causing them to understate the LLC's true effects. To improve our understanding, this paper examines performance and retention in the inaugural Engineering LLCs at a small, private non-profit, regional university in the northeastern United States.

Results indicate that 82% of the Engineering LLC participants were retained within the engineering program, compared to 66% of first-year engineering students who chose not to participate. More strikingly, the average first-semester GPA of the LLC participants was 0.31 points (nearly a third of a letter grade) higher than that of the non-participants. To address the possibility that these improvements were caused by differences in incoming student characteristics, linear and logistic regression analyses were performed to control for gender, race/ethnicity, SAT scores, and other factors. These analyses suggest that LLC participation increased GPA by 0.35 points compared to first-year engineering students from prior years, while non-participation lowered GPA by 0.07 points. LLC participation increased the odds of retention in the major by 2.3 times compared to first-year students from prior years, while non-participation lowered the odds of retention by 1.35 times.

Introduction

In 2011, President Obama called for U.S. engineering schools to graduate an additional 10,000 engineering students every year.[1] One impetus for making this appeal, as explained by the Jobs Council, was that engineers drive innovation, creating jobs for skilled and unskilled workers alike.[2] In short: more engineers can drive economic recovery, and by extension, stability. In response to the appeal, many engineering school deans recognized that one solution was to improve the retention rate of engineering students,[3] specifically first-year retention, which at the time was reported to be around 60%.[4]

In was in this context that our work to increase the engineering retention rate at our school began, although it was not a direct result of the appeal. The more immediate reason was to maintain our school's enrollment in the face of competition for fewer and fewer high school graduates in the geographic area from which our students typically come.[5]

A number of practices have been identified that, when used appropriately, can address some of the reasons why first-year students leave engineering.[3, 6] Some of these practices, or a combination of two of more of them, have been implemented by engineering programs to improve retention: first-year seminars and experiences,[7-12] writing intensive courses,[13] collaborative assignments and projects,[14, 15] undergraduate research,[16, 17] diversity/global learning,[18, 19] and learning communities.[20-22] In additions to these practices, some authors have reported other interventions designed to improve retention, including peer and faculty mentoring,[23, 24] bridge or college preparatory programs,[24-26] and mandatory math tutoring.[27]

In this study we explore the effectiveness of a variation of a learning community – namely a living-learning community (LLC) of first-year engineering students that was started at our university in the fall of 2013 and is now in its second year. Loosely defined, an LLC is a group of students who live together in a dorm and take one or more courses together. LLCs have been shown to improve engagement, performance and retention in fields other than engineering.[28] There is some evidence that they are effective in engineering as well, and we review relevant literature in the following section. In this paper we focus on two central questions:

1. What effect does participation in an Engineering LLC have on student performance and retention?
2. How do students opting to participate in an Engineering LLC differ from those choosing not to?

The theoretical framework on which we base our work is that of Tinto,[29] which holds that student outcomes are influenced both by the students' prior preparation for higher education (called inputs), and the conditions in which the student operates in college (called the environment). The input and environmental characteristics for our work are described in the results section. In this study, and the ones that we review in the following section, the outcomes are defined as student performance (first-semester GPA) and first-year retention (students are still enrolled in the engineering program after their first-year).

Literature Review

The first use of LLCs in the United States is typically cited to be at The Experimental College at the University of Wisconsin in 1927.[30] These initial LLCs were typically not centered around engineering.[30] More recently, non-engineering LLCs have been shown to be effective at improving student engagement, retention and performance.[28] There are now LLCs at many engineering schools.[3] One of the earliest reported Engineering LLCs was formed at Colorado State University in 1976.[31] The vast majority of LLCs described in the literature are for first-year students, and accordingly are specifically intended to increase freshman retention. Published studies of Engineering LLCs have assessed student engagement,[32-35] or engagement, performance, and retention.[12, 36-39]

As our work focuses on performance and retention, we review the findings of a sample of published work reporting these outcomes. It is not an exhaustive review, but represents typical types of studies and results from a variety of LLCs at several different institutions.

The Engineering LLC at Michigan State University has been in existence since the late 1990s.[39] The control group for this study was defined as students who were freshmen in the engineering program but not housed with the LLC. As measures of student performance, Zmich and Wolff reported the average GPA for the three LLC-related courses, as well as the average cumulative GPA for all courses. They reported these measures for both the LLC members and a control group for three separate offerings of the LLC (in 1996, 1998, and 2000). In 1996 and 1998 the LLC had either no significant impact or a *negative* impact on these measures. However, the 2000 LLC showed improvement in three of the four measures. One possible explanation for this improvement is that the LLC program was refined over time. This study did not report first-year retention, but did report retention up to the year 2000 for students in the 1996 and 1998 offerings. The LLC made no statistical impact on retention of students from 1996. Furthermore, the retention rate for LLC students from 1998 was actually *lower* than that of non-LLC students (70% compared to 81.3%).

The impact that the LLC at Washington State University had on the performance of the entering class of 2003 was measured by final grades in 5 different courses.[38, 40] Light and her colleagues observed differences in student performance but they were not statistically significant. The LLC did, however, have a significant effect on retention. One limitation of this study is that it used a comparison group that differed little from the LLC group, possibly causing it to understate the LLCs' true effects. The comparison group lived in the same dorm as the LLC and took the same classes, but did not participate in peer-led study sessions.

Female students at Virginia Tech have had the opportunity to participate in an LLC since 2001, and male students since 2005.[37] The different starting dates for men and women highlights the fact that LLCs can be used as a tool to increase retention in specific demographic groups. In this study student performance was reported as current GPA in engineering for cohorts since 2001 (for women) and 2005 (for men). Looking at the 2006-2007 cohort (who were freshmen at the time of publication) both men and women show improved performance by participating in the LLC, although we note that statistical probabilities were not reported with their findings. Retention for each cohort up to the date of publication was higher for LLC participants. The control groups for both the women and men were designed to have matched relative demographics.

The LLC at Texas A&M is one of the largest in existence as it includes 600 first-year students.[36] Hodge et al. reported first-year retention as well as student performance. Retention increased for two out of the four of the LLC cohorts compared to control groups. The LLC did not have a statistically significant impact on student performance. Unfortunately, the authors did not control for differences in incoming student characteristics.

Some universities are attempting to increase their retention rate by implementing an LLC as well as other high impact practices. For example, Central Connecticut State University implemented both an Engineering LLC and a first-year experience (FYE).[12] In this case there was no true control group – instead comparisons between the two interventions were made. Both the LLC and the FYE had fairly high freshmen retention rates, compared to the other studies, but the

Table 1: Summary of Outcomes from Selected Studies of Engineering LLCs

Author	Year	Improves Retention	Impact on Performance: # of Measures Improved	# of Measures w/ No Impact	# Measures Worsened
Zmich	1996	Likely[a]	0	3	0
Zmich	1998	Likely[a]	0	2	1
Zmich	2000	n/a[b]	2	1	0
Light	2003	Yes	0	4	0
Kampe	2007	Yes	1	0	0
Hodge	2006	Yes	0	1	0
Hodge	2007	No impact	0	1	0
Hodge	2008	No impact	0	1	0
Hodge	2009	Yes	0	1	0
Vasko	2012	Yes	1	0	0
Tsang	2013	n/a[c]	2	1	0

[a] Freshman retention not reported, but retention at other times was higher for the LLC.
[b] Study was published in 2001 about the 2000 cohort - freshmen retention data was not available.
[c] Study did not report retention.

LLC's was larger (94% compared to 87%). Instead of presenting average GPA as a measure of student performance, the authors provide the distribution of GPA at the end of the freshmen year. They note that although there were no top performing students in the LLC (i.e., none of them earned an A), there were more students in the LLC who performed at or above an acceptable GPA level of 2.0.

In Table 1 we summarize the findings of each study, according to the various authors' definitions of retention and performance and their own statistical methods. To construct the table, we counted the number of measures that the authors said improved. For example, if an author reported that three measures of performance improved, we inserted "3" in that column. From this admittedly limited sampling, the picture that emerges is complex: some LLCs appear to improve student performance, some appear to have no impact, and in one case an LLC seems to have had a negative effect on performance. There seems to be more consensus that LLCs improve retention.

We note that with the exception of one of these studies,[12] all the LLCs were at significantly larger universities than our own. This suggests that studies to determine the impact of LLCs on performance and retention have not been performed for school of our size, or that schools of our size do not typically offer engineering LLCs.

Implementation of Engineering LLCs at the Study University

The study was conducted at Roger Williams University, a small, private non-profit, regional university located in Bristol, RI. The university enrolls about 3900 undergraduate students, 7.5% of whom major in engineering. The engineering program is housed in the School of Engineering, Computing, and Construction Management, and offers a B.S. in Engineering with specializations in Mechanical, Civil, Electrical, and Computer Engineering. Students also have the option to define their own custom specialization. The majority of the students enrolled in the engineering program come from New England, New York, and New Jersey.

Like many post-secondary institutions, the study university has implemented several programs to help first-year students transition to college. Three such programs relevant to this study include:

1. First Year Seminars (FYS) – special sections of a three-credit core curriculum course. Compared to other sections of the core courses, FYS include only first-semester students, are limited to an enrollment of eighteen students per section, are taught by a full-time faculty member (instead of adjunct faculty), and include additional learning outcomes intended to develop academic habits of mind (i.e., reflection, explanation, etc.).
2. RWU Experience (RWUXP)[41] – a non-credit course meeting one hour per week. Led jointly by a faculty member and an upperclass student, sessions introduce first-semester students to campus resources such as the library, the tutoring center, the course registration system, student organizations, etc. To incentivize attendance, participants attending all sessions receive priority registration for the second semester and a University-subsidized passport if they do not already have one.
3. Living-Learning Communities (LLCs) – typically organized by discipline (e.g., Business or Psychology) or interdisciplinary theme (e.g., sustainability, diversity), each LLC takes a 3-4 credit theme-related course together and lives together in an on-campus dormitory. The faculty member teaching the course serves as the LLC mentor. Shortly before the start of fall classes the mentors participate with their LLCs in a day-long community service activity. During the school year each mentor organizes two on-campus and one off-campus course-related events for his or her LLC, and has dinner or coffee with the LLC twice. The mentors also provide informal mentoring as needed. Each LLC has a student Resident Assistant who organizes several events for their LLC per semester. Honors students have their own LLC, with the shared courses being honors sections of expository writing and a core curriculum class.

Because these programs have similar goals, we include all of them as environmental factors in the analysis.

Placement into the various first-year programs was determined primarily by student self-selection. Admitted students were offered the opportunity to choose an LLC when they submitted their housing deposit and preferences. Assignments were made on a first-come, first-served basis. Students who did not request an LLC were assigned to either a First Year Seminar or the RWU Experience.

Although the university has offered LLCs for over a decade, the first Engineering LLCs were run in the Fall of 2013. Two LLCs, each containing 19 students, were mentored by the same faculty member. Each LLC had its own section of Engineering Graphics and Design, the standard first course for the Engineering major. Three non-LLC sections of the same course, identical in design and delivery to the LLC sections, were taught by two other instructors and enrolled a total of 31 true first-year students as well as 30 non-first year students (transfer students, students who had changed major, etc.). Some of these first-year students participated in LLCs other than the Engineering LLC.

Each Engineering LLC had its own housing area, in separate dorms, and its own senior Engineering-major Resident Assistant. The two LLCs had separate meals with the mentor but participated jointly in the extracurricular activities. The service activity involved trash pick-up at a local non-profit community development center. The on-campus events consisted of two guest speakers, one an expert on nuclear proliferation and the other on business innovation. The off-campus event, by popular vote, was a trip to the Boston Science Museum.

In the Fall of 2014 one Engineering LLC was offered, due to reduced student demand. It enrolled 21 students and was mentored by a different faculty member than the previous year. The LLC course was still Engineering Graphics and Design, and was virtually unchanged from the prior year. Four non-LLC sections of the course enrolled a total of 54 first-year students and 19 non-first-year students. The LLC service activity involved assisting with routine maintenance at a local non-profit therapeutic riding facility. The on-campus event consisted of a guided tour of the Mt. Hope suspension bridge. Due to scheduling conflicts, the off-campus event took place in the Spring of 2015. Students toured the innovative HVAC systems of the newly-renovated Harvard Art Museums, designed by Renzo Piano.

Methods

Sample Definition

Because this study seeks to assess the effects of Engineering LLC participation on typical first-year Engineering students, the study sample was defined to include all students taking the introductory Engineering Graphics and Design course during their first college semester in the Fall of 2011, 2012, 2013, or 2014. Based on this definition, the following types of students were *not* included in the sample:

- Students who had transferred into the study university after starting college at another institution. Such students had not been invited to participate in the Engineering LLC.
- Students who were taking the Engineering Graphics and Design course in their second or higher semester (because, for example, they had changed major into Engineering or were taking the course as a non-major). Again, such students did not have the option to participate in the Engineering LLC.

The resulting sample included a total of 314 students. Although Engineering LLCs were not offered prior to 2013, the 2011 and 2012 cohorts were included to provide benchmark values for student inputs and outcomes and to increase the number of observations for regression analyses. Cohorts prior to 2011 were not used due to limited data availability and because the university, the engineering program, and the incoming student demographics have all shifted over time.

Data Collection

Student names were first gathered from the rosters of all sections of the Engineering Graphics and Design course. For these students, university databases were used to determine: enrollment status (transfer or true first-year student), class standing (first-year, second-year, etc.), high school GPA, SAT scores, gender, race/ethnicity, housing location (on- or off-campus), initial

math and writing course placements, participation in an LLC or other first-year program, and first-semester GPA. Engineering LLC participation was confirmed with the Resident Assistants of the three LLCs. Engineering retention was defined as the student clearly progressing through the engineering program. In the vast majority of cases, this meant enrolling in the second- and third-semester engineering courses (Computer Applications and Statics, respectively).

Data Analysis

The data were first thoroughly reviewed for discrepancies and missing values. Two students were admitted with ACT scores rather than SATs. These were converted to equivalent SAT scores using the ACT's published concordance tables.[42] Four students of the 314, all from 2011 or 2012, were missing too much data to be included in multivariate analysis. Of those remaining, one was missing high school GPA, one initial course placements, eight math and verbal SAT scores, and 33 writing SAT scores. These missing values were omitted for descriptive statistics but imputed using all available data for use in the regression models. While this does introduce some small error into the estimates for those particular variables, inclusion of these students in the models reduces uncertainty for all the other variables.

After preparing the data, the input, environmental, and output characteristics of the Engineering LLC participants were compared to those of the non-participants. Numerical variables such as GPA and SAT scores were compared using t-tests, ordinal variables such as initial math course placement using the Wilcoxon rank-sum test (a non-parametric analog to the t-test), and categorical variables such as race/ethnicity and gender using Pearson's chi-square test or Fisher's exact test where appropriate. Unless otherwise noted, all tests were two-tailed (no prior expectation about which group would be higher).

The descriptive analysis revealed that Engineering LLC participants performed better than same-year non-participants on all outcome measures, but also that the LLC participants differed slightly from non-participants in input and environmental characteristics. To determine whether the observed differences in outcomes were truly due to LLC participation, regression models were created to estimate the LLCs' effect independent of all other input and environmental variables. Ordinary least squares regression was used to model first-semester GPA, while logistic regression was used for first-year engineering retention because it is a binary outcome.[43]

Consistent with standard practice,[43] the logistic regression results are reported using *odds ratios*. Readers unfamiliar with logistic regression should keep in mind that odds are not the same as probabilities. For example, if 60% of a cohort of students is retained in engineering (as was typical both nationally and at the study university from 2011-2012), the probability of a particular student being retained is 0.6 while the odds of his or her being retained are 60:40 or 1.5:1. If, on the other hand, 82% of a group of students is retained (as was the case for the 2013 Engineering LLCs at the study university), the probability of retention is 0.82 while the odds of retention are 82:18 or 4.556:1. The *probability* of retention is 1.367 times greater for the second case (=0.82/0.6), but the *odds* of retention are 3.037 times greater (4.556/1.5). This latter value is known as the odds ratio.

Results

Input Characteristics

To address the question of whether students opting to participate in an Engineering LLC differ from those choosing not to, Table 2 provides a demographic summary of the students participating in the Engineering LLCs, the Honors LLC, Other LLCs, as well as those who Chose No LLC (in the 2013 and 2014 cohorts) and those for whom the Engineering LLC was Not Offered (in 2011 and 2012). As one might expect, students in the Honors LLCs had significantly higher SAT scores and high school GPAs (statistical analysis was performed, but the details are omitted so as not to distract from our central research questions).

Those differences aside, our real interest is whether the students participating in the Engineering LLCs differed from those in the Other LLC, Chose No LLC, and Engineering LLC Not Offered groups. The 2014 Engineering LLC, being all male, differed significantly in gender from the same-year Chose No LLC (Fisher's exact test, $p = 0.0207$) and Other LLC ($p = 0.0046$) groups, as well as the 2011-12 Engineering LLC Not Offered group ($p = 0.048$). The 2013 Engineering LLCs differed significantly on high school GPA from the same-year Other LLC group (t-test, $p = 0.0464$). Otherwise the incoming characteristics of the Engineering LLCs were similar to those of the Chose No LLC and Other LLC groups within their respective years.

Table 2: Incoming Student Characteristics

	2014 Cohort				2013 Cohort				2012 & 2011	
	Chose No LLC	Engr. LLC	Honors LLC	Other LLC	Chose No LLC	Engr. LLC	Honors LLC	Other LLC	Engr. LLC Not Offered	Honors LLC
(*N*)	(39)	(21)	(6)	(9)	(29)	(38)	(3)	(2)	(163)	(4)
High School GPA	3.35 ± 0.40	3.32 ± 0.40	3.73 ± 0.27	3.53 ± 0.34	3.32 ± 0.39	3.33 ± 0.35	3.83 ± 0.21	2.80 ± 0.00	3.26 ± 0.39	3.85 ± 0.13
Math SAT	593 ± 64	594 ± 54	670 ± 53	589 ± 70	591 ± 71	604 ± 57	623 ± 67	650 ± n/a	595 ± 55	690 ± 61
Verbal SAT	531 ± 76	540 ± 64	580 ± 43	523 ± 75	537 ± 71	529 ± 72	573 ± 50	510 ± n/a	531 ± 67	635 ± 89
Writing SAT	525 ± 61	527 ± 57	588 ± 61	564 ± 125	529 ± 66	538 ± 66	563 ± 55	510 ± n/a	522 ± 62	583 ± 71
Gender (%)										
Female	23.1	0	33.3	44.4	10.3	13.2	66.7	0	16.0	50
Male	76.9	100	66.7	55.6	89.7	86.8	33.3	100	84.0	50
Race/Ethnicity (%)										
African American	0	0	0	0	0	0	0	0	1.2	0
Asian American	2.6	4.8	16.7	11.1	0	0	0	0	1.9	0
Hispanic	2.6	4.8	0	0	3.4	0	0	0	3.1	0
Intl. Student	2.6	4.8	0	0	10.3	5.3	0	0	2.5	0
White	87.2	81.0	83.3	77.8	82.8	94.7	100	100	87.0	75.0
Two or More	0	0	0	0	0	0	0	0	0.6	25.0
Unknown	5.1	4.8	0	11.1	3.4	0	0	0	3.7	0

Environmental Characteristics

Table 3 compares the first-year environmental characteristics experienced by each of the LLC groups. As with the input characteristics, the Honors students differed significantly on several measures. Disregarding the Honors students, the only noteworthy difference within the 2014 cohort was that students in the Engineering LLC placed into higher writing classes than students in the Other LLC group (Wilcoxon rank-sum test, $p = 0.0527$).

Students in the 2013 Engineering LLCs placed into significantly higher math classes than students in the same-year Chose No LLC group ($p = 0.015$) and significantly higher writing classes than students in the same-year Other LLC group ($p = 0.0147$). Students in the 2013 Engineering LLCs were significantly less likely than the Chose No LLC group to participate in a First Year Seminar (Fisher's exact test, $p = 0.0459$) and the RWU Experience ($p = 0.0071$). This is not surprising because incoming students were intentionally distributed among the LLC, FYS, and RWUXP programs.

In summary, the students participating in the Engineering LLCs were substantially similar to non-participants, with the key exceptions that the 2014 Engineering LLC was entirely male and the 2013 Engineering LLCs placed into significantly higher math courses.

Output Characteristics

Table 4 presents key first-year outcomes for the various LLC groups, while Figure 1 and Figure 2 depict them graphically. The average first-semester GPA of the 2014 Engineering LLC was 0.21 points higher than that of the same-year Chose No LLC group (t-test, $p = 0.128$), and 0.19 points higher than that of the same-year Other LLC ($p = 0.344$) group. The average GPA of the 2013 Engineering LLCs was 0.49 points higher than that of the same-year Chose No LLC group ($p = 0.0023$), and 1.46 points higher than that of the same-year Other LLC group ($p = 0.0020$) though the latter included just two students. When the two cohorts are combined, the average GPA of Engineering LLC participants was 0.31 points higher than that of those who Chose No LLC ($p = 0.0159$) and 0.36 points higher than those from 2011-12 for whom the Engineering LLC was not available ($p = 0.0014$).

The first-year engineering retention rate of the 2013 Engineering LLC participants was 81.6%, compared with 65.5% for the same-year Chose No LLC group (Fisher's exact test, $p = 0.163$), 50% for the same-year Other LLC group, ($p = 0.364$), and 60.1% for the 2011-12 cohorts ($p = 0.0143$). As of this writing, first-year retention is not yet known for the 2014 cohort.

First-semester engineering retention for the 2013 cohort was essentially equal for the Engineering LLCs and the same-year Chose No LLC at 86.8 and 86.2% respectively. First-semester retention for the 2014 cohort is significantly higher – 100% for the LLC group and 94.9% for the Chose No LLC group. All of these rates are higher than first-semester retention for the 2011-12 cohorts.

Table 3: Student First-Year Environment Characteristics

	2014 Cohort				2013 Cohort				2012 & 2011	
	Chose No LLC	Engr. LLC	Honors LLC	Other LLC	Chose No LLC	Engr. LLC	Honors LLC	Other LLC	Engr. LLC Not Offered	Honors LLC
(*N*)	(39)	(21)	(6)	(9)	(29)	(38)	(3)	(2)	(163)	(4)
Math Placement (%)										
College Algebra (remedial)	0	0	0	0	0	0	0	0	18.0	0
Precalculus	30.8	28.6	0	33.3	34.5	10.5	0	0	23.6	0
Calculus I	53.8	57.1	33.3	55.6	58.6	71.1	33.3	100	47.8	25
Calculus II	15.4	14.3	66.7	11.1	3.4	15.8	66.7	0	9.9	75
Differential Equations	0	0	0	0	3.4	2.6	0	0	0.6	0
Writing Placement (%)										
Engl. As Second Language	2.6	0	0	0	3.5	0	0	0	0.6	0
Intro Writing (remedial)	30.8	19.0	0	55.6	17.2	21.1	0	100	25.3	0
Expository Writing	59.0	81.0	83.3	44.4	79.3	78.9	100	0	73.5	75
Critical Writing	7.7	0	16.7	0	0	0	0	0	0.6	25
Residence (%)										
On campus	97.4	100	100	100	93.1	100	100	100	93.8	100
Off campus	2.6	0	0	0	6.9	0	0	0	6.2	0
First Year Seminar (%)										
Yes	0	0	0	0	27.6	7.9	0	0	3.2	0
No	100	100	100	100	72.4	92.1	100	100	96.8	100
RWU Experience (%)										
Yes	15.4	9.5	0	22.2	24.1	2.6	0	0	16.9	25
No	84.6	90.5	100	77.8	75.9	97.4	100	100	83.1	75

Table 4: Student Outcomes

	2014 Cohort				2013 Cohort				2012 & 2011	
	Chose No LLC	Engr. LLC	Honors LLC	Other LLC	Chose No LLC	Engr. LLC	Honors LLC	Other LLC	Engr. LLC Not Offered	Honors LLC
(*N*)	(39)	(21)	(6)	(9)	(29)	(38)	(3)	(2)	(163)	(4)
1st Semester GPA	3.03 ± 0.50	3.24 ± 0.41	3.50 ± 0.58	3.05 ± 0.70	2.68 ± 0.86	3.17 ± 0.39	3.88 ± 0.06	1.71 ± 0.14	2.85 ± 0.82	3.42 ± 0.29
1st Semester Retention (%)										
In Engineering	94.9	95.2	100	77.8	86.2	86.8	100	100	81.0	100
At University	97.4	100	100	100	93.1	92.1	100	100	89.6	100
1st Year Retention (%)										
In Engineering	n/a	n/a	n/a	n/a	65.5	81.6	100	50	60.1	100
At University	n/a	n/a	n/a	n/a	86.2	89.5	100	100	78.5	100

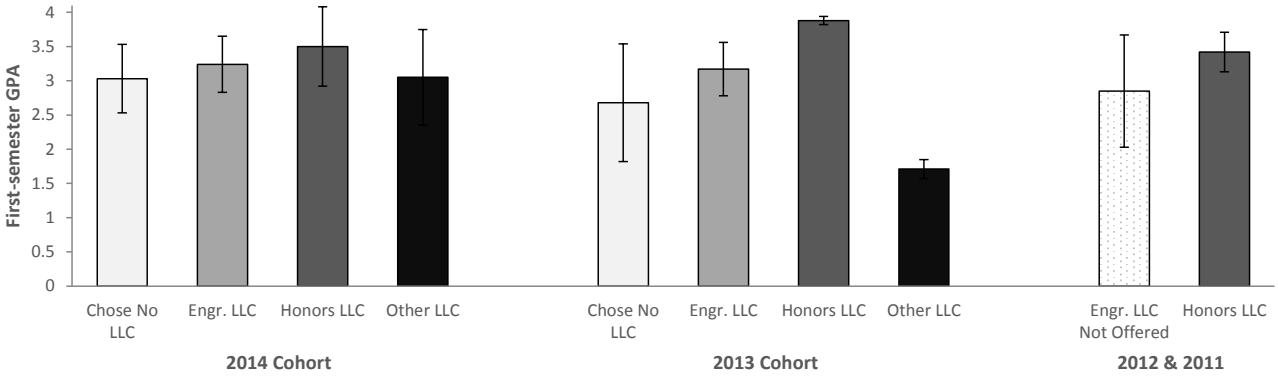

Figure 1: First-semester GPA. The error bars represent the standard deviations.

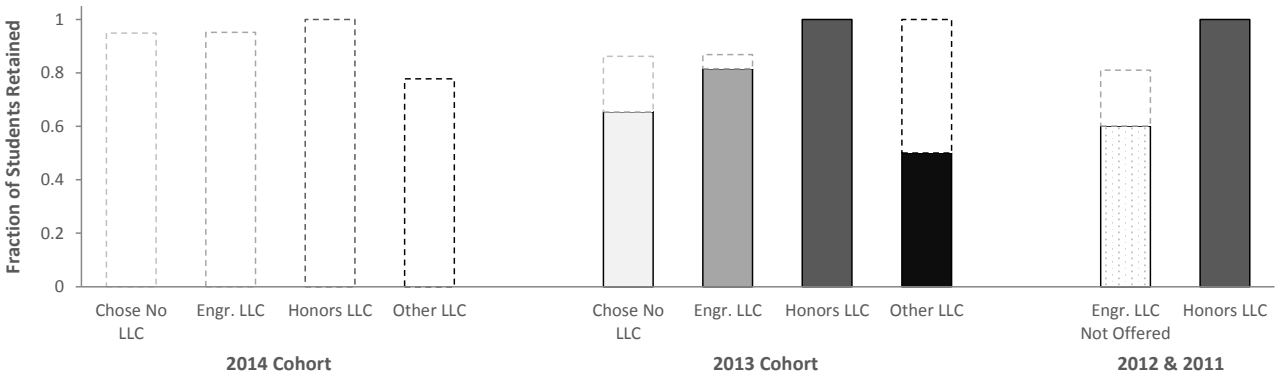

Figure 2: Retention in engineering after one semester (dashed lines) and one year (solid bars).

Based solely on the descriptive statistics, it appears that Engineering LLC participants had higher first-semester GPAs and better first-year engineering retention than non-participants. However, as we noted earlier, this difference may be partly due to the slight differences in input and environmental characteristics. To address this uncertainty, regression models were built to isolate the effect of LLC participation, while controlling for all other input and environmental variables.

Table 5 depicts the results of three linear regression models for first-semester GPA: one for the 2014 cohort, one for 2013, and one for the years 2011-14 combined. The results indicate that after controlling for differences between the LLC groups, participation in the Engineering LLC improved student first-semester GPAs by 0.268 (in 2014) to 0.682 (in 2013) points compared to not participating in any LLC. These effects were nearly ($p = 0.069$) and highly ($p < 0.0001$) significant, respectively. In the four-year combined model, the improvement was 0.422 points ($p = 0.0002$). In contrast, participating in an Other LLC actually lowered first-semester GPA by 0.250 points in the combined model ($p = 0.225$). Other significant explanatory variables included high school GPA, gender, and participation in the RWUXP. To put the magnitude of the Engineering LLC effect in perspective, the 0.422 point improvement in GPA is equivalent to what would be expected from a 0.485 point increase in high school GPA.

Turning now to retention, Table 6 presents the results of two logistic regression models for first-year retention within engineering. The first model was constructed from the 2013 cohort alone, and suffers somewhat from the relatively small sample size (logistic regression requires more observations per variable than does least squares regression). The effects of several variables could not be quantified because all the students in certain categories were retained. For example, all the female students in the 2013 cohort were retained, making their odds of retention infinite. Similarly, all students living off campus were retained. To enable the model to run, those variables were removed. In other cases, individual categories within a multinomial variable created instability. For example, the sole Hispanic student in the cohort was retained, the sole student of unknown race was not, all students starting in Differential Equations were, etc. Such categories were removed from the model or combined with other categories, as noted in the table, for this analysis only. Sensitivity analysis indicated that doing so had little effect on the results, in part because ethnicity and math placement were not strong effects. The Honors students posed a unique problem: they were all retained, yet could not be reclassified to another LLC group without significantly contaminating the model. The only way to proceed was to exclude these three students altogether.

Having said that, the 2013 model suggests that participation in the Engineering LLCs increased the odds of a student being retained in engineering by 2.73 times compared to students who Chose No LLC ($p = 0.172$) and by 2.53 times versus participation in Other LLCs ($p = 0.588$). The other factor having a noteworthy effect on retention was Math SAT ($p = 0.157$).

To address the sample size issue, a second model was created using all students from the 2011, 2012, and 2013 cohorts. Again the Honors students were excluded, and a few math and writing placements were temporarily reclassified.

Table 5: Linear Regression Models for First-semester GPA[a]

	2014 Cohort (N = 75)				2013 Cohort (N = 72)				2011 – 2014 Combined (N = 306)			
	b	*β*	*t*	*p*	*b*	*β*	*t*	*p*	*b*	*β*	*t*	*p*
Intercept	0.133	0	0.10	0.920	0.644	0	0.58	0.563	-1.73	0	-2.66	0.008
High School GPA	0.396	0.302	2.06	0.044	0.778	0.413	4.14	0.0001	0.871	0.464	8.44	<0.0001
Math SAT	0.00142	0.172	1.04	0.303	-0.000796	-0.0699	-0.63	0.534	0.00105	0.0837	1.34	0.181
Verbal SAT	0.000574	0.0770	0.48	0.634	-0.00174	-0.172	-1.34	0.186	0.000438	0.0407	0.62	0.538
Writing SAT	0.000597	0.0805	0.44	0.664	0.00122	0.108	0.86	0.397	0.00120	0.103	1.42	0.156
Gender (1 = female)	0.319	0.247	1.78	0.081	0.301	0.147	1.41	0.165	0.205	0.104	2.07	0.039
Race/Ethnicity[b]												
African American		n/a				n/a			0.198	0.0215	0.44	0.658
Asian American	0.250	0.109	0.78	0.442		n/a			-0.262	-0.0528	-1.09	0.276
Hispanic	-0.301	-0.094	-0.80	0.425	-0.251	-0.0417	-0.46	0.648	-0.561	-0.121	-2.54	0.012
International Student	0.502	0.157	0.98	0.334	-0.190	-0.0685	-0.62	0.535	-0.0106	-0.00255	-0.05	0.963
Two or More		n/a				n/a			-0.668	-0.0725	-1.47	0.143
Unknown	-0.208	-0.0907	-0.76	0.452	-0.426	-0.0705	-0.79	0.430	-0.289	-0.0726	-1.51	0.131
Math Placement[c]												
College Algebra		n/a				n/a			-0.0825	-0.0304	-0.57	0.572
Precalculus	0.0871	0.0758	0.58	0.567	0.0108	0.00606	0.06	0.952	0.211	0.121	2.33	0.021
Calculus II	0.0226	0.0170	0.12	0.905	-0.277	-0.130	-1.35	0.184	-0.0693	-0.0322	-0.57	0.571
Differential Equations		n/a			-0.286	-0.0666	-0.70	0.484	-0.148	-0.0196	-0.41	0.681
Writing Placement[d]												
English as Second Language	-0.768	-0.171	-1.03	0.306	0.896	0.149	1.43	0.158	0.0913	0.00992	0.19	0.853
Intro Writing (remedial)	0.0637	0.0554	0.29	0.775	-0.0283	-0.366	-0.13	0.896	0.339	0.196	2.89	0.004
Critical Writing	-0.0320	-0.0139	-0.10	0.918		n/a			0.0319	0.00595	0.12	0.908
Residence (1 = off-campus)	-0.237	-0.0527	-0.37	0.711	0.394	0.0918	0.99	0.325	0.364	0.0953	1.93	0.055
First Year Seminar		n/a			0.124	0.0632	0.62	0.535	-0.0458	-0.0137	-0.28	0.776
RWU Experience	0.0861	0.0567	0.45	0.652	0.674	0.300	2.98	0.004	0.300	0.142	2.84	0.005
Living Learning Comm.[e]												
Engineering	0.268	0.233	1.86	0.069	0.682	0.482	4.22	<0.0001	0.422	0.224	3.73	0.0002
Honors	0.0930	0.0489	0.37	0.715	1.05	0.298	2.79	0.007	0.324	0.088	1.55	0.122
Other LLC	-0.177	-0.111	-0.87	0.387	-0.349	-0.0813	-0.85	0.397	-0.250	-0.0627	-1.22	0.225
Engr. LLC Not Offered		n/a				n/a			0.0724	0.0488	0.76	0.446
	R^2 = 0.386, R^2_{adj} = 0.174				R^2 = 0.645, R^2_{adj} = 0.515				R^2 = 0.389, R^2_{adj} = 0.335			

[a] The *b* column indicates the regression coefficients, *β* the standardized regression coefficients, *t* the t-statistic for the coefficients, and *p* the p-value.
[b] Reference group for Race/Ethnicity is White, non-Hispanic.
[c] Reference group for Math Placement is Calculus I.
[d] Reference group for Writing Placement is Expository Writing.
[e] Reference group for Living Learning Community is Chose No LLC.

Table 6: Logistic Regression Model for First-Year Engineering Retention

	2013 Cohort (N = 69)			2011 – 2013 Combined (N = 228)		
	Odds Ratio	*95% CI*	*p*	*Odds Ratio*	*95% CI*	*p*
High School GPA	1.96	0.340–11.8	0.447	1.99	0.835–4.77	0.121
Math SAT	0.991	0.978–1.00	0.157	1.00	0.997–1.01	0.260
Verbal SAT	0.993	0.979–1.01	0.249	0.998	0.991–1.00	0.480
Writing SAT	1.01	0.994–1.02	0.268	1.01	0.998–1.01	0.144
Gender (1 = female)	all 8 female students were retained			1.34	0.529–3.61	0.549
Race/Ethnicity[a]						
African American		~		0.469	0.0162–14.1	0.622
Asian American		~		0.828	0.0656–20.0	0.887
Hispanic	the 1 Hispanic student was retained			1.33	0.195–9.19	0.763
International Student	1.97	0.149–51.9	0.616	1.07	0.164–9.46	0.948
Unknown	the 1 student was not retained			0.408	0.063–2.62	0.331
Math Placement[b]						
College Algebra		~		0.199	0.0629–0.584	0.003
Precalculus	0.415	0.0785–2.15	0.288	0.586	0.271–1.27	0.176
Calculus II or higher	3.41	0.347–91.8	0.320	2.06	0.595–9.72	0.270
Writing Placement[c]						
Intro Writing or ESL	0.880	0.114–7.68	0.903	2.10	0.757–6.14	0.156
Residence (1 = off-campus)	both off-campus students retained			1.92	0.406–11.8	0.426
First Year Seminar	2.40	0.379–19.0	0.362	1.64	0.481–6.28	0.436
RWU Experience	3.96	0.457–90.6	0.229	2.19	0.878–5.99	0.094
Living Learning Comm.[d]						
Engineering	2.73	0.646–12.4	0.172	2.30	0.658–8.31	0.192
Other LLC	1.08	0.0263–44.1	0.966	0.581	0.0184–18.2	0.731
Engr LLC Not Offered		n/a		1.35	0.476–3.71	0.564
	pseudo R^2 = 0.157			pseudo R^2 = 0.150		

[a] Reference group for Race/Ethnicity is White, non-Hispanic. For the 2013 model the sole Hispanic and Unknown Race/Ethnicity students were included in the reference group.

[b] Reference group for Math Placement is Calculus I. Students starting in Differential Equations were combined with Calculus II because they were all retained.

[c] Reference group for Writing Placement is Expository Writing. Students starting in the English as a Second Language (ESL) class were included within Intro Writing, while the sole non-Honors student who started in Critical Writing was included with Expository Writing.

[d] Reference group for Living Learning Community is Chose No LLC. Honors students were excluded from both models due to perfect retention.

In addition, because the students from 2011 and 2012 did not have the option of participating in an Engineering LLC, they were categorized as "Engineering LLC Not Offered" rather than the "Chose No LLC" used for the 2013 cohort. The results of the 2011-13 model suggest that participating in the Engineering LLC increased the odds of retention by 2.30 times versus those who chose not to participate (p = 0.192), and by 1.70 times versus those who did not have the option to participate (p = 0.270). The most significant predictors of retention include placement in College Algebra (p = 0.003), participation in the RWUXP (p = 0.094), and high school GPA (p = 0.121).

Discussion

In both the 2013 and 2014 cohorts, we observed a substantial increase in first-semester GPA for students participating in the Engineering LLC (as seen in Table 4 and Table 5). In the 2013 cohort, the only one for which first-year retention is currently known, we observed a substantial increase in engineering retention (Table 4 and Table 6). These results are consistent with results from non-Engineering LLCs as well as Tinto's theory of student departure,[29] but are stronger than have been previously reported for Engineering LLCs. The strength of the effects is surprising given that the study institution is smaller than most of those previously studied, with a more intimate campus, lower student-to-faculty ratio, smaller class sizes, etc. One might expect LLCs to have a stronger effect at larger, less personal institutions.

The positive impacts of Engineering LLC participation are impressive given the minimal additional obligations an LLC imposes on the both the institution and the student. In fact, for the student the additional obligations – field trips, having dinner with their mentor – are far from onerous. For the institution, the additional tasks – screening and placing students in LLCs, faculty participation in the community service day, faculty organization of the field trips and dinners – require a bit more work, but are easily accomplished.

The finding, for the 2013 cohort, that non-participation worsened performance and retention compared to prior years is unexpected. One possible explanation is that the LLC sections included over half of the incoming freshman engineering class. If LLC participation improved those students' grades, other first-year students taking the same courses might have received lower grades if the courses were graded on a curve. Another possibility is that concentrating the more-engaged students in LLC sections may have watered down the non-LLC sections, or left the first-year students in them surrounded by more confident and capable upperclassmen. If either explanation is true, it might also explain why the worsening effect was not observed in 2014, because in this cohort, *less* than half of the first-year students were members of the LLC. This finding suggests that LLCs may cut both ways. While they appear to improve performance for participants, they may worsen it for non-participants. Engineering programs seeking to implement LLCs may wish to encourage either very high participation (to provide the benefits fairly to all students), or relatively low participation (so as not to pull all the highly-engaged students out of the non-LLC sections).

A small number of students who did not participate in the Engineering LLCs were members of other (non-engineering) LLCs. For the 2013 cohort, the results suggest that participating in those LLCs led to a decrease in performance and retention compared to both the Engineering LLC (see Table 5 and Table 6, 2013 Cohort models) and past years' students (Table 5 and Table 6, 2011-2014 and 2011-2013 Combined models, respectively). For the 2014 cohort, participating in the other LLCs also lowered performance (Table 5, 2014 Cohort model). These results might point to the relative effectiveness of the various LLCs. Indeed, an internal university survey of the 2013 LLCs found that Engineering LLC participants rated their LLC experience more favorably than participants of most other LLCs. A more subtle conclusion might be that it is critically

important to place students in the correct LLCs. Placing engineering students in a non-engineering LLC may have soured their entire academic experience.

Comparing the various first-year programs, the Engineering LLCs had the strongest effect on first-semester GPA, increasing it by 0.422 points, followed closely by the Honors LLC and the RWU Experience at 0.324 and 0.300 points, respectively (Table 5, 2011-2014 Combined Model). Of course, the Honors LLC was not open to all students who applied for it. The First Year Seminars had little effect, and the non-Engineering LLCs actually lowered performance as noted above.

With regards to retention, the Engineering LLC had the strongest effect, increasing the odds of retention by 2.30 times for those who chose to participate, followed by the RWU Experience at 2.19 times, then First-Year Seminar at 1.64 times (Table 6, 2011-2013 Combined Model). To put these values in context, note that an increase of 1 point in high school GPA increased the odds of retention by nearly 2 times. The strength of the RWU Experience for both performance and retention is particularly striking, given that it is the type of intervention that some faculty members might scoff at for being too basic (e.g., where is the library, how do I register for classes, etc.).

While it is certainly valuable to know the impacts of the LLC on retention and student performance, it is arguably more important to know why they had the strong effect that they did. Understanding the true reasons will take more study, but we can speculate as follows. One possibility is that housing the LLC engineers together made them feel part of a community. The students faced the challenges of engineering education together and could provide peer-to-peer academic and personal support. Another explanation is that housing the engineers together isolated them from the general university population, which includes many disciplines that are less rigorous than engineering. We speculate, though have no evidence to prove, that the atmosphere in the Engineering LLCs was more conducive to studying than that of a typical freshman dorm. Isolating the engineers also limits the degree to which they can compare their workloads and grades to those of other, grade-inflated, majors. Such comparisons can motivate students to abandon engineering for majors where they can earn better grades while putting in less effort. The isolation hypothesis is also supported by the finding that students living off-campus had substantially higher GPAs and retention than those living on-campus (Tables 5 and 6). Note that first-year students at the study institution may only live off campus if they reside with a family member. We assume that such residences would be more conducive to studying than a typical freshman dorm.

A second possible explanation for the finding that LLC participants had better performance and retention than non-participants is the presence of self-selection bias beyond what our data can control for. While the regression models controlled for high school GPA and gender and SAT scores and the like, it is possible that students opting to participate in the Engineering LLCs were more motivated and/or capable of studying engineering. Additional data from interviews or focus groups or surveys might capture such differences. This is left for future work.

A third, more cynical, explanation is that students participating in the Engineering LLCs may have benefited from cheating. When a group of students is very familiar with each other, as they are in an LLC, there is a sense that they should help each other, which is a desired result unless they take it too far. Academic dishonesty has been previously identified as a possible downside of LLCs, both in the literature[44] and by experienced faculty members at the study institution. Indeed, the 2013 Engineering LLC mentor caught a group of about six students turning in identical CAD files on several homework assignments. Most of them lived in the same suite within their LLC. Their grades were docked accordingly, but any undetected cheating in the Engineering Graphics and Design course or other courses (e.g., Math) could have contributed to higher GPAs for members of the LLCs.

One factor that we do not believe to be responsible for the observed improvements in performance and retention was the extracurricular LLC activities. For the 2013 cohort, attendance at these events was fairly low (about 25% for the on-campus events and meals and 50% for the field trip) because of the difficulty in finding a convenient time for all 38 students. For the 2014 cohort, the field trip has not even occurred, though the on-campus event was well-attended and popular. Perhaps it had a positive effect, but we note that the 2013 cohort, with its poorly-attended extracurriculars, had a much higher improvement in GPA (Table 4).

Conclusions

Our results suggest that participating in an Engineering LLC improves first-semester GPA by 0.4 points, even after controlling for all measured student input and environmental characteristics. This result is both substantial and highly significant. Engineering LLC participation appears to increase the odds of first-year retention in engineering by 2.3 times compared to not participating in any LLC. This result is substantial but not statistically significant, perhaps because retention is presently only known for the 2013 cohort. It is important to reiterate that the study was conducted at a small, undergraduate-only institution. All students in the engineering program (whether they are in the LLC or not) have extensive access to all instructors, and the instruction (lecture content, assignments, exams, etc.) in the freshman class is the same for all students. The fact that the LLC participants performed better than the non-participants indicates that placing first-year students in a carefully-planned residential program is a worthwhile endeavor.

The results also suggest which input and environmental characteristics, other that participation in the LLC, influence first-semester GPA and retention to the greatest degree. High school GPA and gender can be used as predictors of first-semester GPA, while high school GPA and math placement are positively associated with first-year retention. Of all the environmental characteristics, one in particular – participation in the RWUXP – stands out as more important than the others.

These findings are supported by several aspects of the study methods. First, the study was a complete census of all first-year engineering students at the study institution. Thus there is no sampling error. Second, given the relatively small size of the dataset, it was possible to check it very thoroughly for errors (compared to, say, Stassen[28], who had ~7500 students in her sample).

Third, all input, environmental, and output variables are objective and reliably measured. Use of institutional records frees the study from the non-response bias, recollection error, and common-method variance issues that plague subjective surveys of students. Finally, linear and logistic regression were used to isolate the effects of LLC participation from those of input and other environmental characteristics.

The study's primary limitation is the fact that it included just one institution, and just two years of LLC use (though two additional years were included to provide baseline data). First-year retention could only be assessed for one of the two years of LLC use. The study's findings may not generalize to other types of institutions. The second major limitation is that the study's reliance on quantitative data makes it difficult to determine a mechanism to explain why LLC participation improved performance and retention. A third limitation is that the study did not control for the influence that the LLC mentor might have had on student performance and retention. While the Engineering Graphics and Design course content was very similar across years and between LLC and non-LLC sections, the instructors were different. Furthermore, due to factors beyond our control, the 2013 LLC mentor taught both LLC sections and no non-LLC sections that year, making Instructor and LLC-status non-orthogonal in that year. As a result it is impossible to separate the effects of instructor (if any) from those of the LLC for that year. That instructor did, however, teach several sections in 2011 and 2012, which did not perform or retain at the level of his LLC sections, suggesting that the effect of the instructor is minimal.

The study suggests several avenues for future work. Most obviously, we intend to collect first-year retention data for the 2014 cohort and include them in the models to see if they reinforce or subvert our current results. Second, we would like to conduct qualitative research into the causes of the LLCs' effects. One possibility is to analyze existing documents such as a survey we have the students take on the first day of class about why they chose engineering and what they think it is, for differences between LLC participants and non-participants. Another possibility would be to interview or survey LLC participants about their experience, and both participants and non-participants about their decision to participate or not. Going forward, we might investigate other outcomes such as student engagement, as has been done in other studies. More ambitious would be an experiment in which first-year engineering students are simply housed together, without any formal learning community or the attendant activities that go with it. We suspect that shared housing is a necessary component of an effective living learning community – is it a sufficient condition?

This paper joins a growing body of work investigating the effects of a high-impact practice in engineering education: the living-learning community. It makes a unique contribution to this literature by demonstrating that Engineering LLCs can positively impact student performance and retention even at a small, private institution; most prior work has been conducted at large public universities. We conclude that our use of Engineering LLCs should be continued in its current form or expanded to include more students.

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