ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37860

First-Year Engineering Living-Learning Communities Improve Four-Year Graduation Rates at a Small Private University

William Palm

William Palm is Associate Professor of Engineering and Director of the Honors Program at Roger Williams University, where he has taught Engineering Graphics and Design, Machine Design, Manufacturing and Assembly, Materials Science, Biomechanics, Medical Device Design, and other courses. Prior to joining Roger Williams, he worked as a product design engineer and consultant and taught at Boston University and the U.S. Coast Guard Academy. He holds a PhD in Mechanical Engineering from MIT and is licensed as a Professional Engineer in the Commonwealth of Massachusetts.

First-Year Engineering Living-Learning Communities Improve Four-Year Graduation Rates at a Small Private University

Abstract

This complete research paper assesses the long-term benefits of first-year student participation in an Engineering Living-Learning Community (ELLC) at a relatively small private university. Prior research on ELLCs has examined short-term results such as first-year student engagement, academic performance, and retention, but relatively few studies have reported data on long-term outcomes such as graduation rates and GPA at graduation. This paper reports the outcomes of four cohorts of Engineering students who entered the study university between 2013 and 2016.

Students participating in the ELLC had significantly higher 4-year graduation rates in Engineering (55.7% vs. 42%) and in STEM (64.3% vs. 51.2%), and higher 4-year graduation rates from the university (66.1% vs. 56.8%), than non-honors Engineering students who did not participate in the ELLC. Although the average first-semester GPA of ELLC participants was significantly higher than that of non-participants (3.15 vs. 2.82), the difference faded over time. The average GPA at graduation for ELLC Engineering graduates was 3.22, compared to 3.12 for non-honors non-ELLC Engineering graduates.

To determine whether the ELLC's superior outcomes might be explained by differences in incoming student characteristics between the ELLC and non-ELLC groups, or by student participation in other programs such as a first-year seminar or athletics, multinomial logistic and linear regression were used to control for high school GPA, SAT scores, and other factors. The results indicate that ELLC participation doubled the odds of four-year graduation in Engineering or STEM over non-participation, both significant effects, and increased graduation GPA in Engineering by 0.07 points.

This study suggests that a relatively modest intervention implemented in the first year alone may have lasting benefits on student retention and performance, even in small universities that might be thought to have less need for the community development an LLC provides.

Introduction

Living-Learning Communities (LLCs), in which students live together in a dormitory or other residence while participating in common courses and/or co-curricular activities, have been touted as a high-impact educational practice [1]. LLCs can be organized around particular majors such as engineering, identity characteristics such as gender or ethnicity, or interdisciplinary themes such as sustainability. Over one hundred universities have established Engineering-based LLCs over the past four decades [2], [3], and studies have shown that they can improve short-term measures of student success such as engagement, first-year academic performance, and first-year retention [4] - [13]. Less is known about the long-term impacts of LLC participation on student performance, persistence, and graduation in engineering. This paper analyzes the graduation outcomes of the first four cohorts of Engineering LLCs (ELLC) at one university. It extends and complements our previous research, which showed that ELLC participation significantly improved first-semester GPA and first-year retention in engineering [14].

Engineering LLCs were first offered at the study university in 2013, as one of several tools deployed to enhance first-year student success. Others included first-year seminars, a non-credit college transition course, and LLCs organized around general education courses. All such interventions require resources, and so it is natural to assess their effectiveness. While short-term outcomes like first-year performance and retention are commonly used, they are proxies for our ultimate goals: preparing students for future success in their chosen fields, and doing so in a reasonable amount of time. Metrics for these goals include four-year graduation rates and, somewhat crudely, GPA at graduation. Although student success in any academic program should be celebrated, at the national level there remains need to graduate students in engineering and other STEM fields [15], [16]. Doing so in four years, rather than six or more, is more cost-effective and launches students into their careers sooner. Thus, the primary research questions that this paper seeks to address are:

1. How does first-year student participation in an ELLC affect four-year graduation in Engineering, in other STEM majors, and from the university overall?
2. How does ELLC participation affect GPA at graduation in Engineering?

To answer these questions, it is necessary to address a third question:

3. Do students who participate in an ELLC differ from those who do not participate, and if so, how do the differences affect graduation rates or GPA at graduation?

The paper employs Astin's Input-Environment-Output framework as well as Tinto's theory of student departure [17], [18]. Astin's model suggests that student outcomes are influenced by the student's prior preparation for higher education, as well as the conditions the student experiences in college. Tinto theorized that students are more likely to persist if they become engaged socially and academically in the institution, as might occur in an environment such as an LLC. The input and environmental variables for the present study are described in the methods and results sections. The outcome variables are four-year graduation (the student graduates from the program or university to which they were admitted within four calendar years) and GPA at graduation (final cumulative GPA). While not the focus of the paper, short-term outcomes such as first-year retention and GPA are also presented. To provide meaningful comparisons, GPA is calculated only for students persisting in the Engineering major (students changing to other majors may experience different grading norms).

Literature Review

Compared to the body of scholarship examining short-term ELLC outcomes, very few published studies examine graduation rates or GPA at graduation. In a brief work-in-progress paper, Sandvill and colleagues stated that the four-year Engineering and Computer Science (ECS) graduation rate for students participating in the ECS LLC at Baylor University between 2013 and 2018 was 44.3%, compared to 29.8% for non-participants [19]. No additional statistics were provided, nor was the comparison controlled in terms of student input or environmental factors

(the authors did note the possible existence of confounding variables such as academic preparation and socio-economic status).

In another study, Silliman and colleagues showed that students participating in the ECS LLC at Gonzaga University were substantially more likely to persist in ECS disciplines into the 8th semester than non-participants [13]. The results were not tabulated, but a line chart suggests that about 70.5% of LLC participants entering in 2009 persisted to the 8th semester, compared to just 56% of non-participants. The corresponding figures for the 2010 cohort were 64.5% and 52%. No additional information was provided, and the comparison was not controlled.

Caldwell and Hughes report that participants in the Engineering LLC at Florida A&M University persisted to the 4th year at substantially higher rates than the general Engineering student population (51% vs. 26% persistence in Engineering, 74% vs. 50% in STEM majors) [4]. The demographics of LLC participants were somewhat different from those of non-participants. Graduation data were not provided.

Slightly more research has been published for broader STEM-themed LLCs. Participants in the 2006-2009 cohorts of the EXCEL Program at the University of Central Florida, a two-year LLC for higher-risk STEM students, had an average graduation rate in STEM that was 12 percentage points higher than that of a comparison group matched for math SAT and math placement level but not gender or race/ethnicity [20]. LLC participants also had 2-6% higher graduation rates from the university. Unfortunately, the study reports graduation status as of 2013 rather than four- or six-year graduation rates for each cohort (i.e., the 2006 cohort data are for 7-year graduation, the 2007 data are for 6-year graduation, etc.).

At least two studies examine the effect of STEM LLC participation on women specifically. Participants in the first six cohorts of the Women in Science and Engineering LLC at what is inferred to be Florida State University graduated at higher rates from the university (79.1% vs. 69.0%) and at higher rates in Physical Sciences/Engineering/Mathematics/Computer Sciences (23.4% vs. 12.4%) than non-participants matched on gender, race/ethnicity, high school GPA, math SAT score, and first college math class [21]. LLC participants' final GPAs were only slightly higher than non-participants' (2.93 vs. 2.91). The study used logistic regression to show that, all other factors held equal, LLC participation significantly increased the odds of graduation from PEMC fields by 2.9 times and from the university by 1.4 times. Using linear regression, LLC participation was shown to have negligible effect on final GPA. Like the previous study, the authors measured graduation at a single time point rather than using four- or six-year graduation rates for each cohort.

In a study at the University of Michigan [22], Maltby and colleagues found that first-generation and URM participants in the Women in Science and Engineering Residence Program earned undergraduate degrees in science-related fields at 22-23% higher rates than non-participant controls matched on gender, race/ethnicity, ACT score, participation in the Honors Program, and nine other factors. Conversely, the LLC did not produce significant gains for non-first gen, non-URM participants. The authors noted, "given that we are examining the long-term effect of only

one first-year experience on a student's scholarly career, we would expect direct effects for most students to be small."

To summarize, several studies have reported that Engineering or STEM-focused LLCs may improve graduation rates by 10-15% or more, but the three studies on ELLCs did not control for differences in incoming student characteristics or participation in other first-year experiences. Only one study reported the effect of LLC participation on GPA at graduation and found little effect. With the exception of the study at Gonzaga, all studies took place at very large research universities. None have been reported for universities as small as the one examined in this paper. While Gonzaga's undergraduate enrollment of 4,850 is 30% larger than that of the study institution, its engineering enrollment of nearly 950 students [23] is almost four times larger.

Implementation of Engineering LLCs at the Study University

The study took place at Roger Williams University (RWU), a private non-profit regional university with campuses in Bristol and Providence, RI. The university enrolls 3,700 traditional undergraduates including about 250 engineering majors. Students can earn a B.S. in Engineering with a specialization in either Civil, Computer, Electrical, Environmental, or Mechanical Engineering.

During the time period included in this study, the university featured several first-year programs intended to help students transition to college:

1. First Year Seminars (FYS) – special sections of a three-credit course in the university's core curriculum, distinguished from regular core sections in that they enrolled only first-semester students and included additional learning outcomes focused on developing oral communication, information literacy, teamwork, time management, and learning reflection/metacognition skills.
2. RWU Experience (RWUXP) – a zero-credit college transition course that met one hour per week and focused on practical information such as the differences between high school and college, how to access tutoring, how to select and register for courses, drug and alcohol awareness, etc.
3. Living-Learning Communities (LLCs) – members of each LLC lived together in their own floor or section of an on-campus dormitory and took a 3 or 4 credit course together. LLCs were organized by discipline (e.g., Business, Criminal Justice), by theme (e.g., sustainability, world affairs), or by a course in the core curriculum. Each LLC was led by a faculty mentor who taught the course during the Fall semester and organized three co-curricular events throughout the year, as well as a student Resident Assistant who was expected to tie at least half of their programming to the LLC theme. The faculty mentor also participated in a day-long community service project with their LLC just prior to the start of fall classes, and met the students for dinner or coffee once per semester. The university's Honors Program had its own LLC, linked to honors sections of expository writing and a core curriculum course.

Placement into these programs was done through a mix of student preferences, university discretion, and random assignment. Students admitted to the Honors Program were placed in the Honors LLC. Other incoming students could opt into discipline-based or theme-based LLCs during housing selection. Most students who did not request an LLC were placed in a FYS or RWUXP though some students were not assigned either, and others were placed in an LLC simply to fill the dorms.

Two Engineering LLC sections were offered in the Fall of 2013, followed by one section each in 2014 and 2015 due to reduced demand, and then two again in 2016. Collectively these sections enrolled a total of 115 full-time first-year students. Each ELLC had its own section of Engineering Graphics and Design, the first course in the Engineering major. One faculty member mentored both 2013 ELLC sections and one 2016 section, while a second faculty member did one each in 2014, 2015, and 2016. Other sections of the same course, identical in design and delivery to the ELLC sections, enrolled a total of 162 first-year students. Some of these students participated in the Honors LLC or other LLCs rather than the ELLC.

Each ELLC had an Engineering major serve as their Resident Assistant. The community service project served different clients over the years but the activities were similar (e.g., cleaning up litter at a local community development center, doing the same at a local zoo, performing routine maintenance at a therapeutic riding center, etc.). The co-curricular events varied from year to year. On-campus events included guest speakers on topics ranging from nuclear proliferation to business innovation, and a guided tour of a suspension bridge located near campus. Field trips included visits to the Boston Science Museum, a tour of the HVAC systems at the Harvard Art Museums, and a tour of the Rhode Island Resource Recovery Corporation's recycling and composting facilities.

Methods

Sample Definition

Consistent with federal guidelines for reporting and analyzing graduation rates, the sample includes all first-time, full-time students who took the Engineering Graphics and Design course during their first college semester in the Fall of 2013, 2014, 2015, or 2016. The sample does not include students who transferred into the study university after starting college elsewhere, nor does it include students who were taking the Engineering Graphics and Design course in their second semester or later. Such students were not eligible to participate in the ELLC. Course rosters were used to identify 298 students who met the inclusion criteria.

Data Collection

The university's Office of Institutional Research provided the following information for each student in the sample: high school GPA, SAT or ACT scores, gender, race/ethnicity, initial math and writing course placements, residence location (on- or off-campus), participation in an LLC, FYS, or RWUXP, first-semester GPA, first-year GPA, GPA at graduation, and date of

graduation or exit from the Engineering major and/or the university. First-year participation in varsity athletics was determined from team rosters published by the Athletics Department.

Data Analysis

First, the data were checked for errors or missing values. Twenty-two students (7.4%) had ACT scores rather than SATs. These were converted to equivalent SAT scores using the ACT's concordance tables. Nineteen students (6.4%) did not have either SAT or ACT scores, and another twelve (4.0%) were missing just the Writing SAT score. Missing scores were omitted from the descriptive statistics but mean-imputed for regression modeling. Other than test scores, the dataset was remarkably complete.

Next, the input characteristics, environmental characteristics, and outcomes of the ELLC participants were compared to those of non-participants. Statistical tests were performed to determine whether the differences observed in the sample might hold in the larger population of all Engineering students, past and future, at the study institution (or, more ambitiously, all Engineering students at universities like the study institution). All tests were two-tailed (a conservative approach, appropriate when there is no prior expectation about the direction of the difference).

The descriptive analysis indicated that ELLC participants had superior outcomes on most measures, but also that they differed from non-participants on some input and environmental characteristics. To control for these differences, regression analysis was performed to estimate the ELLC's independent effect. Ordinary least squares regression was used to model GPA, while logistic regression was used for graduation rates [24].

Results

Input Characteristics

To address Question 3 – whether students who participate in an ELLC differ from those who do not – Table 1 summarizes student input characteristics for the ELLC, the Honors LLC, Other LLCs, and students who participated in No LLC. The rightmost column combines the Other LLCs and No LLC groups to represent all non-Honors non-ELLC participants. As might be expected, the Honors LLC had significantly higher mean high school GPA and SAT scores than each of the other groups (statistics omitted for brevity). The ELLC's mean math SAT score was significantly higher than that of the Other LLCs (t-test, $p = 0.046$) as well as that of the Other LLCs and No LLC groups combined ($p = 0.047$). The gender ratio in the ELLC was significantly more male than the Other LLCs (Fisher's exact test, $p = 0.008$), and the Other and No LLC groups combined ($p = 0.045$). Otherwise, the incoming characteristics of the ELLC students were similar to those of non-Honors students who did not participate in the ELLC.

Table 1: Incoming Student Characteristics

	Engineering LLC	Honors LLC	Other LLCs	No LLC	Other LLCs & No LLC Combined
(*N*)	(115)	(21)	(24)	(138)	(162)
High School GPA (mean ± S.D.)	3.35 ± 0.38	3.80 ± 0.22	3.32 ± 0.41	3.34 ± 0.38	3.34 ± 0.39
Math SAT (mean ± S.D.)	604 ± 57	653 ± 56	572 ± 62	591 ± 69	588 ± 68
Reading SAT (mean ± S.D.)	534 ± 71	575 ± 58	514 ± 62	535 ± 69	532 ± 68
Writing SAT (mean ± S.D.)	531 ± 63	593 ± 65	508 ± 95	526 ± 67	524 ± 71
Gender (%)					
Female	10.4	52.4	33.3	17.4	19.8
Male	89.6	47.6	66.7	82.6	80.2
Race/Ethnicity (%)					
Asian American	2.6	4.8	4.2	1.4	1.9
Black	0	0	4.2	0	0.6
Hispanic/Latino	5.2	0	4.2	3.6	3.7
International Student	3.5	0	0	5.8	4.9
White	87.8	95.2	87.5	85.5	85.8
Two or More	0	0	0	0.7	0.7
Unknown	0.9	0	0	2.9	2.5

Environmental Characteristics

Table 2 describes the first-year environmental characteristics for each of the LLC groups. In addition to the intentional first-year experience programs (LLCs, FYS, RWUXP), we include the math and writing courses that students started in as well as their participation in varsity athletics, which have been suggested to contribute positively to student success.

The ELLC students started in higher math classes than the Other LLCs students (Wilcoxon rank-sum test, $p = 0.046$) and the combined Other LLCs and No LLC groups ($p = 0.041$), as well as higher writing classes than the Other LLC group ($p = 0.050$). By definition, all ELLC students lived on campus, a significantly higher rate than the No LLC group (Fisher's exact test, $p = 0.002$). The ELLC students were much less likely than the No LLC students to be placed in RWUXP ($p < 0.001$), because students were intentionally distributed among the LLC, FYS, and RWUXP programs.

In summary, ELLC participants were generally similar to non-ELLC participants not in the Honors Program, except that they were more likely to be male, to have higher math SAT scores, and to place into higher math and writing courses than students in the Other LLCs in particular.

Table 2: Student First-Year Environment Characteristics

	Engineering LLC	Honors LLC	Other LLCs	No LLC	Other LLCs & No LLC Combined
(*N*)	(115)	(21)	(24)	(138)	(162)
Math Placement (%)					
College Algebra	0	0	0	0.7	0.6
Precalculus	26.1	4.8	41.7	34.0	35.2
Calculus I	55.7	33.3	54.2	52.2	52.5
Calculus II	15.7	57.1	4.2	11.6	10.5
Differential Equations	2.6	4.8	0	1.4	1.2
Writing Placement (%)					
English as Second Language	0	0	0	1.4	1.2
Intro to Academic Writing	22.6	0	41.7	23.2	25.9
Expository Writing	76.5	90.5	58.3	71.0	69.1
Critical Writing	0.9	9.5	0	3.6	3.1
Critical Writing Completed	0	0	0	0.7	0.6
Residence (%)					
On campus	100	95.2	100	92.8	93.8
Off campus	0	4.8	0	7.2	6.2
First Year Seminar (%)					
Yes	2.6	38.1	12.5	6.5	7.4
No	97.4	61.9	87.5	93.5	92.6
RWUXP (%)					
Yes	7.0	0	12.5	41.3	37.0
No	93.0	100	87.5	58.7	63.0
Varsity Athletics (%)					
Yes	16.5	28.6	25.0	21.0	21.6
No	83.5	71.4	75.0	79.0	78.4

Outcomes

Table 3 presents key outcomes for the various LLC groups. Students participating in the ELLC were retained in the Engineering major or in STEM majors more broadly, and at the university overall, at higher rates than non-Honors students who did not participate (i.e., the combined Other LLCs and No LLC groups). The difference for first-year retention in STEM is statistically significant (Fisher's exact test, $p = 0.037$). More strikingly, ELLC participants also had higher four-year graduation rates in Engineering (a 13.7% improvement, $p = 0.028$), in STEM (13.1%, $p = 0.036$), and from the university (9.3%, $p = 0.135$).

The mean first-semester GPA of the ELLC students was 0.33 points higher than the combined mean of the Other LLCs and No LLC groups (t-test, $p < 0.0001$), but this difference faded to 0.21 points by the conclusion of the first year ($p = 0.001$) and 0.10 points at graduation ($p = 0.109$, only students graduating in Engineering rather than other majors are included, to provide a fair comparison).

Table 3: Student Outcomes

	Engineering LLC	Honors LLC	Other LLCs	No LLC	Other LLCs & No LLC Combined
(*N*)	(115)	(21)	(24)	(138)	(162)
First-Semester GPA	3.15 ± 0.47	3.62 ± 0.41	2.89 ± 0.82	2.81 ± 0.77	2.82 ± 0.78
First-Year GPA	3.11 ± 0.48	3.60 ± 0.48	3.01 ± 0.56	2.88 ± 0.61	2.90 ± 0.60
First-Year Retention (%)					
In Engineering	75.7	90.5	62.5	68.1	67.3
In STEM majors	85.2	90.5	75.0	74.6	74.7
At University	88.7	90.5	95.8	81.9	84.0
Four-Year Graduation (%)					
In Engineering	55.7	85.7	33.3	43.5	42.0
In STEM majors	64.3	85.7	50.0	51.4	51.2
From University	66.1	85.7	62.5	55.8	56.8
Final GPA of Engr. Graduates	3.22 ± 0.36	3.73 ± 0.24	3.04 ± 0.35	3.13 ± 0.41	3.12 ± 0.41

Regression Analysis to Control for Input and Environmental Characteristics

To determine if the superior graduation rates of the ELLC students can be attributed to their participation in the ELLC, rather than the differences noted in their input and environmental characteristics, logistic regression models were used to examine each variable's independent effect. Table 4 presents the results of three models, one each for four-year graduation in Engineering, in STEM majors, and from the university. To prevent numerical instability, categories containing just one student (e.g., math placement in College Algebra) were combined with adjacent categories. Although including weak variables in a regression analysis can reduce predictive performance, they are reported here to demonstrate each one's relative effects. Reduced models including only the significant variables (high school GPA, gender, math placement, and LLC) showed similar results for LLC.

The first model suggests that, all other things being equal, participation in the ELLC increased the odds of a student graduating in Engineering by 1.90 times compared to a student who participated in No LLC ($p = 0.047$), and by 3.36 times compared to students who participated in Other LLCs ($p = 0.029$). The second model indicates that ELLC participation increased odds of graduation in any STEM major by 2.07 times compared to No LLC ($p = 0.024$), and 2.37 times compared to Other LLCs ($p = 0.103$). The third model reveals that ELLC participation increased odds of graduation from the university by 1.76 times compared to No LLC ($p = 0.078$), and 1.36 times compared to Other LLCs (not significant). Besides Living-Learning Communities, other variables having significant effects on four-year graduation were high school GPA, gender (women had roughly three times higher odds of graduating on time than men), and math placement. Math SAT had little independent effect but correlates strongly with math placement (Spearman's rho = 0.460, $p < 0.0001$).

Table 4: Logistic Regression Models for Four-Year Graduation in Engineering, in STEM, and at the University

	4-year Graduation in Engineering (*N* = 298)			4-year Graduation in a STEM major (*N* = 298)			4-year Graduation from study University (*N* = 298)		
	Odds Ratio	*95% CI*	*p*	*Odds Ratio*	*95% CI*	*p*	*Odds Ratio*	*95% CI*	*p*
High School GPA	3.17	1.45-6.95	0.003	2.87	1.32–6.23	0.007	2.98	1.37-6.50	0.005
Math SAT	0.999	0.993-1.004	0.592	1.00	0.994-1.005	0.857	0.999	0.993-1.004	0.620
Reading SAT	1.00	0.996-1.007	0.547	0.998	0.993-1.004	0.574	1.000	0.995-1.006	0.877
Writing SAT	0.999	0.993-1.004	0.666	0.999	0.993-1.004	0.652	0.998	0.993-1.004	0.584
Gender (1 = female)	2.89	1.32-6.33	0.008	3.22	1.41-7.35	0.006	3.14	1.3-7.39	0.006
Race/Ethnicity[a]									
Asian American	2.95	0.445-19.6	0.262	1.70	0.277-10.5	0.566	1.34	0.226-7.89	0.749
Hispanic/Latino	0.307	0.065-1.46	0.138	0.160	0.034-0.759	0.021	0.247	0.061-1.00	0.051
International Student	0.904	0.232-3.52	0.884	0.835	0.228-3.06	0.785	0.742	0.207-2.66	0.648
Unknown	1.75	0.194-15.7	0.619	1.19	0.137-10.4	0.873	0.992	0.118-8.33	0.995
Math Placement[b]									
Precalculus or below	0.410	0.218-0.770	0.006	0.539	0.294-0.986	0.045	0.583	0.319-1.07	0.080
Calculus II	1.98	0.812-4.82	0.133	1.61	0.644-4.02	0.309	1.52	0.604-3.80	0.376
Differential Equations	0.824	0.127-5.33	0.839	0.564	0.084-3.81	0.557	0.499	0.076-3.28	0.469
Writing Placement[c]									
Intro Writing or ESL	1.08	0.431-1.97	0.835	0.679	0.321-1.44	0.311	0.748	0.355-1.57	0.445
Critical Writing or above	4.99	0.515-48.4	0.165	3.19	0.344-29.5	0.307	2.66	0.041-3.48	0.389
Residence (1 = off-campus)	0.734	0.185-2.91	0.660	0.774	0.198-3.02	0.712	1.07	0.267-4.31	0.922
First Year Seminar	1.57	0.519-4.74	0.426	2.19	0.721-6.66	0.166	1.61	0.547-4.74	0.388
RWUXP	1.09	0.528-2.25	0.818	1.14	0.433-1.77	0.712	0.953	0.473-1.92	0.894
Varsity Athletics	1.11	0.568-2.18	0.755	1.01	0.517-1.99	0.970	1.23	0.623-2.44	0.548
Living Learning Comm.[d]									
Engineering LLC	**1.90**	**1.01-3.58**	**0.047**	**2.07**	**1.10–3.89**	**0.024**	**1.76**	**0.940-3.29**	**0.078**
Honors LLC	2.20	0.515-9.43	0.287	1.68	0.393-7.21	0.483	1.41	0.326-6.10	0.645
Other LLCs	0.566	0.194-1.65	0.297	0.875	0.317–2.42	0.797	1.29	0.463-3.62	0.623
	pseudo $R^2 = 0.171$			pseudo $R^2 = 0.142$			pseudo $R^2 = 0.123$		

[a] Reference group for Race/Ethnicity is White, non-Hispanic. The sole Black and Two or More Races students were included in the reference group.

[b] Reference group for Math Placement is Calculus I. The sole student who started in College Algebra was included with Precalculus.

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

[d] Reference group for Living Learning Community is No LLC.

Table 5 presents two linear regression models for final GPA at graduation. The first model includes No LLC and Other LLCs as separate variables, and suggests that ELLC participation increased graduation GPA in Engineering by 0.054 points compared to No LLC and by 0.191 points compared to Other LLCs, but these results were not statistically significant. The second model combines the No LLC and Other LLCs groups to represent all non-Honors students who did not participate in the ELLC. It indicates that ELLC participation improved GPA by 0.074 points over non-participation, but this result too is not statistically significant ($p = 0.238$). The variables that do show significant effects on graduation GPA include high school GPA, Honors LLC, gender (women performed better than men), and first-year varsity athletics (athletes had lower GPAs at graduation).

Discussion

With regards to our research questions, the results suggest the following:

1. ELLC participation appears to substantially increase four-year graduation rates. As seen in Table 3, ELLC participants graduated in Engineering and in STEM at rates that were 13-14 percentage points higher than those of non-honors non-participants, and from the university at a 10% higher rate. After controlling for a variety of input and environmental characteristics, ELLC participants had roughly twice the odds of four-year graduation in Engineering or STEM, and 1.76 times the odds of four-year graduation from the university (Table 4). The ELLC had a stronger impact than did other first-year programs such as the FYS, RWUXP, and Other LLCs. The ELLC even had more influence on graduation in STEM and from the university than did the Honors LLC (though the confidence interval on the Honors LLC's impact is wide due to low numbers).

2. ELLC participation appears to boost GPA initially but the benefits fade over time (as seen in Table 3). At graduation, participants' GPAs were slightly higher than non-participants, but not significantly so (Table 5).

3. Students who participated in the LLC were more likely to be male and tended to have higher math SAT scores and start in higher math and writing classes than students in the Other LLCs (Table 1 and Table 2). After controlling for these differences, however, ELLC participants still graduated at superior rates (Table 4).

The result for Question 1 is consistent with some past literature [13], [19], but nonetheless surprising. Contrary to prior speculation that such a modest intervention should not have long-lasting effects [22], the ELLC had lasting benefits to students and the university, for modest cost. Each LLC mentor received a one-credit overload stipend (~$1500) and a $1150 budget for the field trip and on-campus events, while the LLC Resident Assistant received a $250 stipend. The result is also noteworthy because the study university is much smaller than the R1 universities from which most LLC results have been reported, with a more intimate campus, lower student-faculty ratio, smaller classes, etc. LLCs are theorized to help make a large university feel smaller and more personal, but this might be necessary even at small engineering programs.

Table 5: Linear Regression Models for Final GPA of Students Graduating in Engineering[a]

	Other LLC and No LLC Separate (N = 298)				Other LLC and No LLC Together (N = 298)			
	b	*β*	*t*	*p*	*b*	*β*	*t*	*p*
Intercept	1.561	0	3.42	0.001	1.541	0	3.37	0.001
High School GPA	0.336	0.315	4.24	<0.001	0.332	0.312	4.20	<0.001
Math SAT	0.00050	0.074	0.83	0.406	0.00049	0.072	0.81	0.419
Reading SAT	0.00042	0.067	0.78	0.435	0.00048	0.077	0.90	0.370
Writing SAT	-0.00015	-0.025	-0.29	0.773	-0.00017	-0.028	-0.32	0.751
Gender (1 = female)	0.145	0.151	2.05	0.042	0.127	0.132	1.84	0.068
Race/Ethnicity[b]								
Asian American	0.005	0.002	0.03	0.974	0.0006	0.003	0.04	0.969
Hispanic/Latino	0.038	0.012	0.19	0.852	0.054	0.017	0.27	0.789
International Student	-0.089	-0.040	-0.62	0.536	-0.065	-0.029	-0.46	0.649
Unknown	-0.113	-0.036	-0.57	0.571	-0.105	-0.034	-0.53	0.597
Math Placement[c]								
Precalculus or below	-0.091	-0.090	-1.30	0.196	-0.095	-0.094	-1.35	0.178
Calculus II	0.092	0.093	1.25	0.212	0.094	0.095	1.27	0.205
Differential Equations	0.275	0.102	1.58	0.117	0.284	0.105	1.63	0.106
Writing Placement[d]								
Intro Writing or ESL	0.064	0.013	0.29	0.775	0.0036	0.003	0.04	0.965
Critical Writing or above	0.094	0.048	0.74	0.462	0.108	0.056	0.86	0.392
Residence (1 = off-campus)	-0.192	-0.086	-1.30	0.195	-0.175	-0.079	-1.19	0.235
First Year Seminar	-0.105	-0.070	-1.01	0.313	-0.096	-0.064	-0.92	0.358
RWUXP	0.037	0.036	0.49	0.626	0.049	0.047	0.64	0.522
Varsity Athletics	-0.136	-0.139	-2.09	0.039	-0.145	-0.148	-2.24	0.027
Living Learning Comm.[e]								
Engineering LLC	**0.054**	**0.065**	**0.84**	**0.402**	**0.074**	**0.088**	**1.18**	**0.238**
Honors LLC	0.325	0.243	2.99	0.003	0.349	0.262	3.28	0.001
Other LLCs	-0.137	-0.079	-1.15	0.252	n/a			
	R^2 = 0.463, R^2_{adj} = 0.386				R^2 = 0.460, R^2_{adj} = 0.384			

[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. The sole Black and Two or More Races students were included in the reference group to prevent overfitting and to protect their privacy.
[c] Reference group for Math Placement is Calculus I. The sole student who started in College Algebra was included with Precalculus.
[d] Reference group for Writing Placement is Expository Writing. The sole student who had credit for Critical Writing was included with Critical Writing.
[e] Reference group for Living Learning Community is No LLC for the first model; No or Other LLC for the second.

A logical follow-on question is, why did the ELLC have such a strong effect? Perhaps for the reasons cited in the literature: development of academic and social support networks, more frequent peer-to-peer and student-faculty interactions, increased sense of purpose, group identity, and cohesion, etc. [25], [26]. Another possible explanation is that the early benefits to academic performance set the students up for continued success. Failing calculus freshman year can jeopardize four-year graduation, but ELLC students earned higher first semester math grades than non-participants (mean grade of 2.75, vs. 2.46 for the combined Other LLCs and No LLC groups, $p = 0.047$). A third explanation is self-selection bias beyond what this study's input and environmental variables can control for. ELLC participants may have greater interest, self-

efficacy, and/or other non-cognitive factors that affect persistence in an engineering or STEM major.

Interestingly, engineering student participation in non-honors Other LLCs appears to have *lowered* graduation rates. While the effect is not significant due to low enrollment in the Other LLCs, the result suggests that LLCs organized around a discipline or perhaps another identity characteristic may be more effective at building the social and academic characteristics that support student success than those organized around a general education course. The author recalls some of the ELLC students discussing what they liked about their learning community. They noted that they could have a conversation about calculators and not feel like misfits. Presumably this would not have been the case in the Other LLCs. It is also possible that the ELLCs were simply better executed than the Other LLCs. A 2013 survey found that ELLC participants rated their experience more favorably than participants of most other LLCs.

Turning to Question 2, the finding that ELLC participation did not provide a significant long-term improvement to GPA is consistent with limited past research on STEM LLCs [21] and LLCs more broadly [27]. While not groundbreaking, this result contributes additional evidence to understanding of this little-studied topic. As to why the academic benefits of LLC participation fade with time, there are at least two possible explanations. Caviglia-Harris concludes that LLCs give participants a "jump-start to the development of study habits that translate into higher . . . GPAs" but that "all students who remain at the university eventually figure out how to succeed in their classes" [27]. The observed convergence in GPA can also be explained in terms of attrition. The non-ELLC group lost more members than the ELLC group due to lower persistence, and those students left Engineering with lower GPAs than ELLC students did (mean of 2.28 vs. 2.73 at time of exit from major). Thus, the average GPA of the non-ELLC group rose faster over time than that of the ELLC group. While this gives the appearance that ELLC benefits to academic performance faded over time, the short-term ELLC impact on GPA likely enabled ELLC participants to remain in Engineering, or to leave it with a better academic record.

As with graduation rates, Other LLCs appeared to have a negative though non-significant effect on graduation GPA in Engineering. Perhaps those students failed to establish connections and study groups during the first year that could help them in their later years. As seen in Table 5, the only environmental characteristics to have significant effects on GPA at graduation were the Honors LLC (honors students had a 0.325 higher graduation GPA than students in No LLC) and varsity athletics (first-year athletes had a 0.126 point lower graduation GPA than non-athletes). The likely explanation is that both these programs extend beyond the first year for most students. About one third of honors students remain in the honors dormitory for sophomore year, and others continue to participate in classes and co-curricular events together. While some students do not pursue athletics beyond their first year, many do, and the increased burden of training and travel may compromise their academic performance.

Conclusions

This study contributes to understanding of first-year Engineering Living-Learning Communities by showing that they can have a lasting impact on student persistence, as manifested by superior four-year graduation rates. The study is the first, to the author's knowledge, to attempt to control for students' incoming cognitive characteristics (through high school GPA, SAT scores, and initial course placements) and participation in other first-year programs. It is also the first to document graduation rates and graduation GPA at a small university.

Strengths of the study include its use of four cohorts of entering students – enough to average out random fluctuations, but not so many as to include significant changes to the university, its programs, or its student body during the study period. In addition, the study included all first-year engineering students at the study institution, eliminating sampling error. Furthermore, the dataset was very complete, with little missing data. Consistent four-year graduation rates were calculated for each cohort, rather than considering graduation of all cohorts at a single point in time as past studies of STEM LLC's have done. The single-institution design eliminates the substantial impact of institutional characteristics on student outcomes [21], but does make it harder to generalize to other types of institutions. The use of objective input, environmental, and outcome variables determined from institutional records eliminates the many biases associated with self-reported data and subjective surveys, but institutional records do not contain a variety of non-cognitive factors that likely influence student outcomes.

Another limitation is the low racial and ethnic diversity of the university at the time of the study; the race/ethnicity results are statistically weak due to the sparseness of the data. As is true of most studies of persistence, this one did not track students who transferred to other institutions. They may have graduated in Engineering in four years, and perhaps the LLC participants did so at a higher rate than the non-participants who transferred, but we do not know. Lastly, as of this writing it is too soon to report six-year graduation rates for all cohorts, which limits our ability to make comparisons to prior studies.

The study raises several new questions. Given the importance of four-year graduation rates, and the apparent effectiveness of ELLCs in improving them, why have so many studies focused on first-year retention and so few on graduation? Is it too hard to track students longitudinally? Do developers of novel programs such as LLCs move on to other projects once the early assessment work is complete? Or is assessment abandoned after grant funding expires? Regardless of the cause, opportunity exists to better understand LLCs' long-term effects, including how and why such a modest and early intervention can have such a large effect. Systematic qualitative assessment of students' and faculty's experience with ELLCs would provide valuable insight and complement the quantitative results presented here.

More locally, we might examine how engineering graduation rates have changed since the university discontinued discipline-based LLCs after 2018. If ELLCs do substantially improve student persistence, we should see a drop in graduation rates for the entering classes of 2019 and

beyond. A challenge is that these cohorts were significantly affected by the COVID-19 pandemic, which will likely depress graduation rates independent of the absence of ELLCs.

The reasons why the highly successful ELLCs were discontinued are murky, at least to this author. Some of the non-engineering LLCs experienced social problems, perhaps reflected in the negative results for Other LLCs in our models. The Housing Office struggled a bit in assigning students to LLC residences before they had taken math placement tests (Precalculus is a co-requisite for the Engineering Graphics and Design course that anchored the ELLC), and in matching the gender distribution of the rooms in the residence to that of the students. Other than the author's own work [14], little quantitative assessment was performed. It is my hope that the present study might convince the university, and other institutions, to re-consider the use of this high impact practice.

Acknowledgments

I would like to thank my colleague Charlie Thomas for teaching several of the Engineering Living-Learning Communities and for helping with the short-term assessment of the first two years' offerings [14]. Assistance with data collection was provided by Megan Lynch from the Roger Williams University Office of Institutional Research.

References

[1] A. Brower and K. Inkelas, "Living-learning programs: One high-impact educational practice we now know a lot about," *Liberal Education*, vol. 96, no. 2, pp. 36-43, 2010.

[2] J. Everett and M. Flynn, "Engineering learning communities – USA National Survey 2012," In Proc. 120th ASEE Annual Conference & Exposition, Atlanta, GA, 2013.

[3] L. Karpilo and T. Siller, "Matching student and faculty expectations for student success," In Proc. 114th ASEE Annual Conference & Exposition, Honolulu, HI, 2007.

[4] C. Caldwell and R. Hughes, "Engineering living learning community experience: A model for improving first-year retention and academic performance of Black students," In Proc. 128th ASEE Annual Conference, Virtual, 2021.

[5] S. Ciston, M. Carnasciali, J. Nocito-Gobel, and C. Carr, "Impacts of living learning communities on engineering student engagement and sense of affiliation," In Proc. 118th ASEE Annual Conference & Exposition, Vancouver, Canada, 2011.

[6] M. Flynn, "Engineering residential learning communities: Evaluating the impact on freshmen engineering students," M.A. thesis, Rowan University, Glassboro, NJ, 2012.

[7] J. Hodge, M. Lagoudas, A. Harris, J. Froyd, M. Hobson, and J. Pope, "Influencing the academic success of undergraduate first-year engineering students through a living learning community," In Proc. 118th ASEE Annual Conference & Exposition, Vancouver, Canada, 2011.

[8] J. Kampe, W. Edmister, M. Stimpson, B. Matanin, A. Martin, C. Brozina, and B. Watford, "Freshmen engineering living-learning communities at Virginia Tech," In Proc. 114th ASEE Annual Conference & Exposition, Honolulu, HI, 2007.

[9] J. Light, "Developing and assessing a holistic living-learning community for engineering and science freshmen," Ph.D. dissertation, Washington State University, Pullman, WA, 2005.

[10] J. Light, J. Beller, G. Crouch, and D. Davis, "Evaluation of a living-learning community for freshmen engineering students," In Proc. 112th ASEE Annual Conference & Exposition, Portland, OR, 2005.

[11] J. Light, J. and D. Davis, "Impacts of a combined living-learning community on attitudes and college engagement of engineering freshmen," In Proc 111th ASEE Annual Conference & Exposition, Salt Lake City, UT, 2004.

[12] F. Shushok Jr. and R. Sriram, "Exploring the effect of a residential academic affairs-student affairs partnership: The first year of an engineering and computer science living-learning center," *The Journal of College and University Student Housing,* vol. 36, no. 2, pp. 68-81, 2010.

[13] S. Silliman, T. Boggan, V. Labay, G. Ricco, and S. Girtz, "Characteristics of students self-selecting into a freshman living-learning community for engineers and computer scientists," In Proc. 122nd ASEE Annual Conference & Exposition, Seattle, WA, 2015.

[14] W. Palm and C. Thomas, "Living-learning communities improve first-year engineering student acdemic performance and retention at a small private university," In Proc. 122nd ASEE Annual Conference & Exposition, Seattle, WA, 2015.

[15] President's Council of Advisors on Science and Technology, *Engage to EXCEL: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics.* Washington, DC: The White House, 2012.

[16] President's Council on Jobs and Competitiveness, *Jobs Council solutions: Graduate 10,000 more engineers*. Washington, DC: The White House, 2011.

[17] A. Astin, *Assessment for Excellence: The Philosophy and Practice of Assessment and Evaluation in Higher Education.* Phoenix, Az: Oryx Press, 1993.

[18] V. Tinto, *Leaving college: Rethinking the Causes and Cures of Student Attrition*, 2nd ed. Chicago, IL: University of Chicago Press, 1993.

[19] E. Sandvill, S. Miller, and H. Glisson, "WIP – Living-learning programs: A model for student success and engagement," In Proc. 2019 FYEE Conference, State College, PA, 2019.

[20] M. Dagley, M. Georgiopoulos, A. Reece, and C. Young, "Increasing retention and graduation rates through a STEM learning community," *Journal of College Student Retention: Research, Theory & Practice,* vol. 18, no. 2, pp. 167-182, 2016.

[21] S. Nix, K. Roberts, and R. Hughes, "Female undergraduate STEM persistence: A focus on the role of living and learning communities," *Journal of Women and Minorities in Science and Engineering,* vol. 22, no. 4, pp. 349-374, 2016.

[22] J. Maltby, C. Brooks, M. Horton, and H. Morgan, "Long term benefits for women in a science, technology, engineering, and mathematics living-learning community," Learning Communities Research and Practice, vol. 4, no. 1, article 2, 2016.

[23] Gonzaga University School of Engineering & Applied Science, "History of the school." [Online]. Available: https://www.gonzaga.edu/school-of-engineering-applied-science/about/history. [Accessed Feb. 12, 2022].

[24] D. Hosmer and S. Lemeshow, *Applied Logistic Regression*, 2nd ed. Hoboken, NJ: John Wiley & Sons, 2000.

[25] K. Inkelas and M. Soldner, "Undergraduate living-learning programs and student outcomes," in *Higher Education: Handbook of Theory and Research*, J. Smart and M. Paulsen, Eds. New York: Springer Science+Business, 2011, vol. 26, pp. 1-55.

[26] N. Shapiro and J. Levine, *Creating learning communities: A Practical Guide to Winning Support, Organizing for Change, and Implementing Programs.* San Francisco: Jossey-Bass, 1999.

[27] J. Caviglia-Harris, "Community is key: Estimating the impact of living learning communities on college retention and GPA," *Education Economics*, DOI: 10.1080/09645292.2021.1958167, 2021.