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The Impact of a Living Community for Women Engineering Undergraduates*

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Many approaches for improving engineering student retention have been considered, including living learning communities (LLCs). The current study is focused on evaluating the benefits of intentional housing placement of female students to increase retention in engineering (the "living" portion of an LLC), operationalized by three-year retention to graduation referred to herein as "engineering living community." At the residential university studied, intentional placement of women engineering intent students has taken place since the early 2000s. Using institutional data of a private university, retention of women engineering students is compared to women who were not placed in a residence hall with other engineering students from 2005–2016 by examining the descriptive statistics and conducting statistical analysis, including Kruskal-Wallis rank-sum test and linear logistic regression. Additionally, a short survey was sent to current women engineering students to ask specifically what impact their residential hall placement had on their decision to continue in engineering. Results show that students placed in an engineering living community were significantly more likely to be retained to their third year in engineering and on to graduation than those that were not in an engineering living community. The implication of this finding is that a living community without the added administrative structures of course alignments or formal mentorship can still offer substantial benefit to participants and are a no cost way to improve retention of women and potentially other underrepresented groups.

Keywords: living community; retention; female student; diversity; mixed method

1. Background

This study was conducted in the College of Engineering at a medium sized, Midwestern, private institution. The university is largely residential with nearly all students between 18 and 22 years of age. There is a common First-Year Engineering Program where all students take a two-semester general engineering course sequence to gain engineering project experience and computer programming (in addition to their other math and science courses). At the end of their first year, the students select from nine professional degree programs for their continued study: Aerospace, Mechanical, Civil, Environmental, Earth Sciences, Chemical, Electrical, Computer Science, or Computer Engineering.

The institution only has single-sex residence halls, 14 women's residence halls in total during the studied period. In the early 2000's, all women that indicated engineering as their intended major on their admissions application were automatically placed in one of six residence halls. Those 6 residence halls were not exclusively engineering, rather this just created a critical mass of about 20% of the student populations in each of those 6 halls having engineering students. The remaining 80% of the hall residents were majors other than engineering, such as Liberal Arts, Architecture, Business, and Science. Students cannot select a roommate, the assignment to these halls is pseudo-random to ensure that there is a distribution of majors, athletes, and academic honors among all the halls. Fig. 1 is a representation of the distribution of majors in women's residence halls, note that there are also Architecture students that comprise 2% of every dorm that are not shown graphically. Students at the research site typically live in the same university residential hall for at least three years. Students rarely switch their residential halls.

There has been growth in the number of engineering students over the time studied of 2005–2016. There has also been an increased proportion of women in each incoming class, as shown in Fig. 2. The percentage of women in each incoming class has increased from a low of 20% in 2005 to 33% by 2016.

Over time, the retention of both male and female students has increased as well. For women, first-year to sophomore retention rate has increased from a low of 42% in 2005 to a high of 81% in 2016 during the time period studied. For men, retention rate has increased from a low of 61% in 2005 to a high of 84% in 2015 as shown in Fig. 3.

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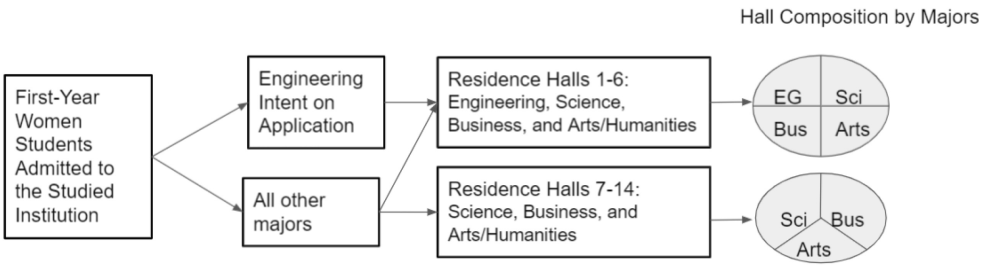

Fig. 1. Composition of Women's Residence Halls.

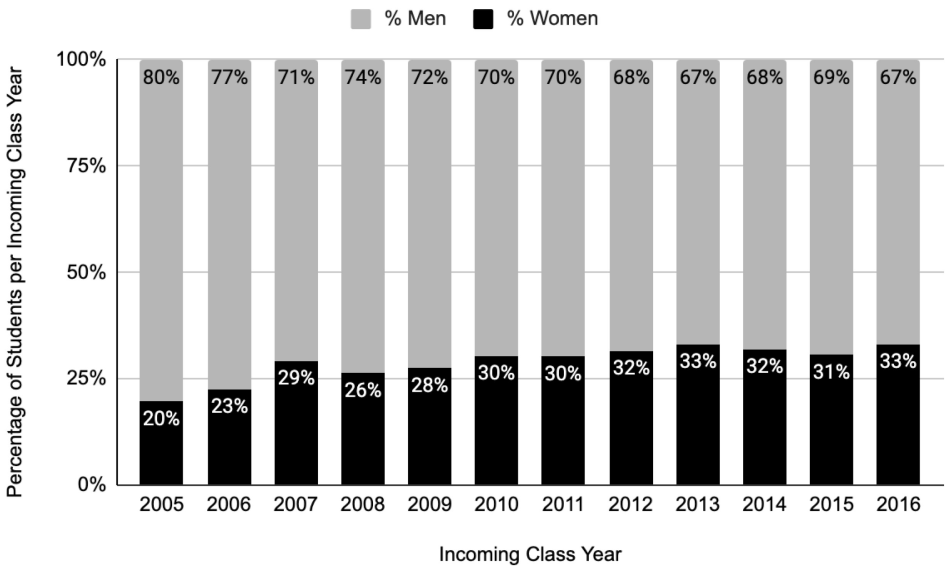

Fig. 2. Gender Composition by Entering Class Year in the College of Engineering.

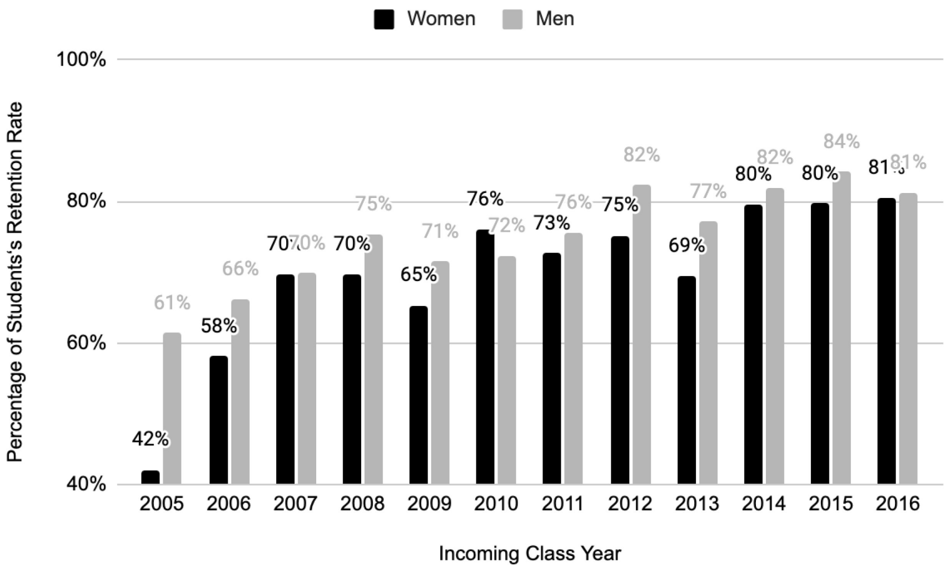

Fig. 3. Retention by Gender and Entering Class Year.

2. Literature Review

The nation's goals for being globally competitive have driven attention towards increasing the number of qualified scientists and engineers [1], and further to broaden the participation of women and underrepresented minorities in the field of engineering as diversity has been shown to improve design solutions [2, 3]. Yet as we seek to engage more women and underrepresented minorities, many programs have found differential rates of retention (lower for non-majority participants) [4]. Studies have shown that female students in STEM majors are more likely to have mental health issues, due to a competitive learning environment and women receiving many negative messages from the male majority students, such as gender stereotypes [5]. Therefore, engineering educational institutions have been looking for ways to address these differential rates of retention and help to create a welcoming environment that enables communities to form.

Many schools have found successful approaches, often working on community building through purposefully built learning communities. One of the primary goals for universities developing learning communities (LC's) was to improve student experiences and retention among student participants. LC's can take many forms, some of the structures identified include [6–10]:

1. Linked Courses (two independent courses, but with common students enrolled).
2. Learning Clusters (multiple courses linked by content).
3. First-Year Interest Groups (courses linked by theme).
4. Federated Learning Communities (faculty member(s) are the central commonality).
5. Coordinated Studies Programs (student's courses are integrated, theme-based, interdisciplinary curriculum with faculty collaboration).
6. Students are formed into class groups around a common characteristic.
7. Collaborative class activities or study groups.

Variations and combinations of these approaches have been introduced which may also include a living element across disciplines and universities. As claimed by Stassen [6, p. 581]:

> "The fact that even simple structures that facilitate student interaction around academic work (even without coordinated faculty involvement) can have a positive effect for students of all preparation levels should provide encouragement to campus leaders working to develop methods for improving the undergraduate educational experience on their campuses."

Among the various programs in operation, many researchers can point to positive outcomes linked with LC participation. Palm and Thomas found increased retention and GPA for both women and men participants [11]. Vasko and Baumann reported increased assignment completion rates for student participants as well as higher grades and retention [12]. Similarly, Davis and Light reported that student LC participants had a more positive outlook towards engineering [13]. In addition, Ciston et al. indicated LC benefits of (1) academic support, (2) a sense of community within the engineering program, (3) access to resources such as faculty liaisons and field trips, (4) study collaboration, and (5) increased engagement with extracurricular activities [14].

From the literature, concerns with LC's were also documented. One study reported neutral findings for engineering student retention among those that participate in LC's, although the students reported high appreciation for the ability to easily make student-student connections for studying and getting peer help [15]. Another potential drawback for student participants in LC's was isolation [14]. While Atwood criticized two additional potential drawbacks (1) increased student anxiety regarding changing majors out of engineering and (2) increased academic dishonesty in completion of engineering assignments when engineering students are grouped together formally [16]; Purdie & Rosser argued that students grouped by interest had a more significant impact on retention that grouping by academic pathway in a residence hall [17]. Finally, there was a concern over the evaluation of LC's given that most programs are voluntary and not random, so the measured effect on retention or grades could be incorrectly and biasedly attributed to the treatment (LC) and those that self-selected into the program. However, it has been demonstrated that students with greater academic need are more likely to voluntarily participate in LC's and that participation leads to 0.75–1 full letter grade improvement [18]. Overall, the reported benefits appear to outweigh the possible drawbacks, which is the reason these programs continue to be popular as they can be low or no cost for institutions to run and have the potential to help students.

While the programs appear to be overall beneficial, there are some limitations to the data currently provided. The previous literature primarily focuses on first-year engineering retention and rarely studies the impact of living community on students' retention beyond sophomore year with relatively small sample sizes. A lack of lens on equity and inclusion also limits the lens of previous studies that only examine the general students, which is assumed to be WEIRD (Western, Educated, Industrialized, Rich, and Democratic) [19]. Therefore, to close these gaps, in this study, we propose two research questions to further investigate undergraduate engineering students' experience in LC's particular towards women students:

Q1: Quantitative – Does placement in a women's engineering living community impact retention to graduation?

Q2: Qualitative – What impact does residential hall placement have on persistence in engineering?

3. Methods

The explanatory sequential mixed-method research design was used as the method paradigm [20]. The factors related to women students' retention were firstly quantitatively analyzed via the institution's longitudinal registrar data and then a survey with free response questions were asked followingly. In the first stage of quantitative exploration, we summarized the descriptive statistics and plotted alluvial flow charts to understand the general trend, and then used Kruskal-Wallis rank sum test [21], the non-parametric alternative to one-way ANOVA test, and logistic regression models to determine the significant factors influencing female student retention. After that, a short survey including a free response question was sent to the current cohort of undergraduate engineering female students to further investigate how the living community experience has shaped their engineering academic retention.

3.1 Population Studied in this Work

All students who took the Introduction to Engineering course in the fall semesters of 2005 to 2016 were considered the original cohort for data collection. The reasons for the end cutoff year to be 2016 include that (1) the registrar's office does not hold complete data entries for all students entered after 2017 at the time of study; and (2) in 2017, two more female residential halls were designated to host more students so that the validity of the study might be compromised. The University Registrar provided student data, including sex, school entry terms, residential hall, entry majors, exit majors, exit terms, and register senior classifications. Table 1 shows the engineering student data by year. Generally, there is a trend that the number of female students grew at a higher rate compared to male students and the university made efforts to increase female students' representations. There were 88.08% (1338 out of 1518) of women students of record living in the university engineering residence halls (only two female students did not live in any residence hall). During the time period studied, the Male-to-Female ratio decreased from 3.10 down to 2.00, consistent with the growing number of female students in each engineering class (from 78 to 164).

3.2 Longitudinal Data Processing

The collected data was further processed as complete secondary data to fulfill the need to answer the proposed research questions of this project. As the dat was acquired from the university register office, all data entries were complete.

Several dichotomous variables, including EngrHall, EntryEngrMajor, and EngrRetention, were generated for further analysis purposes. EngrHall was defined based on if the student's entry residential hall was an engineering community residential hall (where 1 indicates that the student lives in an engineering community residential hall and 0 meaning not). EntryEngrMajor was defined as whether the entry major of a student was classified as an engineering major or not. The inclusion of none as marked entry engineering majors was due to the fact that students were not forced to pick up an initial major in some years of study. For the following analysis, we consider the entry major marked "none" classified as engineering majors for two reasons: (1) the longitudinal data set was pulled based on students' enrollment in engineering foundation courses, which indicated their initial interests in engineering majors; (2) among 5142 pieces of student record, there were only 11 students entered the study institution without indicating interested majors. Lastly, EngrRe-

Table 1. Chronological Engineering Student Data

Entry Year	Male and Female Sample		Female Sample		Male-to-Female Ratio
	Number (n)	Percentage (%)	Number (n)	Percentage (%)	
2005	320	6.22	78	5.13	3.10
2006	359	6.98	85	5.59	3.22
2007	359	6.98	104	6.85	2.45
2008	378	7.35	97	6.38	2.90
2009	433	8.42	118	7.77	2.67
2010	390	7.58	118	7.77	2.30
2011	441	8.57	131	8.62	2.37
2012	435	8.46	133	8.75	2.27
2013	494	9.60	166	10.93	1.97
2014	510	9.91	160	10.53	2.19
2015	531	10.32	164	10.80	2.23
2016	492	9.56	164	10.80	2.00
Total	5142	100	1518	100	

tention describes whether a student stays in an engineering major, operationalized as three-year retention in engineering majors specifically. As (1) there was no direct data to indicate if the student actually graduated from the university; (2) it is unlikely that students switch majors in their fourth year, we marked the retention to be 1 if the students reached to their senior year because within a private university in the U.S., the correlation between the 3-year retention rate and graduation rate is highly positive (98.5%). In our data, the exit majors of 25 students did not have a record (12 were First-Year students and 13 were sophomores), indicating that those students left the university.

3.3 Kruskal-Wallis Signed-Rank Test

To investigate the first research question directly, Kruskal Signed-Rank test was conducted to examine if there is a significant difference in the 3-year retention in engineering majors for female students living in an engineering living community or not. Since both retention and living in an engineering living community are binary variables that do not have Gaussian distribution or in-pair design, standard tests, such as t-test, and chi-square test, are not suited for the analysis. Instead, Kruskal-Wallis Signed-Rank test, the non-parametric alternative method to one-way ANOVA test, was considered for the comparison [21]. Studies in the field of engineering education have widely used this method [e.g., 22–25].

3.4 Linear Logistic Regression

As a classic statistical model to predict categorical outcome (dichotomous in this case) from one or more independent variables either categorical or continuous, logistic regression model estimates the parameter based on maximum likelihood procedures to avoid several strict assumptions held on multiple linear regression modeling and generally provides more accurate conclusions [26]. Logistic regression has been widely used in educational research, especially in studies related to retention. To name a few, French et al. used hierarchical logistic regression to explore factors predicting engineering students' success and persistence [27]; Huerta-Manzanilla et al. utilized logistic regression to predict engineering student retention in 4-year bachelor programs by co-enrollment density [28]; relationship between graduation and demographic and academic characteristics was investigated via multiple logistic regression method [29]. In this study, we specifically explore whether putting female students into engineering living communities will increase the likelihood of three-year retention in engineering majors controlling whether indicating an entry major in engineering by linear logistic model.

3.5 Alluvial Plots

For better visualization on student major transition patterns, student specific majors were grouped as engineering, STEM-other, non-STEM, and none majors. As specified in the background section, engineering majors are classified as Aerospace, Mechanical, Civil, Environmental, Earth Sciences, Chemical, Electrical, Computer Science, and Computer Engineering. STEM-other majors are those majors related to science, technology, and mathematics, but not engineering, e.g., Physics and Chemistry. The non-STEM majors include any majors not related to science, technology, engineering, and mathematics, e.g., Philosophy and Japanese. For whose major was not indicated or recorded, it was marked as none.

Alluvial plots were generally used to reveal visual frequency distributions [30] and analyze structural change within a system [31], by connecting nodes with flows through a sequential stages and visually the identical transition flows forming area, which represents the proportion of each scenario. For example, Reeping et al. relied on alluvial plots to visualize the mechanical course-taking sequence and pathways of students [32]. In this work, we utilized alluvial plots to display the pathways of student major changes from their initial interest to the exit major. By comparing the pathways across whether students living in a residential hall, we were able to identify some unique patterns. The "ggalluvial" package [33] in R [34] was used to generate the diagram.

3.6 Survey Questions

A short survey was developed and administered using Qualtrics. The survey was confidential but not anonymous. Students were asked what residence hall they lived in, followed by a Likert scale table of responses, as shown in Fig. 4. Finally, students were asked to explain their experiences: "Explain how your residence hall experience impacted your engineering studies." The free response question was thematically coded. The survey was sent during the summer of 2021 to 169 current undergraduate female students that had completed their junior year. That class was selected because at the institution studied the students live on campus for their first 3 years, and these students would have had some "normal" residential life experience not impacted by COVID. There were 100 surveys completed, a 59% response rate. As the focus of the survey is to better understand the engineering living community experience, the data from five students who did not live on campus were removed, resulting in 94 valid responses with 70 of respondents who pursued an engineering major while living in an engineering living community.

How did your residence hall experience influence your _____?										
	Very Negatively (1)	(2)	(3)	(4)	Neutral / No Impact (5)	(6)	(7)	(8)	(9)	Very Positively (10)
Overall experience as an engineering student										
Access to study groups										
Access to upper division student mentors										
Decision to continue in engineering										

Fig. 4. Likert scale survey questions regarding impact of residence hall experience.

In the result section, the survey response descriptive statistics were provided. Kruskal Wallis Signed-rank tests were performed to examine the female students' experiences based on whether they lived in an engineering living community or another none-engineering residential hall (75 vs. 19) and whether they were pursuing an engineering major at the time of surveying (87 vs. 7).

3.7 Thematic Analysis

To further analyze the free response comments, researchers individually coded the responses to the open-ended survey question. The entire research team came together to compare and develop consensus and categorize/group codes. This codebook was used independently by two researchers to analyze the data. The resulting themes developed can be seen in Table 4. These categories often represented a dichotomy of whether the theme was positive or negative in the eyes of the survey respondents. For example, the perception of access to upperclassmen, a participant's response where they felt that they had access to upperclassmen was coded as positive, whereas the lack of access was coded as negative. In some cases, themes were coded as only positive, such as increased self-efficacy in school, or only negative.

Two members of the research team used these categories to re-examine the free-response data. The unit of analysis was not limited to single sentences. Responses often had multiple elements and were coded to reflect all categories present. The length of response varied from participant to participant, hence the entire response as well as its components were utilized. Two researchers who reexamined the data met and reviewed all codes, discussing reasoning and sharing insights where there were differences. Interrater reliability was calculated to be 90% after comparison.

4. Results

The results are segregated into the following parts. First, to address research question 1 (RQ1), we presented the results from Kruskal-Wallis Signed-Rank tests and the linear logistic regression model. Next, we shifted our view to holistically analyze of student major transition pattern across sex and the residential hall placement via alluvial plots. Last, to respond to research question 2 (RQ2), the survey results from current enrolled students about their opinions of the impact of the living learning community were provided.

4.1 Longitudinal Registrar Data Results

Kruskal-Wallis Signed-Rank Test was conducted to examine the differences of female students' 3-year retention in engineering majors according to whether they were placed into an engineering living community. There is a statistically significant difference in students' retention rate ($\chi^2(1) = 21.299$, $p < 0.001$) between the various placement of residential halls, which answers our first research question that the impact of the engineering living community indeed impacts female students' retention to graduation in an engineering major. Therefore, we conducted linear logistic regression to further investigate the direction of the impact.

Results of the linear logistic regression model are summarized in Table 2, revealing that whether living in an engineering living community is a

Table 2. Linear Logistic Regression Model Predicting 3-Year Retention Rate of Female Engineering Students

Outcome: Female Engineering Student Retained an Engineering Major for Three Years	Full Model		
	B	**SE**	**OR**
(Intercept)	–1.2482***	0.2689	0.29
Living in an Engineering Living Community	0.5713***	0.1699	1.77
Indicated Entry Major in Engineering	1.7352***	0.2492	5.67

Note. SE = Standard Error; OR = odd ratio; *p < 0.05; **p < 0.01; ***p < 0.001.

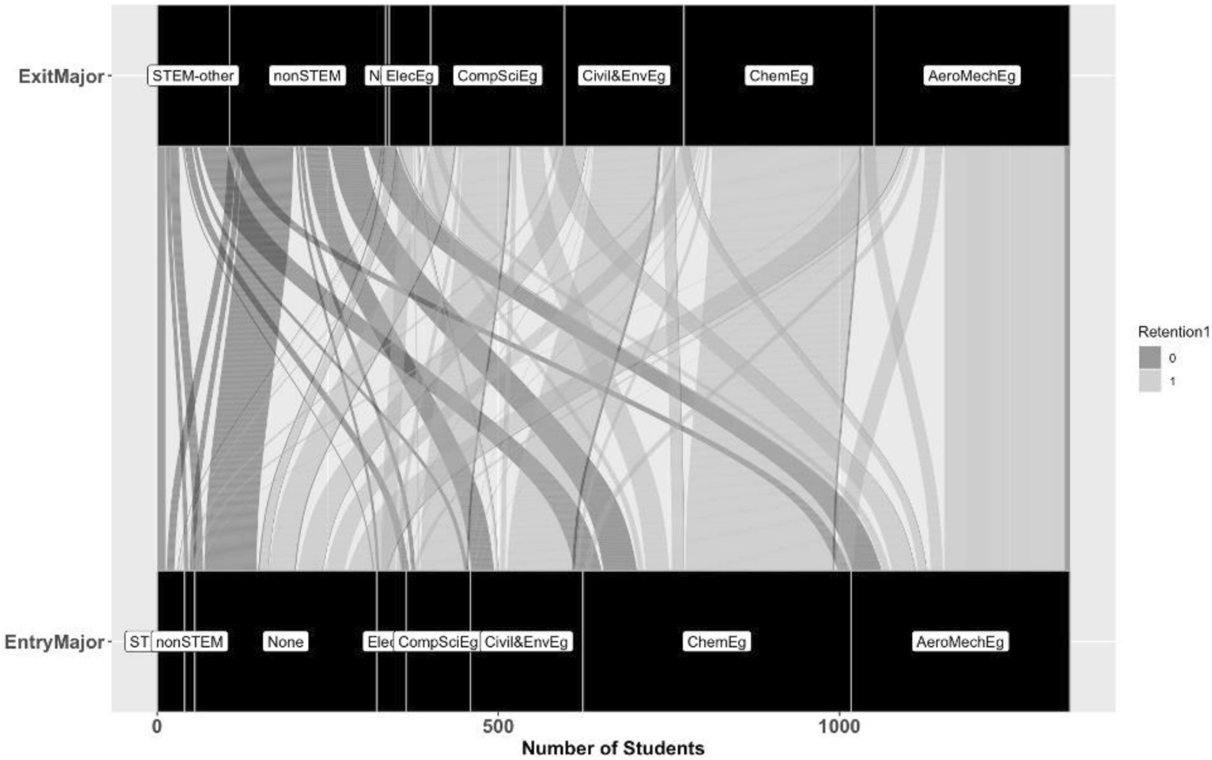

Fig. 5. Major Transition Flow Diagram for Female Students Placed in an Engineering Living Community.

statistically significant factor at the significance level of 0.05 (B = 0.5713, p < 0.001). The odds that the female students reached the 3-year retention in an engineering major is 1.77 times higher for female students who lived in an engineering living community compared to those who did not (OR = 1.77) by controlling whether they indicated the entry major as engineering (B = 0.5713, p < 0.001, OR = 5.67). The result lends support to our hypothesis that female student retention to graduation in an engineering major is associated with the placement in an engineering living community.

Figs. 5 and 6 are the alluvial plots displaying the major flows of female students from the interests prior to the entry of the college to the final degree majors for those who lived in an engineering living community or not respectively. As indicated in the methods section, students' majors were aggregated into STEM-other (majors related to math and science), nonSTEM (e.g., arts and business), None (did not indicate initial major interests for EntryMajor or did not get a degree at the ExitMajor stage), ElecEg (Electrical Engineering), CompSciEg (Computer Science and Engineering), ChemEg (Chemical Engineering), Civil&EnvEg (Civil and Environmental Engineering and Earth Sciences), and AeroMechEg (Aerospace Engineering and Mechanical Engineering) from the left to right in both figures for better visualization. The x-axis of the figures displays the cumulative number of female students in each case. There were 1138 female students placed in engineering living community halls (Fig. 5) and 181 not in an engineering residence hall (Fig. 6). In addition, the widths of each trunk represent the relative percentage of the total sample size. For example, about one third of female students expressed their initial interest in Chemical Engineering (Fig. 5). Regarding the flow, as shown in the legend, we used darker flows to indicate that the exit majors are not in engineering (Retention = 0) while the lighter lines represent the students' degree majors containing engineering majors (Retention = 1).

In Fig. 5, the vast majority of students begin in an engineering major and are retained in some engineering discipline, as indicated by the lighter flow segments. As shown, there is a significant amount of movement between engineering disciplines, which is encouraged at the studied institution as the first year is devoted to discernment which is not considered in this paper. In addition, a higher percentage of students starting out in nonSTEM, STEM-other, or None majors, although in the first-year engineering course sequence, did not continue to pursue engineering majors as compared to those with an engineering entry major.

Fig. 6, by comparison, shows a larger percentage of students in the STEM-other, nonSTEM, and None entry major categories. This is expected and demonstrated above as placement in the engineer-

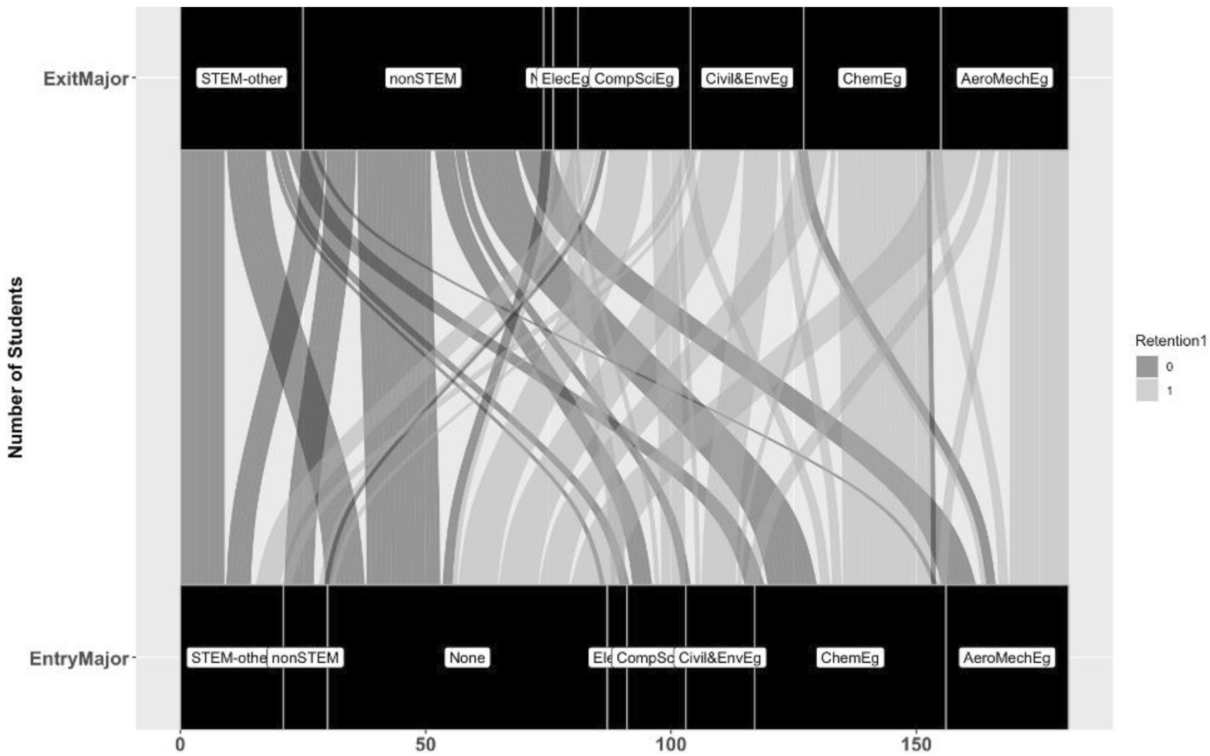

Fig. 6. Major Transition Flow for Female Students NOT Placed in an Engineering Living Community.

ing living community dorms is largely based on student expressed engineering interest at the time of application. As before, there is considerable movement between engineering majors as well as into or out of engineering. Compared to Fig. 5, a larger percentage of this population ended outside of engineering as indicated by the overall width of the combination of none engineering major bars at the top of Fig. 6 compared to Fig. 5 (a graphical representation of the percent of students who did not complete an engineering major).

It was evident that compared to female students who did not live in an engineering living community, students in the engineering living communities were less likely to transition out of engineering majors, which was visually represented by a large portion of engineering majors at the exit major stage. Similarly, this phenomenon applied to female students who did not indicate their intended majors at the time of application to the university such that only one third of the students who lived in an engineering living community did not continue an engineering major compared to half of the counterparts.

4.2 Survey Results

Table 3 shows both the descriptive statistics and the Kruskal-Wallis Signed-Rank Sum results of the quantitative survey items. Results are shown for: (1) the entire group, (2) for the students in the engineering living community and for those who are not, and (3) for students that continued in engineering and for those who did not. The results tended towards "neutral" responses which were not expected based on anecdotal feedback from students in the women's engineering living communities over the past several years which has been almost unanimously positive. As explained by measurement theory, people provide ratings based on norm- (performance relative to the norm group) and/or criterion-referenced (more absolute performance) information [35]. However, in our study, students might not be able to easily find a reference group to provide a context for interpreting the rating scales. In other words, when reflecting on the questions, there is a question of frame of reference as the students only know what they have experienced and cannot know what the alternative would have held for them. For example, if you lived in an engineering living community it would be impossible to know if it would be better/worse for you to get access to study groups. Note responses were on a Likert scale from 1 (very negative) and 10 (very positive).

Within the qualitative responses to the open-ended prompt: "Explain how your residence hall experience impacted your engineering studies," participants noted the presence, or lack thereof, of three kinds of support: Social, Academic, and Environmental. Table 4 details codes and definitions used when analyzing the data.

Table 3. Descriptive Statistics and Kruskal-Wallis Signed-Rank Test Results of Survey Question Responses

Categorization	Overall Experience as an engineering student	Access to study groups	Access to upper division student mentors	Decision to continue engineering
Whole Sample	6.31	5.95	6.30	5.88
Engineering Living Community				
Yes	6.32	6.24	5.72	5.93
No	6.28	5.88	6.45	5.65
Kruskal-Wallis Test	$\chi^2(1) = 0.4243$, $p = 0.5148$	$\chi^2(1) = 1.0557$, $p = 0.3042$	$\chi^2(1) = 1.6414$, $p = 0.2001$	$\chi^2(1) = 0.3798$, $p = 0.5377$
Pursuing an Engineering Major				
Yes	6.30	5.87	6.25	5.99
No	6.43	6.86	7.00	4.57
Kruskal-Wallis Test	$\chi^2(1) = 0.0881$, $p = 0.7666$	$\chi^2(1) = 3.2036$, $p = 0.0735$	$\chi^2(1) = 0.5167$, $p = 0.4722$	$\chi^2(1) = 6.6166$, $\mathbf{p = 0.0101}$

Note. Scales are from 1 (very negative) to 10 (very positive).

Table 4. Codebook of students' experiences of residence halls

Code	Positive	Negative
Access to upperclassmen	Were able to ask upperclassmen about a variety of topics	Did not perceive having upperclassmen as resources for information
Make friends in my major/engineering	Were able to make friends that lived in the dorms and were in the same/similar discipline	Did not make friends within the dorms who were in engineering
Support/study groups (HW and projects)	Worked with others who lived in the dorms	Did not work with students who lived in the same dorms
Increase self-efficacy for school	Felt living in dorm contributed to their success/continuance in engineering	X
Positive STEM environment	Felt that living in dorms built community and confidence as a women in STEM	X
Dorm infrastructure (AC, water quality, study rooms, etc)	X	Felt that the quality of the dorm negatively impacted their experience
Comparison to other dorms (community, upperclass students, etc.)	X	Awareness of other dorms' resources led to criticism of own dorm

The social component of perceived support that students found in the resident halls centered on folks that they interacted with in class and were able to bridge connections outside of the classroom as they were present in the dorms. These connections are presented in the form of friendships and study groups.

> "Having other girls in the same classes allowed me to just randomly come across girls studying for the same test that I could ask questions to. In classes when there were semester long projects or final projects, it was so helpful having girls in the dorm I could work with weekly. Or, if it was late at night and I was freaking out about an issue in a code, or not having a calculator, or anything of the sorts, it was so helpful to have girls I could just find in my dorm Groupme message to text. I switched engineering majors because of conversations I had with upperclassmen in my dorm. I definitely would not be so confident in continuing in engineering if it weren't for having the community of engineers in my dorm."

For this participant, the consistent access to peers in their residence hall provided them with comfort, built confidence, and assuaged concerns they experienced as an engineering student. The social nature of the engineering living community made access to these groups second nature. The engineering living community allows for spontaneity in the support found by students and facilitated engagement with a range of persons that resulted in a positive experience.

Academic support was also perceived as impactful by participants in the residential halls. This came from having access to upper class engineering students, the study groups they were able to form where they lived, and whether students viewed the residential halls as beneficial to their continuance and success in engineering (self-efficacy):

> "I found the three people I study with for my engineering classes the most in my residence hall or in a residence hall close to mine. I don't think I would have been able to succeed in my courses as well as I have without meeting these individuals."

The culture that exists due to the presence of the engineering living communities extended into participants' courses. One participant noted:

> "I met upperclassmen with similar major paths and asked them questions about future classes/professors.

One of my professors matched students in the class based on dorms for study groups."

Professors were able to utilize residence halls in the creation of groups to facilitate teamwork. The convenience and proximity of the residence halls resulted in dependable academic support for these students. Upperclassmen seem willing to provide this support because it was helpful to them and they wanted to continue that trend, or perceived this support as lacking and desired to provide it for those who came after them.

Environmental support is often related to the physical nature of the residential halls or a comparison to other halls. One participant alluded to the availability of study spaces in her dorm:

"My residence hall had only one study room so I could never be there and had to [walk] home from other areas like the library very late at night. . ."

This physical limitation of the residence hall signifies that even if students have access to engineering peers, if the hall is not equipped with study spots, there is still effort required to work together. One pushback referenced by participants was the shared stress students experienced as a whole:

"My residence hall was very supportive to [people] studying engineering. Many of my peers were in STEM, engineering specifically, and I often found many other girls around me in the same major. On the other hand, this meant everyone was experiencing the same stress and deadlines which sometimes created stressful environments."

Many of the codes developed within the analysis of the free response indicated that several areas participants noted to be of importance in the engineering living community were dichotomous. Responses centered on the same areas of support, social, academic, and environmental, had both positive and negative connotations. A quantization of these codes reveal that participants noted positive aspects of the engineering living communities approximately twice as frequently as the negative. Those who did not perceive support often mentioned feelings of loneliness or isolation. It is difficult to determine why these participants were not as positively influenced by their residential experiences, many citing the lack of other female engineering students in their major or a gap in the resources afforded to them. Another potential cause for the negative perception is the lack of awareness, engineering living communities do not offer the same programming or advertisement as a living learning community.

5. Discussion

The findings of this work align with the previous research on the positive impact of living community [11–14] and contribute in extending the benefit to female engineering students' three year retention and on to graduation. Specially, the qualitative results illustrate the social integration aspect of the living community to enhance the sense of belongingness and self-efficacy for female engineering students to motivate them pursue engineering studies.

Several limitations are identified. Additional demographic data, such as race and ethnicity and socioeconomic status, would be helpful to reveal additional patterns that associate female students' retention in engineering majors, but the information was protected by the institutional registrar for privacy concerns. Although the sample size seems sufficient in terms of power to perform the proposed statistical analysis, we acknowledge that we did not take into consideration the cohort difference as a possible confounding variable interacting with the relationship between student residential hall placement and retention in an engineering major, as we assumed that the cohort effect will be minimal as there was no change in the placement practice. Furthermore, the data was acquired at only one private institution, so the findings and results might not hold firmly for other types of institutions where students do not stay in the same residence hall for multiple years.

We would also offer practical implications and future research direction beyond this work. Practically, this research encourages policy makers at the university and department level to pay more attention to the well-being and better accommodate underrepresented students, such as female students, international students, and students of color. Meanwhile, analysis in this study could also serve as an implicit assessment of the practice of diversity, equity, and inclusion principles on campus. Future research should also investigate the influence of living community on other minoritized students with respect to race/ethnicity, sex orientation, socio-economic status, etc. Furthermore, scholars are encouraged to reexamine the current practice of living communities and actively improve the experience of undergraduate engineering students so as to maintain and even foster the retention rate and graduation rate.

6. Conclusion

We present findings to uncover the relationship between engineering living communities and undergraduate students' three-year retention in engineering majors. The mixed method paradigm guided the analysis of the historical registrar data of female engineering students' retention and the free responses of current students' perception of the impact of the engineering living community on their study in engineering majors. The results indicate that placing female students in an engineering living community positively impacts their three-year retention in engineering majors. As we think of ways to expand the benefits of an engineering living community to other minority groups include being a no cost way to improve retention.

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