Female Undergraduate STEM Persistence: A Focus on the Role of Living and Learning Communities
Samantha Nix, Kari Roberts and Roxanne Hughes
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A Focus on the Role of Living and Learning Communities

Over the last three decades, women have surpassed their male peers in overall bachelor’s degree attainment (DiPrete & Buchmann, 2013; OECD, 2013), yet, women still trail men in persistence rates within science, technology, engineering, and mathematics (STEM) fields (NSF, 2013). This issue has become a major policy concern for federal and state governments as well as higher education institutions, as STEM fields are crucial for the US economy and for individuals, who may benefit from these industries’ higher than average pay (Kennedy, 2012; Koebler, 2012; Obama, 2013, PCAST, 2012). Colleges and universities have created a number of recruitment and retention policies to address women’s underrepresentation in STEM fields. One of the longest running responses has been living-learning communities, programs designed to provide safe places for women to network and meet role models who can help them through their respective STEM courses and disciplinary climates. This study investigates how participation in a STEM living-learning community at one university relates to college and STEM-related educational outcomes by comparing participants to matched (via propensity score matching) STEM majors in the institution’s general population.

Living-learning communities (LLCs) are programs designed to give students with a common connection (e.g. college major) a shared residence hall space and some form of academic and social support. Examples of student populations served by LLCs include: first-generation college students; students who wish to remain alcohol and drug free; and, students who share a common major, such as women in STEM fields. These programs can also integrate social events to strengthen students’ connection to each other and the university. LLCs have been in existence since the early 1990s. Research on LLCs has demonstrated positive impacts of these
 programs on participants, such as: smoother transitions for first generation students (Inkelas, Daver, Vogt, & Leonard, 2007); increased self-reported cognitive complexity (Inkelas, Soldner, Longerbeam, & Leonard, 2008); and increased openness to diversity by way of peer interaction (Longerbeam, 2010). In a review of the literature about the effects of STEM LLC participation in particular, Inkelas (2011) described improved persistence and retention in these fields for female participants. She further concluded that STEM LLCs had the potential to increase other positive outcomes, such as plans to enter graduate school, perceived confidence in STEM coursework, college satisfaction, and easing the transition from high school to college. Some scholars additionally stress the importance of the social benefits that women gain from belonging to STEM LLCs, such as conversations with academically driven peers, supportive residence hall climates, and increased interactions outside of the classroom with faculty (Hughes, 2014; Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012).

One of the major limitations of previous STEM LLC studies is the inability to limit the effects of selection bias. Women who choose these programs may also have background characteristics or other qualities that give them a higher propensity for academic success compared to their peers, independent of their participation in the college program. Most STEM LLC studies lack a direct comparison between women who participate in the program to non-participants with similar background characteristics, particularly at the same institution. In this study, we sought to clarify whether participation in a STEM LLC was positively associated with STEM degree attainment at our institution of interest, limiting exogenous variables as much as we were able. Through the use of six years of longitudinal data at a research-intensive university, we directly compared participants in a women-only STEM LLC (Women in Science and Engineering [WISE]) to STEM majors with similar background characteristics at the same
institution using propensity score matching. Our analyses test the relationships between WISE participation and four outcomes: final grade point average (GPA), graduation from the institution, graduation from a STEM field, and graduation within specific STEM fields. Through our analyses, we sought to answer the following research question: How does participation in a STEM LLC relate to college and STEM-related educational outcomes?

**Literature Review**

There are many factors besides LLC participation that can affect undergraduates’ (both men and women) persistence in their chosen STEM field. These include: demographics; high school academic preparation; postsecondary course enrollment; institutional context; and specific STEM major. We will discuss the role that each of these plays in STEM persistence here.

**Demographics**

Research has shown differences in enrollment and persistence patterns based on gender, race, and ethnicity. Research indicates that part of the issue affecting women’s underrepresentation in STEM is the lower rates of women declaring STEM majors as they enter college (Ceci et al., 2014). Specifically, studies of nationally representative datasets have shown that once in STEM fields, women have persistence rates similar to men across STEM fields (Chen, 2009; Hill, Corbett, & St Rose, 2010), as well as specifically in engineering majors (Lord et al., 2009). Yet, due to their lower rate of entry into STEM majors, any loss of women during the postsecondary educational experience is meaningful. Gender is a key variable in our analysis.

For many women, gender can intersect with race and ethnicity to create a double bind (e.g. women of color often feel like that are a double minority within these fields which can negatively affect their STEM identity) (Carlone & Johnson, 2007). Research on women of color’s persistence in STEM demonstrates that these trajectories are best understood by
examining the intersection of gender and race/ethnicity (Hurtado et al., 2009). For example, looking at race and ethnicity alone, Anderson and Kim (2006) reported that underrepresented minority groups had similar rates of selecting STEM majors upon entry to college, but took more time to earn their degrees than their White and Asian counterparts. Bonous-Hammarth (2000) used Cooperative Institutional Research Program data to investigate enrollment over time. They found that Native American, Black, and Latino students had a 44.1% decrease in STEM participation between 1985 and 1989, compared to a 25.7% and 24.5% drop in those same majors for Asians and Whites, respectively. When looking at the intersection of race/ethnicity and gender, the dataset revealed a tiered system of attrition, with White and Asian females persisting at higher rates than underrepresented males, who persisted at higher rates than underrepresented females. These findings for race/ethnicity and gender suggest that postsecondary environments have differential impacts on underrepresented minority groups’ persistence in STEM fields. Therefore, while the program that we examined was not specifically designed to serve minority women, we consider race/ethnicity in our models as the LLC makes up a part of the institutional environment and may have differential impacts on women of color.

**High School Academic Preparation**

High school is an important step in the trajectory towards or away from STEM persistence. Students who take certain courses in high school (e.g. chemistry and physics and at least through geometry, trigonometry, or statistics, if not higher) are more likely to complete postsecondary STEM degrees (Chen, 2009; Tyson, Lee, Borman, & Hanson, 2007). Without completing these high school classes, it is possible that students struggle in their postsecondary major-specific courses or take remedial classes, which can prolong their college experience and discourage their persistence. Similarly, these studies on STEM persistence point to related
academic preparation measures such as GPAs and standardized test scores as important predictors of college STEM success, cementing its importance for inclusion in future studies. Current research provides some mixed results related to the gender gap in standardized test scores, course taking, and GPA. In one study, Hill and colleagues (2010) found that high school women outperformed their male counterparts in math and science courses taken as well as grades earned in those courses, but they underperformed compared to their male counterparts in math and science Advanced Placement tests. In another study, Riegle-Crumb and King (2010) analyzed Education Longitudinal Study 2002 (ELS) data and found that girls earned a higher mean high school math GPA compared to their male counterparts. However, these young women had significantly lower standardized math test scores. Other research points to a decrease in the gender gap in standardized test scores (Ceci et al., 2014). Despite the improvements to the gender gap in performance and course taking, women are less likely to select STEM majors in college (Ceci et al., 2014; NSF, 2013). To test these predictors and compare members of WISE to women in the university population with similar levels of preparation, we included the following variables in our analysis: high school GPA and SAT and/or ACT score. We did not have access to students’ high school transcripts, so we could not predict STEM outcomes using high school science or mathematics course taking.

Postsecondary Course Enrollment

We included measures of postsecondary course enrollment due to its importance in the literature. For instance, using nationally-representative data, Maltese and Tai (2011) found that there was an 88% increase in the odds of completing a degree in STEM with an increase of one math or science credit taken in the first year of college. In contrast, Crisp et al.’s (2009) research on STEM enrollment and persistence at a Hispanic Serving Institution showed that students who
enrolled in algebra I or higher and biology I or higher in their first year of college had significantly lower odds of completing a STEM degree. In addition to specific course enrollment, full-time versus part-time enrollment has been of concern in the scholarly and policy literature (e.g. Adelman, 2006; Attewell, Heil, & Reisel, 2012; CCA, 2011). Therefore, to test the role that these postsecondary course enrollment variables have on persistence, we consider students’ first mathematics course and measures of part-time enrollment in our analysis.

**Institutional Context**

Institutional characteristics—size, mission, control, and faculty, staff, and student composition—have also been studied in the literature. Single-sex institutions have long been regarded as particularly successful at helping women to persist in STEM fields (Perna et al., 2009; Rayman & Brett, 1995). Similarly, Historically Black Colleges and Universities (HBCUs) appear to be major sources of underrepresented minority degree completion in STEM (Leggon, 2006; Lundy-Wagner, 2013). More generally, factors such as research expenditure and size is negatively related to STEM persistence for both women and minority students, while the number of female and minority faculty appear to be positively related to degree completion for these same groups (Griffith, 2010; Sonnert, Fox, & Adkins, 2007). All of these characteristics combine to form a unique institutional context at every institution. Therefore, like previous studies that focused on STEM LLCs at single institutions (e.g. Allen, 1999; Brainard & Carlin, 1998; Hughes, 2014; Kahveci, Southerland, & Gilmer, 2006), we attempt to limit the differential effects of institutional characteristics by limiting the scope of our study to one institution during a stable five years when the institution did not experience significant changes.

**Specific STEM Major**
Descriptive statistics reveal differences in the intent to major in specific math and science fields (Hill et al., 2010). This has led to increased attention to disaggregating the STEM block of majors, to reveal more nuanced variations in participation by men and women in specific majors. Specifically, overall statistics show low-participation by women in engineering and computer science, middle-low participation in the physical sciences and math, and medium participation in biology (NSF, 2013). Follow-up studies using the ELS dataset reveal that high school course taking (Riegle-Crumb & King, 2010) and orientation towards math (Perez-Felkner, McDonald, Schneider, & Grogan, 2012) could be linked to gendered/racial/ethnic differentials in enrollment in engineering, physical and computer sciences, and math fields. Further, Riegle-Crumb, King, Grodsky, and Muller (2012) analyzed three NCES datasets and found persistent gaps over two decades in physical science and engineering major enrollment. Therefore, we disaggregate the STEM fields to see the possible impact of an LLC on women’s choices to persist in fields in which they are particularly underrepresented.

Social Psychological Constructs

Social psychological constructs have been featured prominently in the scholarly literature. Constructs such as self-concept (domain-specific belief in ability) (Guay, Marsh, & Boivin, 2003; Marsh, 1986, 1990) and self-efficacy (task-specific belief in ability) (Bandura, 1977; Pajares & Miller, 1994; Zimmerman, 2000) are still used today in studies of STEM outcomes (OECD, 2015; Van de Gaer, Grisay, Schulz, & Gebhardt, 2012). While these constructs are helpful to understanding the role of individual beliefs, more recent theories examine the role that individuals and culture play in shaping STEM identity and STEM persistence. For instance, studies using expectancy-value theory often feature both self-efficacy or self-construct and gender socialization to describe why women tend to have lower interest in
STEM careers and lower beliefs in abilities (Eccles, 1987; Wigfield & Eccles, 2000). Concurrent with this research, scholars have also examined the role of field culture (Cheryan, Master, & Meltzoff, 2015; Margolis & Fisher, 2002) and science or math identity (Cribbs, Hazari, Sonnert, & Sadler, 2015). Stereotype threat research additionally provides evidence of how specific cultures or environments can inhibit women’s and racially underrepresented people’s performance through working memory (Beilock, 2008; DeCaro, Rotar, Kendra, & Beilock, 2010; Rydell, McConnell, & Beilock, 2009). Overall, this research suggests that not only are demographics, high school academic preparation, postsecondary course enrollment, institutional context, and specific STEM major meaningful factors in students’ persistence in STEM, but environment and interactions with others plays a meaningful role in how people identify as scientists and persist in STEM fields to degree attainment. Using theories which address the relationship between the environment and self, this study examines the role of a STEM-only LLC on women’s overall college GPA, bachelor’s degree attainment, and STEM degree attainment.

**Conceptual Framework**

Two conceptual frameworks inform the development of our study: the “chilly climate” concept (Hall & Sandler, 1982, 1984) and Astin’s input-environment-outcome (I-E-O) model (Astin & antonio, 2012). Hall and Sandler’s (1982, 1984) work clarified the relevance of college environments and faculty-to-student, staff-to-student, and peer-to-student interaction on women’s higher education success. They pointed out specific populations of women that are vulnerable to chilly climates, including older women, graduate students, and women studying in fields traditionally pursued by men, like STEM (our population of interest). Since their publications, the “chilly climate” has become an essential piece of dialogue in the research on
women’s parity in STEM fields. The program of interest in this study—WISE—was developed to help combat this chilly climate (Hughes, 2010). By connecting women in STEM fields with one another, the WISE directors’ intent was to build positive peer-to-peer interactions that Hall and Sandler (1984) described as beneficial to women’s decisions to persist in college and, more specifically, in male-dominated fields. Further, the WISE living-learning community intentionally engaged a senior woman faculty member in STEM, to provide both a model for success and a sympathetic ear for the participating women’s concerns. Therefore, this study examines evidence of WISE’s efforts to “warm” the climate for their participants, by comparing their outcomes to non-participants.

Astin’s I-E-O model, typically described in terms of evaluation and assessment, provides a simple framework for understanding how college environments might intervene to effect student outcomes. The model accounts for student background characteristics and their effects on both selection of an environment/program and educational outcomes. It additionally describes how environments might also affect those outcomes. Applying the I-E-O model to the study at hand, we consider how student background characteristics might inform choices to engage in a special program. Since WISE participants must apply to be a part of the program, accounting for selection bias is an important issue in this study. By measuring the outcomes for both groups that participate in WISE and those who do not, we test if participation in the living-learning community is a significant factor in GPA, graduation, and STEM degree outcomes. Therefore, Astin’s I-E-O model provides a method of understanding the extent to which a college program might decrease women’s perceptions of “chilly” STEM climates.

**Program and Institution of Interest**
The institution of interest for this study is a large (over 40,000 students), public, research-intensive university located in the southeast. Because we studied a population over a span of six years, the demographics for the university are given as a range. During the years studied, the institution reported between 56 and 57% female enrollment. While the institution primarily serves White students, its location in a diverse state was apparent in the 11-12% enrollment of Black students; 7-10% enrollment of Hispanic students; 3% enrollment of Asian students; and 0.4-0.6% enrollment of Native American students. The full-time student enrollment ranged between 80 and 81% during the years studied, and about 60% of all students were undergraduates.

The program of interest for this study is a women-only LLC for first-year STEM majors, referred to in this paper as WISE (Women in Science and Engineering). The program began in 2001 and continues to this day. The program accepts 33 new first-year students each fall. Applications are open to any first-year female student who intends to major in actuarial science, biology, chemistry, biochemistry, engineering, computer science, geology, environmental science, mathematics, meteorology, physics, psychology, or statistics. Program participants are primarily selected based on their interest in science, commitment to their major, and their prior academic achievement (especially high school GPA, which the program staff felt was a better indicator than standardized test scores of students’ high school efforts). Race/ethnicity and socioeconomic status are not considered in the application process, unless students mention these identities in their essays. During the first year, all participants live in the same residence hall and attend a weekly colloquium together. After the first year, students are not required to participate in WISE activities, though those activities are still open to them. Activities and presentations offered through WISE are primarily focused on professional development and community
building. During the first five years of the program (2001-2006, the same time period as this study), the program included tutoring services and a small research internship program. Program staff consisted of a faculty director (a full professor of oceanography) and no more than two graduate students from either the oceanography or the women’s studies department.

**Methods**

**Data and Sample**

Data for this project were collected by the institution of interest’s Institutional Research office, and contained records for all students (male and female) who matriculated between fall 2001 and fall 2006 with an eligible WISE major. In total, the dataset had information for 9,892 students. Data for each student included demographics (gender and race/ethnicity), high school standardized test scores, high school GPA, all coursework completed at the university including grades for each class, WISE participation, and degree information for those who graduated. Our sub-population of interest was the group of female students who participated in WISE \( n = 201 \) during the same timeframe.

**Missing Data Procedures**

Our analytic procedures included propensity score matching (described later). Propensity score generation required a complete dataset, beyond just those variables that were used in matching. To preserve all of the cases of data, we used multiple imputation in SPSS 20 to impute all missing values, based on procedures outlined by Rubin (2004). This procedure is considered to be a stronger methodological choice than more common methods such as case or pairwise deletion (Cox, McIntosh, Reason, & Terenzini, 2014). A new dataset was created after 100 iterations of the multiple imputation procedure for a total of 10 datasets. For the analyses, each imputed dataset was examined individually, and the results were pooled. Of the variables that were missing data, only four were used in our regression analyses: high school GPA (missing \( n = \))
69, 0.6%), SAT Math (missing \( n = 19 \), after concordance, 0.2%), full-time enrollment status (missing \( n = 18 \), 0.2%), and college GPA (missing \( n = 8 \), 0.08%). These data were missing due to incomplete student records at the institution.

**Variables**

Our independent variable for all of our analyses was *participation in WISE*, represented by a yes/no dichotomous variable. Additionally, there were four dependent variables used in our analyses. First, *college GPA* was calculated based on the university’s grading scale using the credit hour and grade data for each student. This variable represents the cumulative GPA of all courses taken and ranges from 0.0-4.0. Next, we measured *graduation* as a dichotomous variable representing whether or not each student had graduated as of 2012. We additionally measured *graduation in STEM* as a dichotomous variable representing whether or not a student had graduated with a degree in a STEM field. Lastly, our final analysis was on *type of STEM degree*. Of those who graduated, we categorized the degree field into one of five areas: non-STEM, PEMC (physical sciences, engineering, math, and computer science) (Perez-Felkner et al., 2012), biological sciences, health sciences, and socio-behavioral sciences. PEMC fields were grouped together because women have been traditionally underrepresented in these fields (NSF, 2013). A list of majors for each subcategory is available in Appendix A.

Additionally, the analyses included several covariates, which allowed us to examine and compare the statistical impact of potentially confounding variables. These covariates fell into three broad categories: demographic information, high school academic achievement, and college course enrollment. Demographic information included *race/ethnicity* and *gender*, both of which were dichotomously coded and reported via the institution (rather than self-reported). High school academic achievement was represented by *GPA* and *SAT math scores*. When an SAT math score was unavailable, it was calculated using ACT concordance tables. If neither
SAT nor ACT scores were unavailable, it was imputed in the multiple imputation process. For college course enrollment, two variables were included: *first math class* and *enrollment status*. Both of these variables were created using transcript data. First math class represents each student’s preparedness for college-level math via their first chosen mathematics course at the institution of interest. Categories for this variable were: (0) no math course completed, (1) College Algebra; (2) Trigonometry, Pre-calculus/Trigonometry, Pre-calculus; (3) Calculus for Business; (4) Calculus 1; (5) Calculus 2; and (6) Calculus 3. Enrollment status represents whether or not a student completed course work as a part-time student during any point of their time in college. While students at this institution are required to complete some courses in summer sessions, these terms were not included in the calculation of enrollment status, as this requirement varies between majors.

**Analyses**

**Propensity Score Matching.** Analyses for this project occurred in two phases. In phase one, we compared WISE participants to the greater population of STEM students (both men and women) at the university to provide a sample-to-population type analysis. Phase two endeavored to compare WISE participants to a subsample of the population which resembled them in terms of demographics and prior academic achievement, to further limit the influence of extraneous variables. The same analyses were run for both phase one and phase two. This subsample was selected using propensity score matching yielding 804 students from the larger population matched to the 201 WISE participants. To calculate propensity scores, we used the SPSS add-on developed by Thoemmes (2012). We did a 4:1 nearest neighbor matching based on the following covariates: race/ethnicity, gender, high school GPA, SAT math score, and first college math class. These variables were selected for conceptual reasons: these are the primary characteristics
either considered for acceptance into the WISE program or theorized to be related to selection bias. Our goal for the propensity score matching was to select a sample of the population who were similar in these regards to our WISE participants, allowing us to make a comparison to students of similar backgrounds. Table 1 shows the descriptive results of the propensity score matching procedure.

**Table 1. Descriptive Statistics for Matched and Unmatched Datasets**

<table>
<thead>
<tr>
<th></th>
<th>Matched Data (n=1,005)</th>
<th>Unmatched Data (n=9,892)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Demographic characteristics</td>
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<td></td>
</tr>
<tr>
<td>Female</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>68.7%</td>
<td>68.7%</td>
</tr>
<tr>
<td>Black</td>
<td>18.4%</td>
<td>18.4%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>9.5%</td>
<td>9.5%</td>
</tr>
<tr>
<td>Native American</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Asian</td>
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<td>2.5%</td>
</tr>
<tr>
<td>Graduated</td>
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<td></td>
</tr>
<tr>
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<td>79.1%</td>
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<tr>
<td>No</td>
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<td>20.9%</td>
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<tr>
<td>Graduated in STEM</td>
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</tr>
<tr>
<td>Yes</td>
<td>64.7%</td>
<td>64.7%</td>
</tr>
<tr>
<td>No</td>
<td>35.3%</td>
<td>35.3%</td>
</tr>
<tr>
<td>Degree Types</td>
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<td></td>
</tr>
<tr>
<td>Engineering, Mathematics,</td>
<td>23.4%</td>
<td>23.4%</td>
</tr>
<tr>
<td>and Computer Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological Sciences</td>
<td>13.9%</td>
<td>13.9%</td>
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<tr>
<td>Health Sciences</td>
<td>15.4%</td>
<td>15.4%</td>
</tr>
<tr>
<td>Socio-Behavioral Sciences</td>
<td>11.9%</td>
<td>11.9%</td>
</tr>
<tr>
<td>Non-STEM</td>
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<td>35.3%</td>
</tr>
<tr>
<td>Academic Performance</td>
<td>SAT Math</td>
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</tr>
<tr>
<td></td>
<td>High School GPA</td>
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<td></td>
<td>College GPA</td>
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</tr>
<tr>
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<tr>
<td>Stopped Out</td>
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<td>0.0%</td>
</tr>
<tr>
<td>Part-Time</td>
<td>52.2%</td>
<td>52.2%</td>
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</table>
WOMEN-ONLY STEM LLC PARTICIPATION AND PERSISTENCE

<table>
<thead>
<tr>
<th>Full-Time</th>
<th>47.8%</th>
<th>43.3%</th>
<th>47.8%</th>
<th>43.3%</th>
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<tbody>
<tr>
<td>First Math Class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Math Courses</td>
<td>7.4%</td>
<td>8.3%</td>
<td>7.4%</td>
<td>11.9%</td>
</tr>
<tr>
<td>College Algebra</td>
<td>37.8%</td>
<td>42.8%</td>
<td>37.8%</td>
<td>48.5%</td>
</tr>
<tr>
<td>Trigonometry, Pre-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>calculus/Trigonometry, Pre-Calculus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculus for Business</td>
<td>1.0%</td>
<td>0.9%</td>
<td>1.0%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Calculus 1</td>
<td>6.5%</td>
<td>6.9%</td>
<td>6.5%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Calculus 2</td>
<td>6.5%</td>
<td>6.7%</td>
<td>6.5%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Calculus 3</td>
<td>1.0%</td>
<td>1.9%</td>
<td>1.0%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

**Analytic Procedures.** The hypotheses for our study are based on our overall research objective to investigate the role of women’s participation in a STEM LLC (WISE) on STEM persistence. These hypotheses are:

**H₁:** WISE participants are more likely to have a higher college GPA compared to their non-WISE counterparts.

**H₂:** WISE participants are more likely to graduate with a STEM major compared to their non-WISE counterparts.

**H₃:** WISE participants are more likely to persist in a physical science, math, computer science, or engineering (PEMC) field compared to their non-WISE counterparts.

The same analytic procedures were used for both phases of analyses. The only thing that changed from phase one to phase two were the students included in the analyses. For **H₁**, we conducted a linear regression comparing college GPA on the covariates of interest and participation in WISE. For **H₂** and **H₃**, we used a logistic regression to examine the likelihood of graduating in STEM and the likelihood of graduating within specific STEM fields. **H₂** required a binary logistic regression, while **H₃** required a multinomial logistic regression.

In this paper, we report both phase one and phase two results in tables. In general, the direction of the findings was consistent between phase one and phase two results (with
exceptions noted throughout the narrative). The main difference between the two phases occurred with the number of significant $p$-scores. As a result of a larger $n$, there were more significant values throughout phase one compared to phase two results. This difference was expected, and in fact, motivated our decision to use propensity score matching. Finally, because the propensity score matching narrowed our sample to only women, phase two results display the relationships between the dependent and independent variables for females.

**Limitations**

Due to the limitations of institutional data, we were unable to measure non-cognitive factors that may also be relevant to students’ choices to participate in the WISE program. For instance, there was not a reliable measure of motivation or STEM interest. While future cohorts of students applied to WISE using an online system which might allow for analyses on motivation, the 2001-2006 matriculates applied using paper applications that we are no longer in existence. In addition, we were unable to include socio-economic status (SES) in our models. We know that, generally, socio-economic status is a factor in college enrollment and completion (Goldrick-Rab, 2007; Paulsen & John, 2002). Conceptually, we also know that SES plays a role in participation in WISE, as participation in the program requires students to pay to live in a residence hall. At our institution of interest, living on campus is not always a cost-effective option, and many low-SES students choose to live off-campus in an effort to save money. However, our institution of interest does not collect data on socioeconomic status in a form that is usable for researchers, and we were unable to approximate SES using the data we had received.

Additionally, we were unable to fully examine the impact of a multi-racial/ethnic or Native American identity on students’ STEM persistence because of the sparseness of this data.
Several of our regression models were unable to achieve convergence when these variables were included in the model. We do not want to dismiss these populations as unimportant or without their own issues in STEM persistence. However, we did not have sufficient data to examine these groups within the context of our study, so they were omitted from the models.

Lastly, our study is limited to one institution. Therefore it is not generalizable to all institutions with similar programs. However, we feel that this method of inquiry can be replicated at other institutions as a way of evaluating the efficacy of women-only STEM LLC programs within specific institutional contexts. All of our results are explained within the context of the university of interest, and speculate the role of the WISE program in the persistence of its students. We do not propose that a women-only STEM LLC is the one-size-fits-all answer to solving the gender gap in STEM fields, but our data does suggest that this program has a positive role within its institution.

**Results**

For the first round of analyses, we examined the role of WISE participation and background characteristics on college GPA. In the phase one analyses, all variables except Hispanic, SAT Math score, and WISE participation had a statistically significant relationship with college GPA. In phase two, fewer variables were found to be statistically significant, but some trends did emerge (Table 2).

<table>
<thead>
<tr>
<th>Race/Ethnicity (white reference)</th>
<th>Beta</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>African American</td>
<td>-0.143***</td>
<td>0.051</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.030</td>
<td>0.068</td>
</tr>
<tr>
<td>Native American</td>
<td>0.165</td>
<td>0.322</td>
</tr>
<tr>
<td>Asian</td>
<td>-0.102</td>
<td>0.119</td>
</tr>
<tr>
<td>High School Preparation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School GPA</td>
<td>0.547***</td>
<td>0.043</td>
</tr>
</tbody>
</table>
The results showed that the most significant positive predictors of college GPA were high school GPA and enrollment status. Specifically, a one-point increase in high school GPA is predicted to increase college GPA by just over half a point ($p = .000$), while continuous full-time enrollment during the fall and spring semesters is expected to increase college GPA by 0.138 points ($p = .000$), holding all other factors constant. This supports the idea that long-term high school academic achievement is predictive of college academic performance, and that students who enroll in college full time are more likely to have better grades. One race/ethnicity category was shown to have a significant relationship with college GPA, while the others did not reach significance. Recall that the matched sample only includes women. Therefore, holding all other factors constant African American women are expected to earn an average of 0.143 fewer GPA points than white women ($p = .005$). Next, while it was significant, SAT math score had a negligible association with college GPA. Finally, participation in WISE was not shown to have a significant relationship with college GPA. Possible explanations for this finding will be examined in the discussion and conclusion of this manuscript.

For the second round of analyses, we examined the likelihood of graduation in general and graduation in a STEM field, and report the results using odds ratios (OR) (Table 3). Phase one of this round of analyses indicated that women were more likely to graduate from college.
and graduate with a degree in STEM compared to men. While women’s increased likelihood of graduating from college compared to men is consistent with the literature (DiPrete & Buchmann, 2013), their increased odds of graduating with a degree in STEM was a surprising finding. The next round of analyses on STEM degree type shed light on why the odds for women’s graduation in STEM were so high. When we looked at the phase one breakdown of women’s graduation within the different types of STEM fields, we saw that women were significantly more likely to graduate in biological science and health fields, and the increased odds in these fields accounted for the overall greater odds of women graduating in STEM. Additionally in phase one, first math class was shown to be a statistically significant positive predictor for graduation in general and graduation in STEM. However, this significance is lost in phase two.

Table 3. Student Characteristics and Graduation from College (Matched Data)

<table>
<thead>
<tr>
<th></th>
<th>Graduation with a Degree in STEM</th>
<th>Graduation from College, Regardless of Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>SE</td>
</tr>
<tr>
<td><strong>Race/Ethnicity (white reference)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>1.329</td>
<td>0.204</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1.335</td>
<td>0.257</td>
</tr>
<tr>
<td>Native American</td>
<td>0.476</td>
<td>1.256</td>
</tr>
<tr>
<td>Asian</td>
<td>0.935</td>
<td>0.449</td>
</tr>
<tr>
<td><strong>High School Preparation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School GPA</td>
<td>2.606***</td>
<td>0.177</td>
</tr>
<tr>
<td>SAT Math Score</td>
<td>1.001</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>College Experiences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part-Time Enrollment Status</td>
<td>0.669***</td>
<td>0.146</td>
</tr>
<tr>
<td>First Math Class</td>
<td>1.119*</td>
<td>0.062</td>
</tr>
<tr>
<td>WISE Participation</td>
<td>1.208</td>
<td>0.173</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>0.025***</td>
<td>0.842</td>
</tr>
<tr>
<td><strong>Cox and Snell R²</strong></td>
<td>0.066</td>
<td></td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>1.005</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** n=1,005. Gender was not included in the model because all members of the sample are female. OR indicates odds ratios and SE indicates standard error. *** p<0.01, ** p<0.05, * p<0.1
Results from the logistic regression on graduation from college and from a STEM field using only the matched sample showed similar patterns as in the analyses on college GPA, as well as two new findings. As students increased their high school GPA by one point, they had a 3.333 times higher odds of graduating from college ($p = .000$) and a 2.606 times higher odds of graduating with a degree in STEM ($p = .000$), net of all other variables. Students who went part-time during any spring or fall semester had about a third lower odds of both graduating from college and graduating with a degree in STEM compared to their counterparts who took on full-time loads throughout their time in college. Neither of these findings are surprising considering the findings for college GPA. One new finding in this round of analyses was that selection of a higher math class increased the odds of graduating with a degree in STEM by 11.9% ($p = .069$). Additionally, holding all other variables constant, WISE participation was also shown to increase the odds of graduation from college by 40% ($p = .098$), although the association with graduation in a STEM field was not statistically significant.

Lastly, we analyzed the role of student characteristics and WISE participation on graduation within the different categories of STEM fields, with special attention to the physical sciences, engineering, mathematics, and computer science (PEMC) fields. In phase one of analyses, we found similar patterns as presented for phase two. Several findings emerged from this round of analyses (Table 4). We report these results using relative risk ratios (RRRs).

### Table 4. Student Characteristics and Degree Types (Matched Data)

<table>
<thead>
<tr>
<th></th>
<th>Non-STEM Reference</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PEMC</td>
<td>Biological Sciences</td>
<td>Health Sciences</td>
<td>Socio-Behavioral</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RRR</td>
<td>SE</td>
<td>RRR</td>
<td>SE</td>
<td>RRR</td>
</tr>
<tr>
<td><strong>Race/Ethnicity (white reference)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Afr. American</td>
<td>1.723</td>
<td>0.336</td>
<td>1.503</td>
<td>0.317</td>
<td>1.923**</td>
</tr>
<tr>
<td>Hispanic</td>
<td>2.198**</td>
<td>0.381</td>
<td>1.498</td>
<td>0.414</td>
<td>1.284</td>
</tr>
</tbody>
</table>
First, there was variation in STEM degree type via race/ethnicity. For instance, holding all other factors constant, African American women had a 92.3% higher likelihood of graduating in health sciences than white women \( (p = .015) \) and Hispanic women were over two times more likely to graduate in PEMC fields than white women \( (p = .039) \). As with the previous analysis, high school GPA had the largest RRRs compared to all other variables, increasing the risk of graduating in each field by between 1.844 and 4.352 times, compared to non-STEM degrees. In addition, consistent with the analysis on college GPA, part-time enrollment status during any spring or fall semester negatively predicted completion of degrees for all categories of STEM (although the relationship between enrollment status and majoring in the socio-behavioral sciences was not statistically significant). These were the only two trends that were consistent across all types of STEM fields.

Within individual fields, there were several findings. First math course was more highly predictive of graduation from a PEMC field than the other fields \( (\text{RRR} = 1.913; p = .000) \), and was shown to negatively predict graduation in the socio-behavioral sciences \( (\text{RRR} = 0.637; p = \)
Finally, perhaps the most important finding from this table is the relationship between WISE participation and graduation from PEMC and social/behavioral fields. Up to this point, WISE participation has had little statistical significance in our outcomes of interest. While WISE participation is predicted to decrease the likelihood of graduating from a social/behavioral field by 38.6% \( (p = .078) \), WISE students had almost three times higher odds than their non-WISE counterparts of graduating in a PEMC field compared to non-STEM fields, holding all other factors constant. Given that PEMC fields have been identified as those in which women have not yet gained parity, this finding is both important and merits increased discussion.

**Discussion**

This study provides a focused investigation of the role of a women-only STEM LLC program on participants’ STEM persistence. Specifically, we utilized Astin’s I-E-O model to understand how a specific part of the college environment at our institution of interest related to student outcomes. As cited previously, much research has concentrated on the link between secondary school experiences and postsecondary structural barriers on STEM degree outcomes. However, there are also hints that social cues can discourage women from participating in STEM fields, causing them to change their majors midway through their university experiences (Hall & Sandler, 1982, 1984). The development of programs like living-learning communities sought to combat the “chilly climate” that women may feel in the classroom (Inkelas, 2011). The presentation of this data provides information on whether or not one such program has been successful in this objective and if it has had any relationship with persistence in fields with the largest gender disparities: the physical and computer sciences, math, and engineering.

Our results reveal that participation in the WISE program was a positive and significant predictor of graduation from college and completion of PEMC degrees. However, there were no
statistically significant relationships between WISE participation and GPA or graduation with a degree in STEM in general. Finally, WISE participation negatively predicted completion of degrees in the socio-behavioral sciences. Therefore, although WISE participants were not expected to earn higher GPAs or graduate at higher rates in STEM in general compared to their non-WISE counterparts, the results suggest that the program might have encouraged students’ overall graduation from the institution of interest and specifically almost tripled their expected graduation rate from PEMC fields, which supports previous qualitative research (Hughes, 2014). However, high school GPA was still the most important predictor, indicating the continuing importance of high school preparation on women’s persistence in STEM.

When we examined the association between WISE participation and graduation from college with any STEM degree, it did not seem to have a strong relationship. However, when we further examined STEM degree completion of different types of STEM degrees (PEMC, Biological Sciences, Health Sciences, and Socio-Behavioral Sciences), we see that the association with WISE participation is much more nuanced. WISE students were about three times more likely to complete PEMC degrees than non-WISE students. This finding is important since these majors (the physical sciences, engineering, mathematics, and computer sciences) have shown the most persistent gender disparities over time in the U.S. (NSF, 2013; Riegle-Crumb et al., 2012). The relatively strong and significant positive finding for WISE participation suggests that colleges and universities can contribute to strengthening the participation of women in these fields in particular through the development of living-learning programs. Importantly, WISE recruits participants from across the STEM disciplines, and the program staff in place during the time that these students attended college primarily consisted of faculty and graduate students from the oceanography department. Thus, while there did not appear to be formal efforts
to engage women majoring in the PEMC sciences, first-year participation in WISE increased their likelihood of completing degrees in those fields anyway. This relationship could be the result of warming what has been called a “chilly climate” in fields traditionally pursued by men (Hall & Sandler, 1982, 1984). By connecting women with others like them through an intensive first-year program, WISE women in PEMC fields benefited from peer support that may not be available to non-WISE women. This finding should be studied further to determine if other LLCs affect persistence in the PEMC fields, where women are severely underrepresented.

Degree attainment in the socio-behavioral sciences was very different from the PEMC fields for WISE participants, who had 36.3% lower odds of graduating with a degree in the socio-behavioral sciences than non-participants. Appendix A shows that socio-behavioral sciences included majors in anthropology, applied economics, economics, geography, psychology, sociology, and social science. In contrast, due to an interest in serving student populations in fields with the highest risk of attrition, WISE purposefully recruits students from only one socio-behavioral science field: psychology. Psychology was chosen as a field of interest for the WISE program because the psychology department at the institution of interest has a particularly heavy emphasis on the neurosciences and clinical psychology. Yet, our analysis included the other fields of study within the umbrella of socio-behavioral sciences to be more consistent with national definitions of those fields. Therefore, even with the expanded availability of fields from which to graduate, WISE students were unlikely to complete degrees in socio-behavioral sciences compared to non-STEM fields. This finding was surprising and current analyses do not reveal empirical explanations. The finding does suggest that WISE women who chose to leave a STEM major were no more attracted to the socio-behavioral sciences than non-STEM fields.
Our non-finding on college GPA is somewhat surprising given that the WISE program hired a tutor for their students during the time of the sample’s enrollment in college. However, program staff perceived that the tutoring program was inappropriately utilized and ineffective, so it was cut from the WISE program around 2006 (Communication with Program Staff, 2/1/2014). Beginning in 2006, the program staff chose to focus more on professional development and community building, rather than academic skills building. Therefore, it is possible that our results do not reveal significant findings on GPA in part because WISE students did not participate in programs to improve their academic standing at a higher rate than non-WISE students.

WISE students were about 40% more likely than their non-WISE counterparts to graduate from college. The graduation variable measured students’ completion of a degree by 2012, which is between eleven and six years after matriculation (depending on the year students enrolled at the institution of interest). Also, the WISE program is designed for first-year students, with only two second-year students returning each year to serve as peer mentors. Previous research supports the finding that college engagement in general reinforces persistence and degree attainment (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008). However, research specifically on women in STEM fields and their college retention rates suggests that first year programs may not overcome negative environments that students encounter later in their college experiences (Leggon, 2006; Seymour, 1999). Framed with previous research, our finding that WISE positively predicts graduation from college suggests that some first-year programs for women in STEM are positively associated with students’ decisions to complete a college degree.

Finally, the predictor with the most consistent and largest coefficient throughout our models was high school GPA, which predicted over a half-point increase in college GPA per
point increase in high school GPA, over doubled the odds of graduating with a degree in STEM, and over tripled the odds of graduating at all. Consequently, high school GPA was an important variable. The largest effect sizes, however, were seen within the analysis on degree type, where high school GPA predicted almost a three and a half times increase in the likelihood of completing a PEMC degree and just over a four times increase in the likelihood of completing a degree in biology. Therefore, while WISE participation is an important factor in women’s degree completion and persistence in STEM fields, high school experiences appear to have a larger association.

**Implications and Conclusions**

In conclusion, we did not find statistical evidence that WISE participation supports higher GPAs ($H_1$) or graduation from STEM degree programs in general ($H_2$). However, WISE participation did increase the likelihood of women’s completion of PEMC degrees, even when comparing students with similar background characteristics to one another ($H_3$). These findings have clear implications for both research and practice. First, while our results are not generalizable because it is limited to students at a specific institution, our analyses highlight the importance of comparing program participants with like-peers. Phase one analyses, which compared the sample of WISE participants against the population of students who matriculated into STEM programs, had more significant results. However, non-WISE students had very different background characteristics that could explain these results. By narrowing the non-WISE sample down to those with similar background characteristics as WISE participants, we were able to more accurately compare the outcomes of both groups.

This study further provides a solid foundation for future research. Specifically, intersectionality between race/ethnicity and gender in conjunction with women in STEM LLC
participation has not yet been considered using the same methods as in this manuscript. In addition, due to propensity score match results, our research excluded men from the phase two analyses. Therefore, a comparison between women in STEM LLC participants and their male peers (with similar background characteristics) might yield interesting results, in particular for underrepresented minority men who face their own issues with parity in STEM (Anderson & Kim, 2006). In addition, we were not able to account for socioeconomic status in our research, so future considerations for that independent variable may illuminate other important findings. Finally, while we know that WISE participation has some quantifiable association with graduation from PEMC degree programs, we do not yet know how. We are also limited to conjecture on the non-findings for college GPA and graduation from STEM degree fields in general, as well as the negative finding for WISE participation and socio-behavioral degree attainment. Future qualitative research could provide important insights to these questions.

Additionally, this study has practical implications. Practitioners may benefit from the methodology and results presented in this manuscript. The use of propensity score matching shown in this study is replicable at other institutions and may be more effective and enlightening than graduate-tracking or satisfaction evaluations. Furthermore, the positive and significant finding for WISE’s relationship with PEMC degree completion suggests that faculty and staff should continue to invest their time and energy into similar programs at their institutions, particularly when women are still underrepresented in these fields.

Overall, this study highlights an association previously unknown: the positive relationship between participation in a single-sex STEM LLC on women’s persistence in PEMC majors. These majors have maintained a stubbornly low level of women for more than 30 years. Therefore, this study suggests that STEM LLC’s—or other postsecondary interventions—may be
a valuable piece of the answer to improving the representation of women in the physical science, engineering, mathematics, and computer science majors. We hope that this study will inspire further research and increased practice to support such programs and the students that they serve.
Appendix A: Major Classifications

1. Non-STEM majors:
   - Accounting
   - Actuarial Science
   - Advertising
   - African American Studies
   - American And Florida Studies
   - Apparel Design And Technology
   - Art History
   - Asian Studies
   - Business Administration
   - Chinese Language And Culture
   - Classical Archaeology
   - Classical Civilizations
   - Comm. Arts
   - Commercial Music
   - Communication Studies
   - Creative Writing
   - Criminology
   - Early Childhood Education
   - Elementary Ed.
   - Emotional Dis/Learning Dis
   - English Ed.
   - English/Business
   - Entrepreneur
   - Exceptional Student Education
   - Finance
   - French
   - French And Spanish
   - French/Business
   - German
   - German And Italian
   - Graphic Design
   - Greek & Latin
   - Health Education
   - History
   - Hospitality Administration

2. Other majors:
   - Human Resource Management
   - Information Studies
   - Information Technology
   - Interdisciplinary Humanities
   - Interior Design
   - International Affairs
   - Italian
   - Italian And Spanish
   - Japanese Language And Culture
   - Japanese/Business
   - Latin
   - Literature
   - Management
   - Management Information Sys
   - Marketing
   - Media Communication
   - Media Production
   - Media/Communication Studies
   - Merchandising
   - Middle Eastern Studies
   - Middle Grade Mathematics
   - Multilingual/Cultural Education
   - Multinational Business
   - Operate
   - Music - Liberal Arts
   - Music Ed.-Instrumental
   - Music Education-General
   - Philosophy
   - Physical Education
   - Political Science
   - Public Relations
   - Real Estate
   - Rec.& Leisure Serv. Admin.
   - Religion
   - Risk Management-Insurance
   - Russian
   - Russian/Business
   - Science Education
• Secondary Mathematics
• Secondary Science/Math Teach
• Social Science Education
• Social Work
• Spanish
• Spanish/Business
• Sport Management
• Sports Management
• Studio Art
• Textiles
• Theatre
• Visual Disabilities Studies
• Women’s Studies

2. PEMC Majors
• Applied And Computational Mathematics
• Biochemistry
• Biochemistry
• Biomathematics
• Biomedical Mathematics
• Chemical Engineering
• Chemical Science
• Chemical-Bioengineering
• Chemical-Biomedical Engineering
• Chemical-Environmental
• Chemical-Materials
• Chemistry
• Chemistry
• Civil Engineering
• Computational Biology
• Computer Criminology
• Computer Engineering
• Computer Science
• Computer Science
• Computer Science Ba
• Electrical Engineering
• Electrical Engineering
• Environmental Chemistry
• Environmental Eng.- Civil
• Geology
• Indust. & Manufacturing Eng.
• Industrial Engineering
• Information Technology
• Mathematics
• Mathematics
• Mechanical Engineering
• Mechanical Engineering
• Meteorology
• Physical Science
• Physics
• Physics (Bio-Premedicine)
• Physics (Biophysics)
• Physics (Computer Science)
• Physics (Geology)
• Physics (Government)
• Physics (Philosophy)
• Physics And Astronomy
• Software Engineering
• Statistics

3. Bio Majors
• Biological Sciences

4. Health Majors
• Athlete-Training/Sports Med.
• Athletic Training
• Communication Sciences & Disorders
• Dietetics
• Exercise Science
• Exercise Science
• Food & Nutrition Science
• General Human Sciences
• Human Sciences
• Neuroscience-Movement Science
• Nursing
• Nursing (Rn-Bsn)
• Rehabilitation Services

5. Socio-Behavioral Majors
• Anthropology
• Anthropology
• Applied Economics
• Child Development
• Economics
• Environmental Studies
• Environmental Science and Policy
• Family And Child Sciences
• Geography
• Housing
• Psychology
• Psychology
• Social Science
• Sociology