# AC 2011-1377: DEFINING AN EVALUATION FRAMEWORK FOR UNDERGRADUATE RESEARCH EXPERIENCES

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# Defining an Evaluation Framework for Undergraduate Research Experiences


Abstract

In an effort to improve the evaluation framework for the authors' NSF-funded S-STEM program (Scholarships in Science, Technology, Engineering, and Mathematics) that supports undergraduate research experiences (UREs) for its participating students, we analyzed quantitative and qualitative data from the 2009-10 senior exit survey for graduating students in the College of Engineering and Computer Science at a large, metropolitan, research university. The survey data offered a large sample size (n=687) of which 104 or 15% of students reported participation in a URE; non-URE students were used as a comparison group. We then compared our findings with five published studies with large sample sizes. Our survey results showed 41% of gains in "clarification or confirmation of career/education paths," and 51% of gains in the "personal/professional" domain (which includes "thinking and working like a scientist"). Female and male students showed the same level of interest in continuing on to graduate school. White and Hispanic students showed a higher level of interest in continuing on to graduate school compared to other ethnic groups (but this finding should be interpreted with caution).


## Introduction

The authors' experience with undergraduate research experience (URE) programs is that they typically involve 10-30 students per year. Student perception surveys are often used as part of URE program evaluations. Findings from this type of survey tend to be limited to characteristics specific only to that particular cohort since generalization is not possible because of small sample sizes. Researchers also run the risk of committing Type II errors (failing to detect an effect when one actually exists – one of the problems with small sample sizes). This was the dilemma we faced with our currently funded NSF S-STEM (Scholarships in Science Technology Engineering and Mathematics) program which we called YES (the Young Entrepreneur and Scholar scholarship program). The YES program offers students a choice of participation in a Research Path (apprenticeship with a faculty mentor) or Entrepreneurship Path (internship with an industry mentor). In our third year of operation, 35 students have participated in the program to date, and of those 28 are active. Twenty three (of the 28 students) are in the Research Path of the program; over the lifetime of the grant (5 years), we expect 70-80 STEM students to have participated in the Research Path. The YES program is open to eligible students from two programs: EXCEL (a NSF-funded STEP program with an optional URE component) or RAMP (a university-funded URE program). STEP stands for Science, Technology, Engineering, and Mathematics Talent Expansion Program. The YES program eligibility requirements include: a minimum overall GPA of 3.0, full-time enrollment, STEM major, US citizen or permanent resident, and financial

need. Through a competitive application process, accepted students join the YES program in their junior or senior year (those in the senior year must have at least two remaining semesters of fall/spring). YES students are on average 70% engineering and computer science majors, and the remaining 30% math and science majors. As is typical of UREs for STEM majors, institutional program outcomes center on recruitment, retention, and graduation, in particular, of under-represented populations (female, Hispanic, African-American, and First-Generation students). Student learning outcomes focus on indirect measures using student perceptions of the benefits of the URE experience.

In an effort to improve the URE evaluation framework for the YES program, we analyzed quantitative and qualitative data from the 2009-10 senior exit survey for graduating students in the College of Engineering and Computer Science at a large, metropolitan, research university. This study helped us to identify the common and unique features of UREs at our institution and to compare them with the YES program and similar studies at other institutions. The survey data offered a large sample size (n=687) of which 104 or 15% of students reported participation in a URE; non-URE students were used as a comparison group. The comparison group of non-URE students in our survey was not based on a true, experimental research design of random assignment to groups for obvious ethical and legal reasons. But it does provide a useful comparison (albeit with limitations). First, we looked for patterns in the data that would provide some insight into three hypothesized claims (see below) for our YES program. We then compared our findings with five studies, two of which are described here: a study of 76 rising seniors in eight science disciplines at four liberal arts schools by Seymour et al.[1] and a study of 1,135 students (primarily in engineering and the sciences) surveyed at 41 institutions by Lopatto[2] who had participated in a URE.

*Claim 1. The URE is one pathway by which students explore their sense of "becoming" i.e., establishing a career identity which is often inextricably bound up with personal identity*[3]**.** Forty three percent of our URE students expressed interest in continuing on to graduate school compared with 17% of non-URE students. In our survey, we found 41% of gains in "clarification or confirmation of career/education paths" compared with 20% of gains reported in the Seymour et al. study. We believe that the difference is probably attributable to the timing of the studies – we surveyed graduating seniors whereas Seymour interviewed rising seniors.

*Claim 2. The URE is a transformational experience*[4]**.** Fifty one percent of gains in the personal/professional domain (which includes "thinking and working like a scientist") were found in both our study and the Seymour[1] study.

*Claim 3. The URE is an attractive proposition to recruit and retain under-represented groups*[2,5,6]**.** In our survey data, male and female students showed the same level of interest in continuing on to graduate school as did Lopatto[2,5]. In our data, there were mixed results when looking at groups by ethnicity due to limitations in the data. The rule of thumb for large sample sizes in Chi Square tests is that no more than 20% of expected counts should have values less

than 5, and all expected count values should be greater than 1[6]. The Chi Square test for our data violated this assumption by having 25% (3 cells) with expected counts of less than 5 (compared with the 20% allowed as a rule of thumb); however, the minimum expected count was 1.28 (within the accepted values of greater than 1). At critical t values of ± 1.96 at a significance level of $p < .05$, the standardized residuals for the Chi Square test of independence showed that White, Hispanic, and African American students who had participated in UREs were more likely to chose graduate school over employment (but it was statistically significant for White students only) than non-URE students. The standardized residual for Hispanic students (1.6) was much closer to the critical t value of 1.96 for statistical significance at the $p<.05$ level than for African American students (0.6). One interpretation is that White and Hispanic students showed higher levels of interest in continuing on to graduate school (but this finding should be interpreted with caution due to the Chi Square violation described above) whereas Lopatto[2,5] found no differences among ethnic groups. This finding may be unique to our institution.

With our next data collection of the senior exit survey, we can rerun this test with both sets of data (2009-10 and 2010-11 years), thereby doubling our sample size (about 1,400 expected survey participants), which should take care of the problem of insufficient sample sizes in some cells when the data are dissected by students' ethnic grouping. Based on this preliminary finding, we can then test our hypothesis that Hispanic students who participate in UREs at our institution are more likely to choose graduate school in statistically significant numbers than African American students. It is important to us to examine this further because representation of Hispanic students in our undergraduate population of engineering students is double that of national figures (see below in the Background section for the statistics). We also need to focus our efforts on understanding why graduate school is not equally attractive to African American students.

In this study, we constructed our YES program URE evaluation framework by 1) looking for patterns in our program data that would provide some insight into our three hypothesized claims; 2) comparing the data with institutional survey data with larger sample sizes; 3) validating the data with published studies with large sample sizes; 4) refining existing assessment instruments based on the results of this study; and 5) identifying other areas of interest for future research. The paper is organized into five sections. The Background section describes demographic statistics on students so that readers may determine if our findings are likely to apply to their institutions. The Methodology section provides details on the research design of the study. The Results section presents the findings of the study. The Discussion section identifies other areas of interest for future research. The Conclusion section summarizes highlights of the study.

Background

In this section, we provide some general statistics about students at our university, the College of Engineering and Computer Science (CECS), and the YES program. Readers may find this information useful to determine if the results of our study are likely to apply to their institution. Our university is a public, metropolitan university (the second largest in the nation in terms of total student enrollment, n = 56,235). Undergraduate enrollment (by percentages of the total in each group) is displayed by gender in Figure 1. At the University level, 54% (25,876/47,580) of undergraduates are female; CECS 14% (805/5,834) are female; and YES 43% (12/28) are female (all STEM majors). At the national level 18% of female undergraduate students are enrolled in engineering and computer science disciplines[7] (in comparison, 14% female students in CECS shows that we need to improve our recruitment of women). The YES program still attracts higher percentages of women (when subtracting out non-CECS majors, n=9) 32% (6/19) of YES CECS majors.

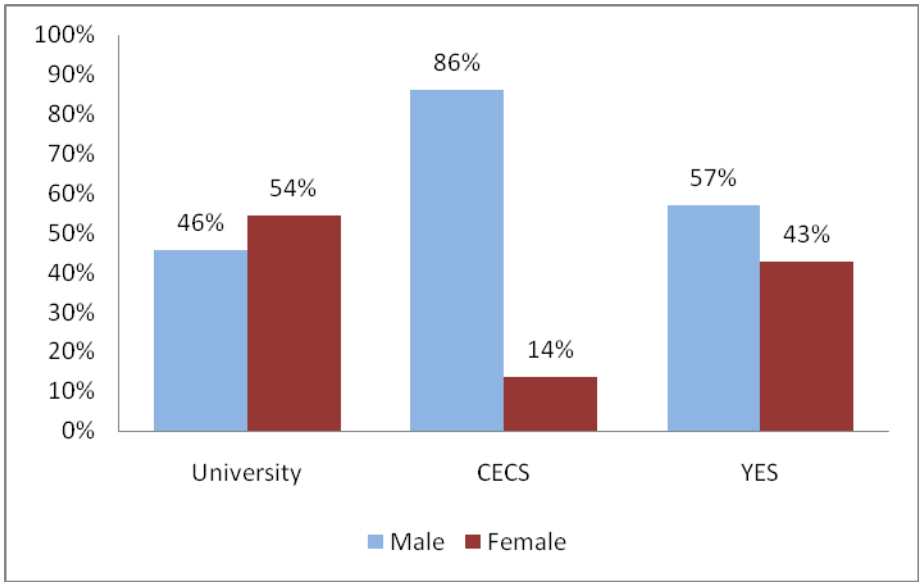


Figure 1. Fall 2010 Undergraduate Enrollment by Gender

Undergraduate enrollment is shown in Table 1 by ethnicity. The ethnicity numbers reported in Table 1 for YES students do not yet reflect recent national changes to reporting ethnicity and race. YES student cohorts are recruited in the spring and summer of each year for the fall semester. At the University level, 17% (8,070) of undergraduates are Hispanic and 9.6% (4,573) are African American; CECS 18% (1,041) are Hispanic and 7.5% (438) are African American; YES 21% (6) are Hispanic and 10.7% (3) are African American (all STEM majors). At the national level, 9% of engineering undergraduates are Hispanic and 5% are African American[7]. Representation of Hispanic undergraduate students in CECS is double the national figure (18% compared with 9%), and the YES program is higher at 21%.

Overall, the student demographics for our YES program exceed national, university, and CECS averages. But is this unique to our YES program? The sample size is too small to generalize even to our institution. For the reader who wonders if a disproportionate number of under-represented students are recruited into the YES program, Table 2 shows that most of the demographic groups are about equally represented in the numbers who applied and the numbers who were admitted/enrolled. We discuss why YES students apply to the program in the Results section.

Table 1. Fall 2010 Undergraduate Enrollment by Ethnicity

| Group | Hispanic | Afr. Am. | Asian | White | Other* |
|---|---|---|---|---|---|
| University | 8,070 | 4,573 | 2,642 | 30,360 | 1,935 |
| CECS | 1,041 | 438 | 423 | 3,691 | 241 |
| YES** | 6 | 3 | 2 | 17 | 0 |

*Other= Multiracial, Native Hawaiian, International, Unknown
** 43% (12/28) of YES students are First-Generation college students (similar data were not available for CECS nor the University)

Table 2. Application Statistics for the YES Program (all STEM Majors) Since Inception

| Admission | F | M | H | A | B | W | O | 1st Gen. |
|---|---|---|---|---|---|---|---|---|
| Applied n=53 | 21 | 32 | 12 | 3 | 5 | 28 | 5 | 20 |
| %Applied | 40% | 60% | 23% | 6% | 9% | 53% | 9% | 38% |
| Admitted/ Enrolled n = 35 | 15 | 20 | 11 | 3 | 4 | 17 | 0 | 17 |
| %Admitted/ Enrolled | 43% | 57% | 31% | 9% | 11% | 49% | 0% | 49% |

Key F=Female, M=Male, H= Hispanic, A=Asian, B=African American, W=White, O=Other, 1st Gen. = First Generation College Student

## Methodology

In this section, we describe our proposed URE evaluation framework, the research design of the study, and the assessment instruments used. Figure 2 shows the proposed URE evaluation framework. We, perhaps like many URE PIs (program investigators) and program directors, tend to work within the picture (individual URE programs) but not within the combination of the inner frame (URE participation at the institutional level) and outer frame (comparison of results

with reliable, published studies). The middle frame with the dotted line border (Multi-Institutions) is for PIs and program directors who have the resources (more likely than not through a funded proposal) to conduct URE evaluation with partnership institutions that agree to share data from a common URE study. For most URE PIs and program directors, multi-institutional data collection is not feasible without funding. This is the reason why searching for multi-institutional published research on UREs as part of our review of the literature was so important to us. The arrow in the diagram (Figure 2) is an acknowledgment that URE programs are developed based on prior experience of the PI or program director and prior research based on a review of literature. The arrow serves as a reminder to return to the review of literature conducted for the proposal to fund the program and to expand the search for new studies published in the area upon which to support (or refute) our hypotheses . This proposed URE framework (Figure 2) helped us to identify the common and unique features of UREs at our institution in comparison with similar studies at other institutions.

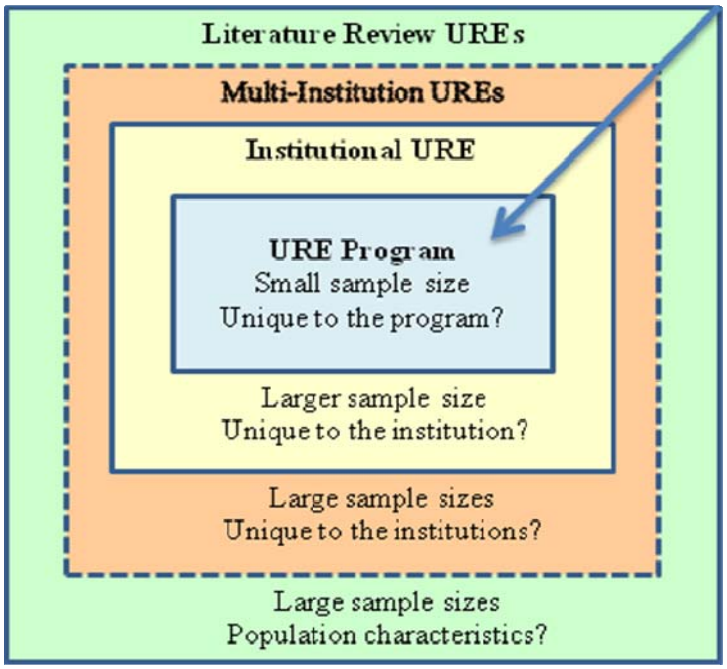


Figure 2. URE Evaluation Framework

The first part of the study begins with the picture in the URE evaluation framework – our URE program (Research Pathway) of our YES program. The assessment instruments used to evaluate our three hypothesized claims of the program (see below) were: pre- and post-tests, a student focus group, data extracted from student applications, and to a lesser extent, comments by faculty mentors and/or graduate student mentors on student progress reports.

*Claim 1. The URE is one pathway by which students explore their sense of "becoming" i.e., establishing a career identity which is often inextricably bound up with personal identity*[3].

*Claim 2. The URE is a transformational experience*[4].

*Claim 3. The URE is an attractive proposition to recruit and retain under-represented groups*[2,5,6].

Assessment Instruments

*Pre- and Post-Tests.* Students are given an Institutional Review Board (IRB)-approved explanation for exempt research informing them that participation in the pre- and post-tests are voluntary. Completion or not of the pre- and post-tests and ratings by mentors on the student answers are irrelevant to a student's continuation in the program or official academic progress. The pre-test contains four common questions which measure (but not in great depth) the learning growth of students, and the faculty mentor has the option of adding three questions. The post-test contains the same questions as the pre-test. The pre-test is given to students to complete two weeks (some later) after they have been assigned their research project by the mentor (some students have prior research experience and others require longer training periods) during the fall semester. The post-test contains the same questions as the pre-test and is given every 30 weeks (at the end of the spring semester) or upon exit from the program. The pre- and post-tests contain both qualitative and quantitative data. Students answer the questions, and the mentor scores the answers based on a rubric of 0 to 4 where 0 represents the lowest end of the scale and 4 the highest. For this study, we focused on student responses for question 4 (career-related question) in the pre- and post-tests as the other questions are specific to the students' assigned research project. Table 3 shows the pre-/post-test questions and the scoring rubric.

*Student Focus Group.* The student focus group was conducted during the Spring 2010 semester by two staff from the university assessment office. Students were given an IRB-approved explanation of exempt research informing them that participation in the focus group was voluntary. Nine YES students (5 males, 4 females) were present and participated in the meeting, which lasted 80 minutes. Questions asked in the focus group centered around five themes (see Table 4) and overall experience in the program. Examples of questions asked by the interviewer and probe questions are included.

*Student Applications.* On the student application, we analyzed student responses (qualitative data) to the question: What made you decide to apply to the YES program? We also looked at students' written statement of purpose that was submitted with each application.

Table 3. Pre- and Post-Test Questions and Scoring Rubric

1. In your own words, describe the research problem or project you will be working on in your YES Undergraduate Research.

   Student Answer:
   Mentor rubric score:
   Explanation of score:

2. Explain the use of tools and technology in your research project.

3. What is the relevance of this research problem to the current body of knowledge in this discipline? How will work on this research problem contribute to knowledge in the area?

4. In what way(s) will this experience affect your knowledge or future career?

5-7. Specific questions by mentor (optional).

Scoring Rubric Key

4 = The student's response demonstrates a clear depth of knowledge about this research area, and it shows the ability to apply this knowledge in a creative way.
3 = The student clearly understands the research and the use of tools as applied to the research.
2 = The student understands functional skills (e.g., use of equipment) without an understanding of the application of the skills to the research.
1 = The student responded to the question by repeating information in the question or description.
0 = There is not enough information to make a judgment.

Table 4. Student Focus Group Protocol – Sample Questions

- Forming friendships with Other YES Students
  Question: Tell me about forming friendships with other YES students.
  Probe: How does being part of YES influence your relationships?

- Learning in Undergraduate Research and Entrepreneurial Experience
  Question: What was your role in the project?
  Probe: Did you design the project? Or provide input into the design?
  Probe: Did your role on the project change? How?

- Relationship with Faculty and Business Mentors
  Question: What was your relationship with your faculty or business mentor?
  Probe: How often did you meet and how was it structured?
  How meet – One-on-one, team?

Table 4. Student Focus Group Protocol *(continued)*

- Expectations of Faculty or Business Mentors
  Question: What were your faculty or business mentor's expectations?

- Social Events
  Question: Tell me about what organized social events there were for YES students this year.
  Probe: What would you change about the experience?

- Overall Experience
  Question: What has been the best part about your YES experience?

*Progress Reports.* YES students and mentors are required to complete a progress report twice per semester rating each other so that the YES program staff can periodically monitor satisfaction with their experience. Scoring is based on a rating scale of Below Satisfactory to Above Satisfactory and Not Relevant, and open comments are optional. The analysis used for this study was observations by faculty mentors in the open comment section of the progress report.

*Senior Exit Survey.* The second part of the study works outwards from the picture (the URE program) to the inner frame, Institutional URE experience, of the URE evaluation framework (Figure 2). We analyzed college-level (CECS) data of selected questions from the 2009-10 institutional senior exit survey that is administered to graduating seniors. The data collection for this survey is managed by the university's assessment office. Until two years ago, the exit surveys were collected anonymously in paper form. In CECS, the exit surveys were included as part of the student's graduating package when the student filed their intent-to-graduate forms. The completed surveys were separated out from the student intent-to-graduate forms by the front desk staff in the CECS Academic Affairs Office and sent to the university assessment office for processing. More recently, the intent-to-graduate forms and exit surveys were migrated online to the student portals. The 2009-10 senior exit survey contains 33 questions that are common to all programs across campus. In addition to the common program question survey, each program had the option of creating a program-specific survey previously limited to 20 questions and 2 open comment questions in the paper form, but the online format allows more flexibility in the number and types of program-specific questions. The online exit survey data collection follows confidential survey procedures. The university assessment office collects personal identification numbers assigned to each student by the university to be able to match student records in their database, but these identifiers are not included in the datasets to campus personnel requesting data for analysis. The migration from anonymous to confidential data collection should not create a bias in student responses. Completion of the survey is optional and is irrelevant to a

student's graduation status. Moreover, sensitive questions are not asked. A research study by van de Looij-Jansen, Goldschmeding, and Jan de Wilde[8] comparing anonymous versus confidential survey procedures of the effects on health indicators (perceived health, alcohol use, aggressive behavior) in Dutch adolescents found that for most health indicators no significant differences were found. The researchers also cited other studies (substance abuse, striking a teacher) that reached similar conclusions in the type of survey procedure used (anonymous versus confidential), but noted in other studies that when there was a higher degree of sensitivity to the questions (cheating during exams, stealing), differences were found.

For our study, we analyzed quantitative data collected from two questions related to career/advanced studies intentions (near and future) after graduation and other questions related to student demographics from the common program questions of the 2009-10 senior exit survey. The migration to the online format of the exit surveys allowed us to easily add three additional questions (questions 1, 3, and 4 on the YES pre- and post-tests for consistency; see Table 3 above) on the URE experience to the program-specific surveys. For these three questions, qualitative data were collected, but for this study, we focused on the question relating to personal or career benefits. Tables 5 and 6 show the questions used from the common and program-specific questions of the 2009-10 senior exit survey respectively.

Table 5. 2009-10 Senior Exit Survey Questions Used in the Study

| Common Program Questions | Responses |
|---|---|
| Q. 21 What is most likely to be your principal activity upon graduation? *(implicit "now" intention)* | 1. Employment, full-time paid<br>2. Employment, part-time paid<br>3. Graduate or professional school, full-time<br>4. Graduate or professional school, part-time<br>5. Additional undergraduate coursework<br>6. Military service<br>7. Volunteer activity (e.g., Peace Corps)<br>8. Starting or raising a family<br>9. Other |
| Q22. If you intend to engage in further formal study, what is the highest degree you eventually expect to obtain? *(implicit future intention)* | 1. No further study intended<br>2. Second Bachelors Degree<br>3. Certificate or Professional License<br>4. Masters Degree<br>5. Specialist degree (J.D., Ed.S., etc.)<br>6. Medical degree (M.D., D.D.S., etc.)<br>7. Doctorate (Ph.D., Ed.D., etc.)<br>8. Other |

Table 5. 2009-10 Senior Exit Survey Questions *(continued)*

| Common Program Questions | Responses |
|---|---|
| *Grouping & Demographic Data* | |
| Q2. What is your major? | Choices available by college & program |
| Q25. What is your overall grade point average? | 1. 2.00-2.49<br>2. 2.50-2.99<br>3. 3.00-3.49<br>4. 3.50-4.00<br>5. Don't know |
| Q28. What is your gender? | 1. Male<br>2. Female |
| Q30. Please indicate which of the following racial or ethnic group(s) apply to you: (select all that apply) | 1. White<br>2. Hispanic or Latino<br>3. Black or African-American<br>4. Asian<br>5. Native Hawaiian or Other Pacific Islander<br>6. Native American or Alaskan Native<br>7. Other<br>8. Multi-Racial |

Table 6. 2009-10 Program-Specific Exit Survey Questions Used in Study

| |
|---|
| 1. Briefly describe the research project(s) that you worked on in your collaboration with faculty. |
| 2. What is the relevance of this research project to the current body of knowledge in this discipline? |
| 3. In what way(s) will this research experience affect your knowledge or future career? |

*Literature Review.* The third (and final) part of the study uses the outward frame, Literature Review, to verify our findings with reliable, published studies with large sample sizes (Figure 2). We used five journal articles that examined different aspects of the benefits of UREs as comparison data. Four of the articles were all related studies stemming from the initial three-

year study on the benefits of undergraduate research experiences by Seymour et al.[1]. At the end of the Seymour[1] article, the authors describe that this study was the result of series of discussions between Elaine Seymour, David Lopatto, and a group of undergraduate research program directors at an NSF-AIRE (Award for the Integration of Research and Education) meeting. Elaine Seymour is the Director Emerita of Ethnography and Evaluation Research, University of Boulder, Colorado, and co-author of the book, "Talking about leaving: Why undergraduates leave the sciences," which is widely cited (cited 936 times according to Google scholar as of January 2011) for its contribution to improving undergraduate education in the sciences. Two articles are by David Lopatto[2,5], Professor of Psychology, Grinnell College, who builds on Seymour et al.'s[1] study by examining the hypothesis that UREs provide enhanced educational experiences, attract and retain talented students, and act as a pathway for under-represented students in the sciences. The fourth related article is written by Hunter et al.[4] which examines a different aspect of the initial Seymour et al.[1] study. In this study, the researchers examine the role of UREs in students' cognitive, personal, and professional development in becoming a scientist. The fifth article is unrelated to these four articles; in this study, Russell, Hancock, and McCullough[9] also examine the benefits of UREs using large sample sizes. Table 7 provides a brief summary of each journal article, the sample sizes used, sample populations observed, type of data collected, and the data analysis method. We also include our senior exit survey study as a comparison.

Table 7. Referenced Journal Articles on the Benefits of UREs

| Author(s) | Sample Size | URE Sample Population | Data Collected | Data Analysis |
|---|---|---|---|---|
| Seymour et al.[1] | 76 | (mostly) Rising seniors in 8 science disciplines at 4 liberal arts schools | Qualitative – Interviews | Ethnography |
| Lopatto[2] | 1,135 | Undergraduates (mostly juniors and seniors) in primarily engineering and the sciences at 19 research universities, 15 colleges, 7 master's level institutions | Quantitative – Web survey | Means<br>Spearman correlation<br>Mann-Whitney U<br>Chi Square |

Table 7. Referenced Journal Articles on the Benefits of UREs *(continued)*

| Author(s) | Sample Size | URE Sample Population | Data Collected | Data Analysis |
|---|---|---|---|---|
| Lopatto[5] | 2,021 | Undergraduates (mostly juniors and seniors) at 28 universities, 27 colleges, and 11 master's level institutions | Quantitative – Web Survey | Cronbach α<br>Ecological correlation<br>MANOVA<br>Means<br>Multiple regression |
| Hunter et al.[4] | 76 | (mostly) Rising seniors in 8 science disciplines at 4 liberal arts schools | Qualitative – Interviews | Ethnography |
| | 80 | Faculty and administrators | | |
| Russell et al.[9] | 3,400 | STEM graduates with BS degrees | Quantitative – Web survey | Percentages |
| Massi et al. (our study) | 104 | Graduating seniors in engineering & computer science at a public university | Quantitative & Qualitative – Web survey | Chi Square<br>Ethnography |

Results

Data analysis primarily involved Chi Square tests of independence for quantitative data[6] using SPSS 10.0.7 and ethnographic guidelines for qualitative data[10]. The results are organized under the three hypothesized claims of this study and the proposed URE framework (Figure 2). The YES program results represent the "picture" of the URE framework (sample size ranges n = 9-35); institutional data, the "institutional" frame (sample size ranges n = 557-687); and published articles (Table 7), the "Literature Review" frame (sample size ranges n = 76-3,400).

*Claim 1. The URE is one pathway by which students explore their sense of "becoming" i.e., establishing a career identity which is often inextricably bound up with personal identity*[3].

YES Program

*Pre- and Post-Test Participants.* Thirty-five YES students (Research and Entrepreneurship Paths) were asked to participate in the pre- and post-tests (see Table 3). Nine pre-tests were not

turned in because students either decided not to participate or their training took most of the fall semester. Twenty-six students completed pre-tests, of which 16 were new students who started in fall 2010, and their post-tests are not due until the end of spring 2011. There were nine complete sets of pre- and post-tests (six students were in the Research Path and three in the Entrepreneurship Path). In our sample, we found that two of the Entrepreneurship students had intentions of continuing on to graduate school pre-YES, and one who had not stated prior intentions of graduate school was considering it because of YES. While our small sample of YES Entrepreneurship students were motivated to continue on to graduate school, for future research, we plan on examining a new hypothesis using our senior exit survey data (which offer larger sample sizes) that co-op and internship experiences are as likely to lead to students' choice of graduate school as those who participate in undergraduate research experiences.

*Career Intentions.* We looked at question 4 related to career aspirations "In what way(s) will this experience affect your knowledge or future career?" Students gave qualitative answers to this question, and the mentors rated the question on a 5-point scale where 4 was the highest score and 0 the lowest (Table 3) and gave a qualitative answer explaining their rating score. We did not run a repeated measures t-test because the sample size was so small. We did however calculate the means which were high as expected: the pre-test mean was 3.06, and post-test mean was 3.33 (the minimum score was 2, and the maximum score was 4 for both the pre- and post-tests). The open responses of the pre- and post-tests in addition to the career goals stated on students' applications were more valuable in that they provided a glimpse into students' thought processes in establishing a career identity. Due to the small sample size, identification by gender and ethnicity of YES students is not provided to maintain anonymity.

Example 1. Confirmation of graduate school choice.
*The knowledge that I have gained…with the experience of researching will enable me to have something to continue to improve and expand my knowledge in this area in graduate school. Not only will it help in the future but it is helping now by giving me something in the scope of my major that I have found I am interested in.* (This student was in the YES Research Path, graduated, and continued on to graduate school in the discipline.)

Example 2. Consideration of graduate school because of this experience.
*…I also am considering grad school because of this experience and hopefully [I will] continue in this area of research…* (This student is still active in the YES program but has subsequently switched from the Research Path to the Entrepreneurship Path to gain work experience.)

CECS Senior Exit Survey

*Quantitative Data.* Survey data were collected online from seniors who submitted intent to graduate forms in summer 2009, fall 2009, and spring 2010 (see Tables 5 and 6 in the Methodology section above). Quantitative data were collected for "Q21. What is most likely to

be your principal activity upon graduation?" (implicit "now" intention), and the nine response choices were recoded where employment = 1, graduate/professional school = 2, and other choices = 3. To avoid Type II errors in Chi Square tests, Cohen[11] recommends that at $\alpha = .05$ and power of .80, 783 participants are needed for a small effect size ( $r = .10$), 85 participants for a medium effect size ($r = .30$), and 28 participants for a large effect size ($r = .50$). Based on our exit survey sample size, we should be capable of at least detecting medium and large effects. The response rate for this question was 97% (687/708) of survey respondents (743 seniors graduated within this period). Of the 687 respondents, 104 or 15% of students reported participation in a URE; non-URE students were used as a comparison group.

*Career Intentions.* The Chi Square test of independence was used to test if there was a statistically significant difference in intentions to continue on to graduate school between the two groups: URE students compared with non-URE students. There was a statistically significant difference between the two groups, $\chi^2(2) = 37.245$, $p<.001$. Examination of percentages in the output (see Table 8) can be misleading to determine which cell(s) contributed to the statistical differences; examination of the standardized residuals is more reliable when compared to a critical value equivalent to an $\alpha$ value. At critical t values of $\pm 1.96$ at a significance level of $p<.05$, the standardized residuals showed that for URE students (Table 8) fewer students than expected chose employment and more students chose graduate/professional school at statistically significant numbers. For the comparison group of non-URE students, more students (but not a statistically significant number) than expected chose employment, and statistically significant fewer students chose graduate/ professional school. A URE student was 3.39 times more likely to choose graduate school over employment than a non-URE student based on the odds ratio calculations shown below.

$$\text{Odds}_{\text{choosing grad school with research experience}} = \frac{\text{no. that had research experience and chose grad school}}{\text{no. that had research experience and chose employment}} = \frac{45}{58} = 0.78$$

$$\text{Odds}_{\text{choosing grad school without research experience}} = \frac{\text{no. without research experience and chose grad school}}{\text{no. without research experience and chose employment}} = \frac{102}{442} = 0.23$$

$$\text{Odds ratio} = \frac{\text{odds}_{\text{choosing grad school with research experience}}}{\text{odds}_{\text{choosing grad school without research experience}}} = \frac{0.78}{0.23} = 3.39$$

Table 8. Q21. Employment or Graduate School Intentions after Graduation

| Group | Statistics | After Graduation Intention | | | Total |
|---|---|---|---|---|---|
| | | Employment | Graduate School | Other* | |
| URE | Count | 58 | 45 | 1 | 104 |
| | Expected Count | 75.7 | 22.3 | 6.1 | 104 |
| | % of URE | 55.8% | 43.3% | 1.0% | 100% |
| | % of Total | 8.4% | 6.6% | 0.1% | 15.1% |
| | Std. Residual | -2.0 | 4.8 | -2.1 | |
| Non-URE | Count | 442 | 102 | 39 | 583 |
| | Expected Count | 424.3 | 124.7 | 33.9 | 583 |
| | % of non-URE | 75.8% | 17.5% | 6.7% | 100.0% |
| | % of Total | 64.3% | 14.8% | 5.7% | 84.9% |
| | Std. Residual | 0.9 | -2.0 | 0.9 | |
| Total | Count | 500 | 147 | 40 | 687 |
| | % of Total | 72.8% | 21.4% | 5.8% | 100% |

*Other = Additional undergraduate coursework, military service, volunteer activity (e.g, Peace Corps), starting or raising a family, other

*Qualitative Data.* The qualitative part of the senior exit survey focused on the responses to question 3 in Table 6, "In what way(s) will this research experience affect your knowledge or future career?" (Questions 1 and 2 in Table 6 are specific to each student's research project, and these responses are shared with the departments but not analyzed as part of this study.) We found that a small percentage (about 6%) of students had described a senior design project as a URE experience. We coded these students as part of the comparison group (non-URE). In the next survey cycle, we will add a statement to survey respondents to exclude descriptions of senior design as a research experience. Over 86% (90/104) of students with URE experience responded to this question. Data were analyzed using ethnographic guidelines of recognizing patterns in the data (frequency counts of like items describing the same theme) and categorizing the data into themes[10]. The findings were then validated with reliable studies with large sample sizes (see Table 7 above).

*Career Intentions.* Forty three percent of our URE students expressed interest in continuing on to graduate school compared with 17% of non-URE students (Table 8). In our survey, we found 41% of gains in "clarification or confirmation of career/education paths" compared with 20% of gains reported in the Seymour et al.[1] study. We believe that the difference is probably attributable to the timing of the studies - we surveyed graduating seniors whereas Seymour et al.[1] interviewed rising seniors. Lopatto[2] found that a high percentage (close to 91%) of his survey respondents reported sustained or increased interest in continuing on to graduate school, which was again validated in his follow up study[5]. We did not include a question on the senior exit

survey to determine if students had graduate school intentions before their research experience, but we will add this question in our next survey collection cycle. The following examples are student quotations on this topic from the senior exit survey results and from the Seymour et al.[1] study.

Example. Confirmation or consideration of graduate school choice because of this experience.

Senior Exit Survey:
*This research, especially that related to desalination, has given me focus in the topics that I want to pursue and make a career out of. In addition, this research experience has inspired me to continue my education and go to graduate school.* (Female engineering major)

Seymour et al.[1]:
*Up until this year I had always been dead set on grad school, no question…..I guess about part way through the year I was sort of wondering whether I really wanted to continue on in grad school….But I really do think – after getting back into research – that I really want to go on in grad school.* (Male chemistry major) (p. 524)

*Claim 2. The URE is a transformational experience[4].*

Senior Exit Survey

*Validation with the Literature.* This hypothesis (Claim 2) is supported by qualitative data from question 3 in Table 6, "In what way(s) will this research experience affect your knowledge or future career?" and validated with the Hunter et al.[4] and Seymour et al.[1] studies (see Table 7 above) in reference to gains that contributed to students "becoming a scientist." Fifty one percent of gains in the personal/professional domain (which includes "thinking and working like a scientist" and "increased confidence") were found in both our (senior exit survey) study and the Seymour et al.[1] study. Hunter et al.[4] found that 57% of students attributed "gains in confidence" to their "feeling like a scientist." We found 3% of reported gains were negative/mixed in our exit survey compared with 8% in the Seymour et al.[1] study.

*Examples.* The following examples are student quotations from the senior exit survey and from the Seymour et al.[1] study, and students in the Hunter et al.[4] study. Our senior exit survey combines both qualitative and quantitative data. Quantitative data allow large amounts of data collection that can be easily analyzed, and qualitative data can provide some answers to the "why" of the data trends revealed in the quantitative data but are time consuming to analyze. Our senior exit survey examples below are not as in-depth as the examples from student interviews in the studies of Seymour et al.[1] and Hunter et al.[4].

Example 1. "Thinking and working like a scientist"

Senior exit survey:
*It provided me with a multitude of knowledge and practical experience in the field of RF and microwave communication. The work taught be [me] valuable experience working independently, thinking scientifically and developed my problem solving skills.* (Female engineering major)

Seymour et al.[1]:
*It really does help you learn to detect your own dumb mistakes. Like, it's easy to think about something conceptually a little bit wrong, and go with that for about a week. But then you look at what you've got, and your spectra don't make any sense….Then you realize what the problem is. You learn to recognize things like that quicker the more you do it.* (Male physics major) (p. 513)

Example 2. "Becoming a scientist"

Senior exit survey:
*I have learned how to set up, conduct, and present realistic engineering data to a large and well known company (…) knowing that my research data will be used to improve their designs on gas turbine engines being used for aero-propulsion and power generation. This research has provided me a glimpse into my future as an engineer.* (Male engineering student)

Hunter et al.[4]:
*Just being able to sit down and concentrate on one thing and figure it out and understand…. And so just for me to look at that and really, really understand it rather than just getting the big overview. And then, actually thinking about the problem critically and creatively and being, "Okay, Now what can I change to have this effect and to have this outcome?" That's a whole new experience for me.* (Gender and major of student not identified in the study) (p. 50)

YES Program

The YES student focus group (see Table 4 for the questions asked) summarized responses to learning experiences revealed that some students worked on projects on their own with supervision, but the majority worked in groups with other undergraduates and/or graduate students. These questions will be refined for the next student focus group to probe more deeply into the degree to which students "see themselves as becoming scientists," "make independent decisions," and "create new ideas or directions for the research." In the YES progress reports completed by mentors (see description in the Methodology section above), examples of positive comments were: the unexpected resourcefulness and initiative shown by the student; the amazing maturity of the student of what it means to design and carry out a research project; and

the dramatic increase in the student's confidence level. (Writing comments are optional for the mentors.)

*Claim 3. The URE is an attractive proposition to recruit and retain under-represented groups*[2,5,6].

YES Program

*Studies on Under-represented Groups.* As we mentioned above in the Introduction section, the YES program is open to eligible students from two programs: EXCEL (a NSF-funded STEP program with an optional URE component) or RAMP (a university-funded URE program). Studies have shown that several factors under our control may affect a student's decision to enroll and persist in a STEM major. Financial aid is one critical factor for under-represented minorities that affects the decision to pursue a college degree and persist to degree attainment[12,13,14,15,16,17,18,19]. Moreover, African American students are more likely to make a decision in their college choice and persistence decisions based on finances compared with White students[16]. Hispanic students are more likely to persist based on good grades and their integration into college (achieved in this study by opportunities to interact more closely with faculty and peers) and receiving some form of financial aid (work-study awards showed the most positive gains; loans negatively affected persistence)[20]. African American and Hispanic engineering students enjoy working in groups more than other ethnic groups[21], and women enjoy teamwork[22]. Female students tend to have higher grade achievement and persist at higher rates than male students when they used academic support services and received scholarships[23]. Researchers generally agree that female engineering students tend to have lower confidence in their math and science capabilities than their male counterparts, and a confident attitude leads to increases in achievement[25, 26, 27, 28, 29, 30]. These influences that can positively impact under-represented groups (confidence-building activities, team/group activities, financial support, interaction with faculty and peers, mandatory advising) are all components of the YES program. In terms of matching mentors and students, Russell et al.[6] found no difference in PhD intentions for undergraduate students who were paired with like mentors by gender or ethnicity compared with those who were not. In our YES program, students are paired with mentors solely according to the area of research interest of the student.

*Reasons for Applying to the YES Program.* In the Background section above, we described the student demographics of enrolled students in the College of Engineering & Computer Science (CECS) and the YES program, and compared them with national trends published by the American Society of Engineering Education (ASEE). Within CECS, there were higher representations (percentage-wise) of Hispanic and African American students compared with national trends[7]. Within YES, there were higher representations of female and Hispanic students compared with CECS and national trends[7]. The list that follows summarizes the reasons that YES students gave as their reason to applying to the YES program: extension of a childhood dream; hands-on experience; first in family to go to college; continue research experience with a

particular mentor, or special area, or narrow down area of interest; financial support; participation in a community with others who share the same goals; expectation of increased knowledge; growth as a person; and wasted a lot of time and money trying to decide on a major but once the decision made wanted more experience. As suggested by several studies cited above, financial aid and participation in a learning community of like-minded people are some of the factors that attract under-represented groups to enroll and persist in a STEM major. In particular, the YES program offers $5,000 scholarships to juniors or seniors for two semesters (fall/spring); the EXCEL program $2,400 (spring/summer), and RAMP $2,800 (fall/spring). We believe that the size of the financial support offered by UREs seems to be a strong factor in attracting higher percentages of under-represented groups to the YES program (also the fact that it does not have to be paid back like a loan). This is a further area of interest for us to research.

Senior Exit Survey

*Differences by Gender.* Analysis of our senior exit survey data using a Chi Square test of independence to determine if there were differences by gender in graduate school intention for URE students, revealed that female and male students were both likely to have more interest graduate/professional school intentions than employment. Lopatto[2,5] also found that male and female students with research experience showed the same level of interest in continuing on to graduate school. At critical t values of ± 1.96 and a significance level of $p<.05$, the standardized residuals showed that for URE students (Table 9) statistically significant more male and female students than expected chose graduate/professional school. For the comparison group of non-URE students, fewer male and female students (but not statistically significant numbers) chose graduate/ professional school. Male students with research experience were 3.2 times more likely to choose graduate school over employment and female students somewhat higher at 4.2 times. These analyses were performed on 647 student responses because the "Other" category as a choice of activity after graduation was dropped from the analysis to avoid having cells with expected counts of less than five (a general violation of the Chi Square test). (If the "Other" category were also removed from the analysis in Table 8 above, the patterns in the results remained the same.)

Table 9. Q21. Employment or Graduate School Intentions by Gender

| Group | Gender | Statistics | After Graduation Intention | | Total |
|---|---|---|---|---|---|
| | | | Employment | Graduate or professional School | |
| URE | Male | Count | 44 | 34 | 78 |
| | | Expected Count | 60.3 | 17.7 | 78 |
| | | % of URE male | 56.4% | 43.6% | 100% |
| | | % of Total | 6.8% | 5.3% | 12.1% |
| | | Std Residual | -2.1 | 3.9 | |
| | Female | Count | 14 | 11 | 25 |
| | | Expected Count | 19.3 | 5.7 | 25 |
| | | % of URE female | 56.0% | 44.0% | 100% |
| | | % of Total | 2.2% | 1.7% | 3.9% |
| | | Std Residual | -1.2 | 2.2 | |
| Non-URE | Male | Count | 380 | 90 | 470 |
| | | Expected Count | 363.2 | 106.8 | 470 |
| | | % of non-URE male | 80.9% | 19.1% | 100% |
| | | % of Total | 58.7% | 13.9% | 72.6% |
| | | Std Residual | 0.9 | -1.6 | |
| | Female | Count | 62 | 12 | 74 |
| | | Expected Count | 57.2 | 16.8 | 74 |
| | | % of non-URE female | 83.8% | 16.2% | 100% |
| | | % of Total | 9.6% | 1.9% | 11.4% |
| | | Std Residual | 0.6 | -1.2 | |
| Total | | Count | 500 | 147 | 647 |
| | | % of Total | 77.3% | 22.7% | 100% |

*Differences by Ethnicity.* Analysis of our senior exit survey data using a Chi Square test of independence to determine if there were differences by ethnicity in choice of employment or graduate school for those with research experience should be interpreted with caution. Even with removal of categories that had small numbers and were not the focus of this analysis ("Asian" and "Other" categories were removed), 3 cells (25%) had expected counts of less than 5 and the minimum expected count was 1.28 (n=557 student responses analyzed with removal of these two categories). The rule of thumb for large sample sizes in Chi square tests is that no more than 20% of expected counts should have values less than 5, and all expected count values should be greater than 1[9]. With our next data collection cycle (2010-11) of the senior exit survey, we can rerun this test with both sets of data, thereby doubling our sample size (about 1,400 responses total), which should take care of the problem of insufficient sample sizes in some cells when the data are dissected by students' ethnic grouping.

At critical t values of ± 1.96 at a significance level of $p < .05$, the standardized residuals showed that for URE students (Table 10) that more White, Hispanic, and African American students had graduate school intentions (but it was statistically significant for White students only). However, the standardized residual for Hispanic students (1.6) was much closer to the critical t value of 1.96 for statistical significance than for African American students (0.6). For the comparison group of non-URE students, fewer White and African American students (but it was statistically significant for White students only) than expected chose graduate school, and more Hispanic students (but not statistically significant numbers) chose graduate school. White students with research experience were 4.3 times more likely to select graduate/professional school than employment, and Hispanic students 1.9.

In our data, there were mixed results when looking at groups by ethnicity due to limitations in the data described above. One interpretation is that White and Hispanic students showed higher levels of interest in continuing on to graduate school (but this finding should be interpreted with caution) whereas Lopatto[2,5] found no differences among ethnic groups. This finding may be unique to our institution. Based on this preliminary finding, we can then test our hypothesis that that Hispanic students who participate in UREs at our institution are more likely to have graduate school intentions in statistically significant numbers compared with African American students. It is important to us to examine this further because representation of Hispanic students in our undergraduate population of engineering students is double that of national figures (see above in the Background section for the statistics). We also need to focus our efforts on understanding why graduate school is not equally attractive to African American students.

Table 10. Q21. Employment or Graduate School Intentions by Ethnicity

| Group | Ethnicity | Statistics | After Graduation Intention | | Total |
|---|---|---|---|---|---|
| | | | Employment | Graduate or professional School | |
| URE | White | Count | 37 | 30 | 67 |
| | | Expected Count | 52.7 | 14.3 | 67 |
| | | % of URE White | 55.2% | 44.8% | 100% |
| | | % of Total | 6.6% | 5.4% | 12.0% |
| | | Std Residual | -2.2 | 4.1 | |
| | Hispanic | Count | 9 | 6 | 15 |
| | | Expected Count | 11.8 | 3.2 | 15 |
| | | % of URE Hispanic | 60.0% | 40.0% | 100% |
| | | % of Total | 1.6% | 1.1% | 2.7% |
| | | Std Residual | -0.8 | 1.6 | |
| | African American | Count | 4 | 2 | 6 |
| | | Expected Count | 4.7 | 1.3 | 6 |
| | | % of URE African American | 66.7% | 33.3% | 100% |
| | | % of Total | 0.7% | 0.4% | 1.1% |
| | | Std Residual | -0.3 | 0.6 | |
| Non-URE | White | Count | 299 | 56 | 355 |
| | | Expected Count | 279.2 | 75.8 | 355 |
| | | % of URE White | 84.2% | 15.8% | 100% |
| | | % of Total | 53.7% | 10.1% | 63.7% |
| | | Std Residual | 1.2 | -2.3 | |
| | Hispanic | Count | 57 | 20 | 77 |
| | | Expected Count | 60.5 | 16.5 | 77 |
| | | % of URE Hispanic | 74.0% | 26.0% | 100% |
| | | % of Total | 10.2% | 3.6% | 13.8% |
| | | Std Residual | -0.5 | 0.9 | |
| | African American | Count | 32 | 5 | 37 |
| | | Expected Count | 29.1 | 7.9 | 37 |
| | | % of URE African American | 86.5% | 13.5% | 100% |
| | | % of Total | 5.7% | 0.9% | 6.6% |
| | | Std Residual | 0.5 | -1.0 | |
| Total | | Count | 438 | 119 | 557 |
| | | % of Total | 78.6% | 21.4% | 100% |

Discussion

We began this paper by describing the problem of not being able to generalize the benefits of the URE experience of students in our YES program because of small sample sizes. This proposed URE framework (Figure 2) helped us to identify the common and unique features of the YES program and UREs at our institution in comparison with similar studies at other institutions. However, until more studies are conducted on the benefits of undergraduate research experiences, we cannot say that these benefits are general to the population. Do students in European countries, Asia, Latin America, the Middle East, etc. experience the same benefits regardless of how the URE experience is structured? However, we can now state with some degree of confidence (irrespective of our small sample size) that the YES program does provide a pathway by which STEM undergraduates have the opportunity to develop their career identity and confirm/clarify/refine career goals and transform into scientists. These statements are supported by our senior exit survey data and the comparative URE studies published by experts (see Table 7). It would be misleading to say at this point that the goal of a URE program is to prompt undergraduates to choose graduate school. Seymour et al.[1] and Hunter et al.[4] found no evidence to support this statement. We also found no evidence to support this statement. But rather, the goal of the URE is that it confirms/clarifies/ refines a student's choice.

To further explore the idea of pre-existing ideas of students' graduate school intention, we analyzed responses to Q. 22 "If you intend to engage in further formal study, what is the highest degree you eventually expect to obtain?" (implied time period is some time in the future) in our senior exit survey. The Chi Square test of independence revealed statistically significant difference between the two groups (students with research experience and those without), $\chi^2(2) = 27.831$, $p<.001$, $n = 640$ (Table 11). At critical t values of ± 1.96 at a significance level of $p<.05$, the standardized residuals showed that for URE students (Table 11) statistically significant more URE students than expected chose a PhD as the highest expected degree. URE students were three times as likely to expect a PhD compared with non-URE students. Russell et al.[9] found that URE STEM students were twice as likely to expect a PhD compared with non-URE students. However, Q22 implies some distant future plan after graduation (Table 11), whereas Q21 (Table 8) implies "now" after graduation.

What is interesting in these data (Table 11) is that both URE and non-URE students expressed a high level of interest in pursuing graduate studies (at some future time), particularly at the master's level (59.6% of UREs and 71% of non-UREs). This preliminary finding suggests that graduate school intention may be present prior to participation in the URE. Female students were as likely as male students to desire an advanced degree. Non-URE (79%) and URE (80%) students in the GPA range of 3.0-3.4 were about as likely to desire an advanced degree (see Figure 3 below), but in the upper GPA ranges 3.5-4.0, URE students (98%) were more likely to desire an advanced degree than non-URE students (78%). Do these data give some insight into the question of self-selection in deciding to apply to URE programs and validate use of this comparison group of non-URE students? That is, both URE and non-URE students seem to have

the desire to obtain an advanced degree but the difference may be in the degree of the desire to actually make the decision to enroll in a graduate program. To further examine this idea of prior graduate school intention before participation in the URE, we have added this question for the next data collection cycle of our senior exit survey: "Before you participated in a research experience, had you planned on attending graduate school after graduation?"

Table 11. Q22. Future Plan of Graduate School Intentions

| Group | Statistics | Future Graduate School Intentions | | | Total |
|---|---|---|---|---|---|
| | | No further study | Masters | Doctoral | |
| URE | Count | 8 | 59 | 32 | 99 |
| | Expected Count | 15.3 | 68.5 | 15.2 | 99 |
| | % of URE | 8.1% | 59.6% | 32.3% | 100% |
| | % of Total | 1.3% | 9.2% | 5.0% | 15.5% |
| | Std. Residual | -1.9 | -1.2 | 4.3 | |
| Non-URE | Count | 91 | 384 | 66 | 541 |
| | Expected Count | 83.7 | 374.5 | 82.8 | 541 |
| | % of non-URE | 16.8% | 71.0% | 12.2% | 100% |
| | % of Total | 14.2% | 60.0% | 10.3% | 84.5% |
| | Std. Residual | 0.8 | 0.5 | -1.9 | |
| Total | Count | 99 | 443 | 98 | 640 |
| | % of Total | 15.5% | 69.2% | 15.3% | 100% |

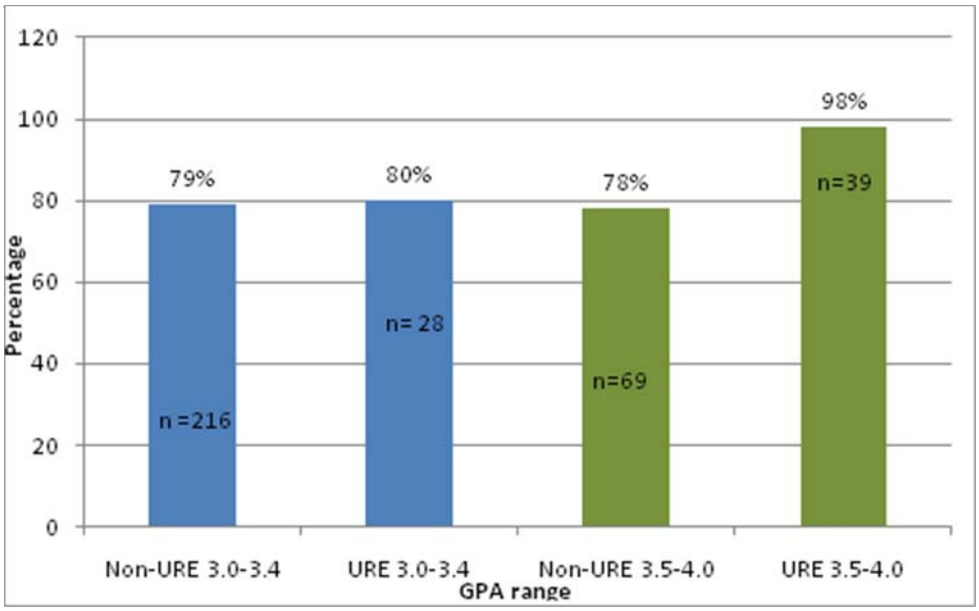


Figure 3. Q22. Future Graduate School Intention by GPA

Moreover, as may often happen as part of the research process, new questions are generated or other hypotheses not posited as part of the initial study emerge:

- If students who participate in research experiences are more likely to continue on to graduate school, are students who participate in internships more likely to choose employment over graduate school or as likely to choose graduate school? (Our YES program also offers an Entrepreneurship/Internship path.)
- What are the factors that prompt students to make a final decision on career choice? A study by Betz and Voyten[24] suggest that career decision-making efficacy expectations predict career indecision and career outcome expectations predict intentions to explore careers. (We observed switching behavior between the Research and Entrepreneurship/ Internship Paths of several YES students. This switching behavior suggests that offering students different types of experiences will prompt a well grounded career choice.)

## Conclusion

In an effort to improve the URE evaluation framework for the authors' NSF-funded S-STEM program (Scholarships in Science, Technology, Engineering, and Mathematics) that supports research experiences for its participating students, we analyzed quantitative and qualitative data from the 2009-10 senior exit survey for graduating students in the College of Engineering and Computer Science at a large, metropolitan, research university. The survey data offered a large sample size (n=687) of which 104 or 15% of students reported participation in a URE; non-URE students were used as a comparison group. First, we looked for patterns in the data that would provide some insight into three hypothesized claims for our NSF program, which we called the Young Entrepreneur and Scholar (YES) scholarship program. We then compared our findings with five published studies. First, forty three percent of our URE students expressed interest in continuing on to graduate school compared with 17% of non-URE students. Moreover, a URE student was 3.39 times more likely to indicate graduate school intentions over employment upon graduation than a non-URE student. URE students were also three times as likely to desire a PhD compared with non-URE students. Russell et al.[9] found that URE STEM students were twice as likely to expect a PhD compared with non-URE students.

In our survey, we found 41% of gains in "clarification or confirmation of career/education paths" compared with 20% of gains reported in the Seymour et al.[1] study. We believe that the difference is probably attributable to the timing of both studies - we surveyed graduating seniors whereas Seymour et al.[1] interviewed rising seniors. As students approach graduation time, their thoughts are turned more towards deciding on a career. Second, 51% of gains in the personal/professional domain (which includes "thinking and working like a scientist") were found in both our study and the Seymour et al.[1] study. Hunter et al.[4] found that 57% of students attributed "gains in confidence" to their "feeling like a scientist." Third, in our survey data, male

and female students showed the same level of interest in continuing on to graduate school as did Lopatto[2,5]. While the literature[2,5] seems to support that UREs also provide equal opportunities across ethnic groups, our survey data seem to indicate that it is more positive for White and Hispanic students (but but this finding should be interpreted with caution due to limited size of the data). This finding may be unique to our institution.

We found 3% of reported gains were negative/mixed in our exit survey compared with 8% in the Seymour et al.[1] study. For the majority of students who participate in UREs, positive benefits are claimed. The comparative analysis of our data with the five studies reaffirms the three hypothesized claims and defines an appropriate URE evaluation framework upon which our future YES program assessments will rely. We believe these assessments will be stronger since we expect to recruit two more YES cohorts of 25 URE students (currently, 23 students are in the Research Path). As more research is conducted on the benefits of the undergraduate research experience, researchers will be able to sort out the common features of the UREs that can be true of the population (the goal of our URE evaluation framework as depicted in the outermost frame of Figure 2 above) and the unique features of a sample or group.

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