# Students' Perception of a Summer Undergraduate Research Experience: Across the Disciplines

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## Introduction

Undergraduate research is considered one of the high impact practices, which are routinely found on college campuses today. The outcomes from undergraduate research range from increasing a student's retention in the major to increased numbers of students attending graduate school [1]. In addition, Hu and colleagues find that students who participate in undergraduate research have greater interactions and relationships with their faculty, improved writing and communication skills, and enhanced critical thinking skills [2]. Moreover, summer undergraduate research has also been found to support these outcomes, with Lopatto finding that such programs support networking skills and professional development for students [3]. Due to these findings, The Citadel initiated the Undergraduate Research Office in 2016 and the inaugural The Citadel SURE (Summer Undergraduate Research Experience) program in the summer of 2017. Note that this program is not quite the same as typical REU programs where students come from multiple universities to work on one or closely related projects such as the NSF-funded REU presented by Youssef et al. [4].

Undergraduate research at all types of higher education institutions is now being emphasized. Since undergraduate research is listed as one of five, high-impact practices on student learning outcomes [5], it is beneficial to expose as many students to research as possible. Undergraduate research has been linked to retention in undergraduate degree programs [6], improved skills in data acquisition, data reduction, and public speaking [7], and increased participation in graduate programs [8]. There are even journals dedicated to undergraduate research. These might be within a single academic department at an institution [9], school wide [10], or discipline specific across many institutions [11]. The summer break makes the most sense for research activities since both faculty and students have greater availability. While it is not feasible to engage every student in undergraduate research simply based on numbers, having just a few students in any classroom who have been involved in undergraduate research can greatly enhance the learning environment.

The relationship between the student and mentor is especially critical in the impact the research experience has on the student [12]. Students who rate their mentor very high typically also report the best gains from their experience. It is difficult to quantify, but anecdotally, students usually report the interpersonal relationships developed with mentors is just as important if not more important to them than the actual research [13]. The objectives of this study were to (1) examine the students' perception of the SURE program, and (2) to assess the students' perception based upon their gender at The Citadel. This paper discusses the SURE program, scope of the student projects, results and analyses of the students' perception, direct assessment of SURE and potential future improvements for the program.

## Institution Context and SURE Program

The Citadel enrolls approximately 2,300 in its undergraduate Corps of Cadets (Day program) and approximately 700 undergraduate civilian students (Evening program). Out of these, roughly eight percent are female and 30% are minorities. Day classes are taken primarily by members of the Corps of Cadets. A relatively small percentage of the classes are occupied by active duty or veteran students, who take day classes with the Corps of Cadets. Evening classes are populated with students who live in the community, many of whom work full or part-time. Veterans that have been approved for day status may also attend evening classes in the fall and spring.

The SURE program was initiated out of the Office of the Provost at The Citadel. This office enabled funding for students from all disciplines to participate in either a 5-6 week or an 8-10 week research experience. Students with the assistance of faculty self-selected which program they could attend. Due to student obligations to attend military training in the summer or other institutional requirements, The Citadel was not able to hold a traditional 8-10 week program. Thus, by offering options for students, they were allowed to participate in the SURE program and complete their military and other obligations. Based on the number of weeks which students worked, they were provided a stipend that ranged from $2,000-$3,000 along with housing and meals. The faculty working with the students received a modest stipend which ranged from $1,000-$1,500. In addition to working in their research laboratories, students were required to participate in meetings with other SURE students, as well as present their outcomes during the first week of fall 2017 at The Citadel.

## Brief Description of Several Research Projects

During summer 2017, undergraduate researchers were engaged in discovery and learning in the SURE program at The Citadel.

In one project, a veteran student built a low-cost particle image velocimetry (PIV) system. A research level system can cost over $100,000, but this system costs less than $2,500. It will be used for undergraduate laboratory exercises in thermal/fluids courses in the future. The student designed the layout of the system, ordered and/or 3D printed necessary optics and mounting hardware, and ran test cases of a cylinder in crossflow to demonstrate the system. The student determined appropriate levels of particle seeding density for best results and optimal settings for the camera and laser. An open source MATLAB code, PIVLab, was used for data reduction. The system was able to capture the classic von Karman vortex street in the wake of the cylinder.

In another project, two evening undergraduate researchers compiled the shear wave velocity data from 130 sites in the Charleston area. Next, they worked on estimating the time-averaged shear-wave velocity ($V_{S30}$) to a depth of 30-m at each site. The $V_{s30}$ is the basis for specifying site classes in building codes [14]. They found out that approximately 80% of the shear-wave velocity profiles did not extend to a depth of 30-m. Therefore, the students employed two methods to deal with these situations. (1) They used Boore 2004 model [15] (a model based on data from boreholes in California) to estimate the $V_{s30}$ at each site. (2) They applied the local geologic conditions at each site to estimate the $V_{s30}$. All local sites consisted of soft soils and

Marl strata within top 30-m. The students estimated the shear wave velocities of the soft soil and the Marl based on published values [16]. They used these estimated values to compute a composite $V_{s30}$ at each site. The students compared the results from the two methods and they found that they were within 10-20% of each other. Lastly, the students employed the resulting $V_{s30}$ profiles to investigate the seismic site responses at each site.

Two students worked to understand how non-invasive neurologic devices can play a role in understanding traumatic brain injury. Through the summer, the students specifically utilized an eye tracking device and tested subjects with a protocol that included parameters such as reaction time, memory guided sequence, and light reflex. The pilot data collected at the study site enabled the developer to understand aspects of the data collection which were effective and which were not. Future data will be collected on healthy subjects and compared to those who have experienced traumatic brain injury (TBI), so the areas in the brain, which are affected after TBI, can be mapped.

A senior Cadet continued work from a previous summer on the design and synthesis of a "peelable" nitric oxide-releasing material to be used for the remediation of bacterial contamination on cultural heritage items. Following the synthesis of superparamagnetic iron oxide nanoparticles, the student functionalized their surface to allow for the storage of nitric oxide, a broad-spectrum antimicrobial compound. Various methods for this functionalization were explored and evaluated for nitric oxide storage capacity and release rate. Optimized particles were then doped into hydrogels with varying ratios of poly (vinyl acetate), poly (ethylene oxide), and borate. These materials are currently undergoing testing for stability, removability, and particle leaching.

A senior Cadet continued work started the previous summer on the creation and implementation of an algorithm to solve a remodel of the Delay and Delay-Variation Bounded Multicast Tree problem. The algorithm creates paths between a source and destinations which all have weight within a specified delay interval. The student defined this problem, created the algorithm, proved its correctness and complexity, and ran simulations to support the findings. The algorithm can be used in collaborative and competitive applications, such as gaming, where information needs to be received almost simultaneously. This algorithm runs more efficiently in these situations and can be run on larger networks than previous algorithms.

It is important to note that due to small sample size, no comparisons were made among disciplines.

## Study Methods

The following describe the guiding research questions for this study:

1. What is the overall perception of the Summer Undergraduate Research Experience at The Citadel?
2. Do male and female research participants have same perception about the Summer Undergraduate Research Experience at The Citadel?

## Assessment Measure

The effectiveness of the SURE program was examined indirectly by analyzing a survey of student perception. The survey was only administered at the end of the program. A total of eight students (four males and four females) completed the survey. The student perception was measured by analyzing a '1-5' Likert scale survey ('1' indicating that students strongly disagree with the statement (i.e., the SURE is very ineffective) and a '5' indicating that students strongly agree with the statement (i.e., the SURE is very effective). Students were asked to respond to the statements listed in Table 1.

Table 1. Survey of student perception of SURE.

| Question |
|---|
| Q1. I am considering applying for and attending graduate school.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q2. I understand the research process.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q3. I am confident in my ability to analyze data.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q4. I am confident in my research ability.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q5. I have good communication skills.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q6. I have good critical thinking skills.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q7. I am confident in my problem solving skills.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q8. I think it is important to learn about the work conducted by other researchers.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q9. I am interested in the subject that I am researching.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q10. I am able to work independently and collaboratively.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q11. I know how to connect theory with research practice.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q12. I am able to develop my active learning attitude.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q13. I am able to enhance my lifelong learning skills.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |
| Q14. I have positive working relationships with faculty mentor (s) and peers.<br>Strongly Disagree 1 2 3 4 5 Strongly Agree |

It is important to note that the future iterations of the survey will include a modified version of these questions to incorporate the role of the program in development of the listed skills. In addition, the future survey will be administered at the beginning and at the end of the SURE program to determine how the student's perception changes from the beginning to the end of program.

**Results and Discussion**
The results of the study are organized according to each research question.

**Research Question 1:** What is the overall student perception of the Summer Undergraduate Research Experience at The Citadel?

The student responses to the survey were evaluated by computing a weighted average for each survey question. Figure 1 shows that 62.5% of the mentees either strongly agree (Likert scale 5) or agree (Likert scale 4) that they are considering applying for and attending graduate school. A significant percentage (37.5) expresses an unsure response (Likert scale of 3) to question #1. Figure 1 also illustrates that 100% of students either strongly agree or agree to Questions 2-7 and Questions 9-14. Furthermore, 87.5% of the mentees either strongly agree or agree that it is important to learn about the work conducted by other researchers and 12.5% are unsure.

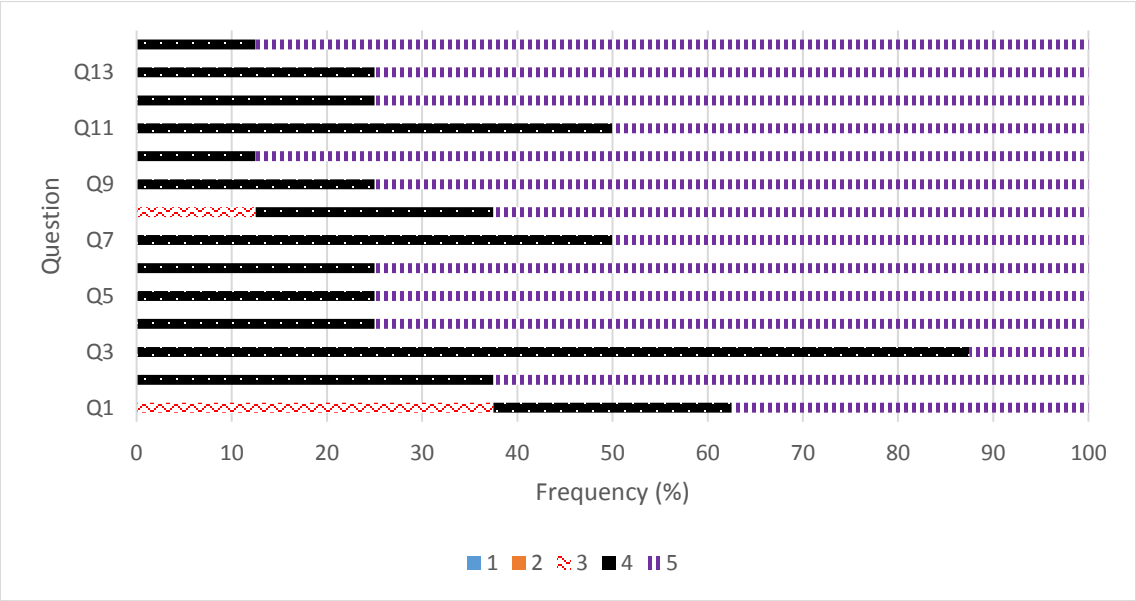


Figure 1. Results of student perception survey.

The mean and standard deviation of each survey response was determined and the results are shown in Figure 2. Question 10 (I am able to work independently and collaboratively) and Question 14 (I have positive working relationships with faculty mentor (s) and peers.) resulted in highest mean. Question 1 (I am considering applying for and attending graduate school) and Question 3 (I am confident in my ability to analyze data.) resulted in lowest mean. Questions 4, 5, 6, 9, 12 and 13 resulted in a mean and standard deviation of 4.75 and 0.46, respectively. Questions 3, 10, and 14 results in lowest standard deviation and Question 1 has the highest standard deviation.

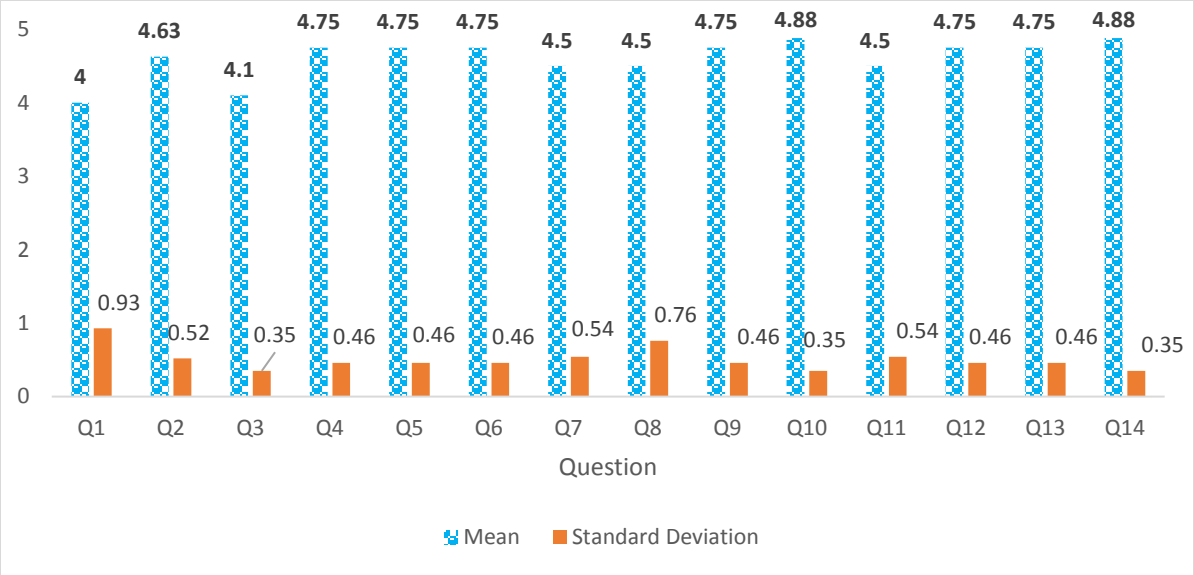


Figure 2. Summary statistics of survey questions.

**Research question 2**: Do male and female participants have same perception about the Summer Undergraduate Research Experience at The Citadel?

Figures 3 and 4 display a comparison of mean and standard deviation of the responses of male and female mentees to the survey. Mean perception scores are constantly higher for female, except in Questions #3, 7, and 14. Standard deviations of perception scores of female participant are all lower than the males except in Question 14.

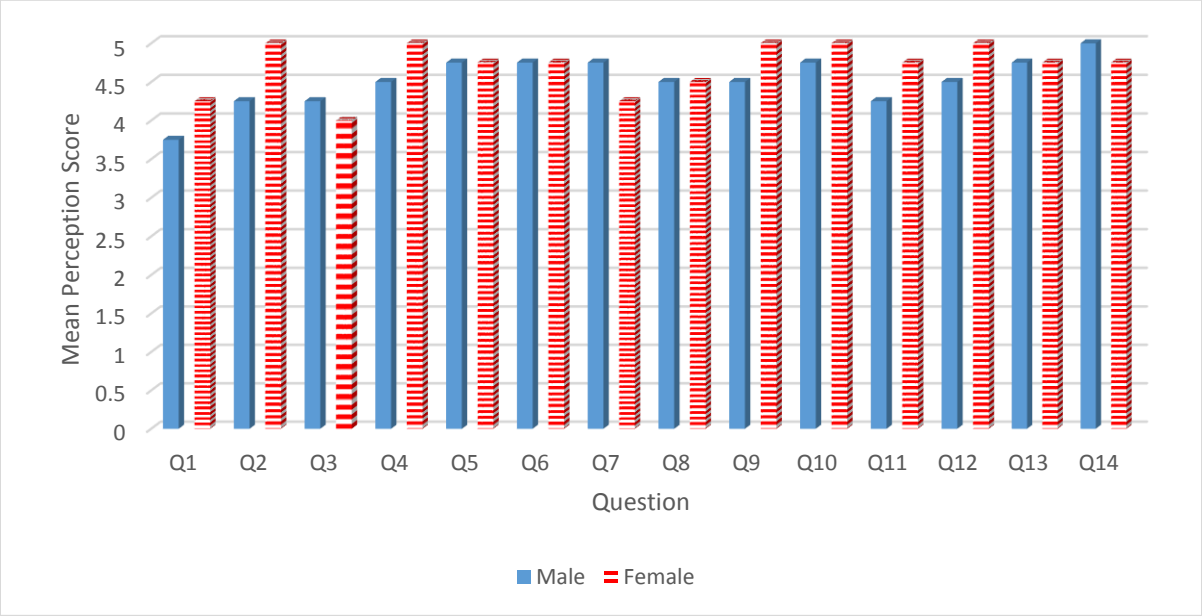


Figure 3. Comparison of mean values of male and female mentees responses.

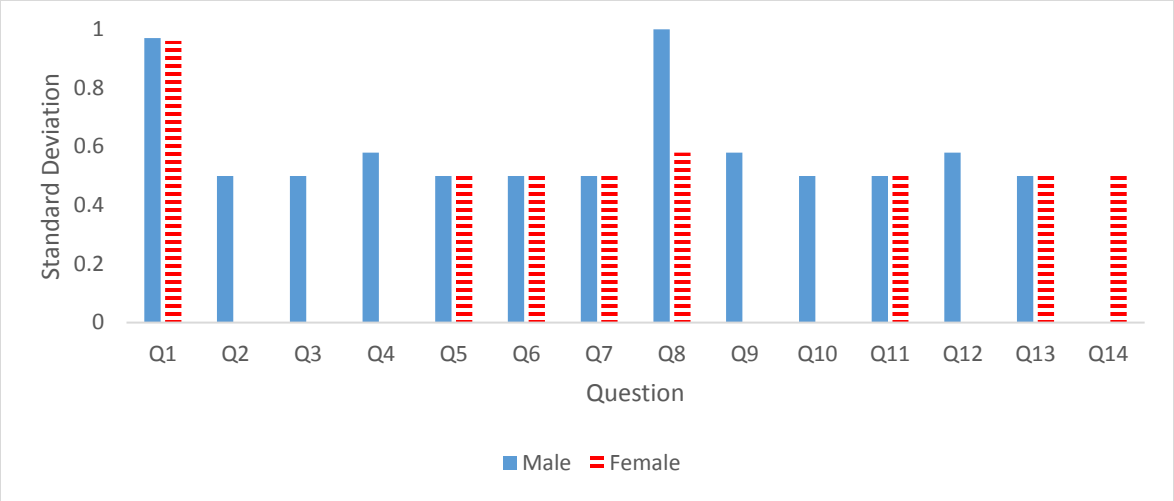


Figure 4. Comparison of the standard deviation of male and female mentees responses.

It was hypothesized that the mean of perception scores of male and female are not different from each other (i.e., $H_0$: $\mu_1 = \mu_2$, $H_a$: $\mu_1 \neq \mu_2$). Comparison of the male and female mean perception scores was completed using the 2-sample t-test assuming equal variances at five percent level of significance, and the results are shown in Table 2. The statistical test was conducted for each question to test for statistically significant differences between male and female responses. Table 2 summarizes the weighted mean of perception scores for male and female, calculated t-values and p-value for each question. The results show that difference between the mean responses of male and female participants was only statistically significant for question #2 (I understand the research process).

Table 2. Summary results of statistical analysis.

| | Weighted Mean (Male) (N=4) | Weighted Mean (Female) (N =4) | t-statistics | P-value |
|---|---|---|---|---|
| Q1 | 3.75 | 4.25 | -0.739 | 0.488 |
| Q2 | 4.25 | 5.00 | -3.00 | < 0.05 |
| Q3 | 4.25 | 4.00 | 1.00 | 0.356 |
| Q4 | 4.50 | 5.00 | -1.73 | 0.134 |
| Q5 | 4.75 | 4.75 | 0.00 | 1.00 |
| Q6 | 4.75 | 4.75 | 0.00 | 1.00 |
| Q7 | 4.75 | 4.25 | 1.414 | 0.207 |
| Q8 | 4.50 | 4.50 | 0.00 | 1.00 |
| Q9 | 4.50 | 5.00 | -1.732 | 0.134 |
| Q10 | 4.75 | 5.00 | -1.00 | 0.356 |
| Q11 | 4.25 | 4.75 | -1.414 | 0.207 |
| Q12 | 4.50 | 5.00 | -1.732 | 0.134 |
| Q13 | 4.75 | 4.75 | 0.00 | 1.00 |
| Q14 | 5.00 | 4.75 | 1.00 | 0.356 |

## Direct Assessment of SURE

The success of the SURE program was measured by the number of student presentations of research at local, regional or national level. The goal of the program was for each participant to present his or her research in the form of poster at the beginning of fall 2017 at The Citadel. The goal set by the program at the local level was achieved, since 100 percent of the participants presented their posters at The Citadel. At the regional level, three posters were presented at the Southern Conference Research Forum at Wofford University in Fall 2017 and one student presented his research at the 2018 ASEE-SE Conference in March 2018 at Daytona Beach, Florida. At the national level, one student has submitted a paper to the 2018 ASEE Conference in Salt Lake City, Utah.

## Conclusions and Potential Future Improvements for the Program

Students' perception of the SURE program at The Citadel was examined and the results show that at least 80% of the students rated the program as effective or very effective. Students' perception was also assessed based upon gender and the results show that male and female participants almost had same perception about the SURE program. Engagement in the SURE program led to positive impacts on participants' confidence in research abilities, working independently or collaboratively, lifelong learning and communication skills, while some were still unsure about applying and attending graduate school and their ability to analyze data.

One piece of the inaugural SURE program, which was not fully developed, was the mentoring piece. During the first summer of offering the program, the director was tasked with setting up the program and all of its logistic requirements as the institution had never offered such a program in the past. As a result, parking, housing, meals and how to pay stipends often became difficult obstacles to overcome during the course of the program. Thus, the piece that was neglected, assumed to occur between faculty and student was the mentoring piece. However, research shows that mentoring must be purposeful and intentional to achieve desired outcomes for a variety of businesses and organizations. Within organizations, Ragins and Cotton found that those who had formal versus informal mentoring program were more effective [17]. Interestingly as it relates to this current study's findings, [17] found that women benefit even less from informal mentoring programs. Therefore, it is incumbent on SURE to develop formal mentoring programs which may positively affect female experiences.
The structure of formal mentoring in undergraduate research can have a variety of models as illustrated by [18]. Despite the normal perception of one-on-one (faculty/student) mentoring program, student's perception of how they are best supported appears to include a multi-mentoring approach, with a network of people who take interest in the student's success [18]. In addition to understanding what students perceive as supportive mentoring, whether one-on-one or the multi-person, successful mentoring must be detailed to include five components: communication, psychosocial support, career/professional development, science integrity, and research development [19]. However, in order to achieve such outcomes during a summer SURE program, then an interdisciplinary/multi mentor approach would seem most productive. In addition, part of this program must include appropriate training and support for those who are mentoring the students. Assessments need to continually redefine desired outcomes and goals of such programs.

Another shortcoming was that the program gave students and faculty a stipend, but it did not provide any research related expenses. This is potentially limiting for some projects if faculty do not plan for student researchers far enough in advance.

Changes that will be made for the upcoming summer program will include faculty sessions to provide structure and methods for appropriate mentoring. In addition, SURE students will be paired with a faculty member who is not a part of the research project, serving as a role model and guide for professional development. Finally, plans for upcoming summer program will also include more interaction between students and faculty within social group settings to encourage opportunities for growth and development outside of the research process. With more structure and planning implemented for the mentoring piece, the hope is that students will become more engaged and their perception of the impact of the program will be enhanced.

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