Impact of Undergraduate Teaching Assistants (UTAs) on Gender-inclusive Student Engagement in an Introductory Computer Programming Course

Mrs. Tiana Solis, Florida International University

Tiana Solis is an instructor and a part-time Ph.D. student at Florida International University. She received her Bachelor's and Master's degrees in Computer Science from SUNY (State University of New York) Polytechnic Institute in Utica, New York.

Her research and instructional interests include student access and success in computing, Diversity, Equity, and Inclusion in Higher Education.

Dr. Stephen Secules, Florida International University

Stephen is an Assistant Professor Engineering and Computing Education at Florida International University. He has a prior academic and professional background in engineering, having worked professionally as an acoustical engineer. He has taught a number of courses on design, sociotechnical contexts, education, and learning. He conducts research on equity and culture in engineering education and supports undergraduate and graduate student researchers through the Equity Research Group.

Student engagement with undergraduate teaching assistants (UTAs) in an introductory computer programming course

Abstract

Despite women representing more than half of the US population, they remain underrepresented in Computing fields. An introductory programming course (CS1) is critical for progression in the Computer Science (CS) degrees. It often presents challenges for retention and graduation, especially among underrepresented students. Previous research has indicated that women may be more likely to leave or lose interest in computing due to various challenges. The computing classroom culture needs to improve engagement and create a welcoming environment for women. As more schools are using peer instruction, such as LA (Learning Assistant), PLTL (Peer-Led Team Learning), and UTA (Undergraduate Teaching Assistants), some research indicates that such practice for recitation, laboratory sessions, and grading may promote engagement and improve the educational students' experiences, especially women.

This study aims to determine whether using UTAs is an effective practice for underrepresented students and to identify strategies that UTAs can employ to enhance active engagement. The paper presents institutional data showing the outcomes of students in the programming sequence of the first three courses. This data includes a comparative analysis between classes with UTAs and those without UTAs. Institutional data supported our results of increased student retention in CS1 and progression to CS2 and CS3. We also discuss a qualitative research approach by observing classroom dynamics from video recordings depicting student interactions in computing. Our qualitative findings, informed by video recording observation, suggested positive experiences and comfort for the students in the class and the UTAs. Our findings point towards a future research agenda to investigate the classroom enactment of UTA instruction and the operationalization of inclusive classroom interactions.

Keywords - undergraduate teaching assistant; UTA; computing; computer science; programming class

1. Introduction

Due to the global nature of computing in the 21st century, colleges and universities have faced challenges in keeping up with the increasing demand for Computer Science (CS) courses [4]. Many institutions have faced challenges in developing sustainable ways to expand capacity within introductory computer science courses while remaining committed to providing quality education and inclusive environments for students to thrive. Increasing class size is one of the easiest and quickest solutions institutions turn to meet the growth of CS enrollment nationwide. While these increasing class sizes address the increase in demand for these classes, they can cause a decrease in the inclusiveness and quality of education [3]. This decline has led teachers to experiment and try new ways to tackle this issue. One beneficial solution has been incorporating undergraduate teaching assistants (UTAs) [10].

Studies have shown that near-peer teaching and mentoring relationships can enhance women's sense of belonging and improve their persistence in computing [2]. In our context, UTAs, usually junior or senior undergraduate students, can assist with recitation and laboratory activities, providing a welcoming presence for women in computing and challenging the prevailing culture. A practical solution involves training UTAs in inclusive pedagogy to better cater to the diverse needs of Computer Science (CS) students. Leveraging existing research and the current Learning

Assistants and Graders program at the institution, the study focuses on efficiently and incrementally implementing UTAs in our school's first three programming courses (CS1, CS2, and CS3). The strategy involves undergraduates adopting peer teaching roles in active learning environments. The goal is to offer personalized attention in large classes, aiming for a UTA-to-student ratio of 1 to 20 in CS1, where students experience faculty lectures followed by practical exercises.

The authors of this paper created a study to determine if UTAs would be a critical component that increases the quality and inclusiveness of education for CS students. This study was conducted at a public research institution and Hispanic serving institution (HSI) in the Southeastern US region. The study included hiring UTAs and recruiting faculty to participate in the project. During this process, the faculty and coordinator were focused on UTAs being approachable, patient, and willing to engage in a diverse learning community. The long-term objective is to address the crucial need for computer science classes that maintain the personal attention necessary for student persistence and a sense of belonging. The project setup adopted some potential solutions inspired by the success of peer mentoring [3].

2. Context

2.1 UTAs Implementation and Settings

In this study, the role of UTA is a paid position exclusively available to enrolled undergraduate students. The funding for the UTA's salary is part of broader participation in a three-year grant project [10], with the expectation of continued internal funding from our institution once the grant expires. Programming I (CS1) is a prerequisite course for bachelor's degree students majoring in Computer Science, Information Technology Software, and Computer Engineering. Additionally, some non-science majors may take the course to fulfill basic general education math credits, making it a highly sought-after course.

The traditional CS1 course at the school typically consists of four credits, with three hours of lectures led by a CS faculty member who meets twice a week and a one-hour separate lab conducted by a graduate TA. The new format for CS1, utilizing a best practices approach, also consists of four credits and meets twice a week. However, in this format, classroom meeting hours have doubled to three hours per session, with faculty and UTAs present. This adjustment aims to provide additional teaching support for faculty and extra classroom time for students.

UTAs started being used in Fall 2021, first in Programming 1 (CS1). By the next semester, Spring 2022, they were also used in Programming 2 (CS2). A typical class session will involve the faculty lecturing in an active learning environment for the first half of the session. The second half of the class becomes a lab where the faculty and UTAs facilitate the practice session. Implementing the courses' best practices (BP) includes general expectations such as synchronized content. It is crucial to synchronize the course's content to eliminate factors that may affect the results of this experiment and students' learning experiences. Participating faculty teaching these courses within this experiment meet regularly to agree upon a standard syllabus for the course and joint assessment, where examination questions come from a standard "question bank" agreed upon during these meetings.

Table 1 illustrates the enrollment numbers from Fall 2021 to Spring 2023 when UTAs were introduced in Computer Science classrooms.

Table 1. CS1 enrollments by semester between Fall 2021 and Spring 2023

Fall 2021	Spring 2022	Summer 2022	Fall 2022	Spring 2023
339	427	298	407	463

The first step in implementing the program is to hire UTAs. A faculty coordinator selects UTAs from a pool of students who have achieved a grade of B or higher in the preceding course. The coordinator and the course faculty (whom UTAs will collaborate with) conduct interviews to assess the UTAs' interpersonal skills. UTAs must demonstrate proficiency in the course they will assist with (CS1) by excelling in its prerequisite course, CS2 (Programming 2), and maintaining good academic standing with the University. A deliberate effort is to recruit female UTAs to address the representation gap in STEM education.

UTAs undertake various responsibilities in CS1, working 15 hours per week. This includes attending a combined lecture and lab for six hours, guiding lab sessions, grading for four hours, meeting with the professor for one hour, holding office hours, and responding to emails or Canvas messages for four hours. CS1 typically has a class size of 100 to 120 students per section, with the School of Computing and Information Sciences (SCIS) offering two sections in Fall and Spring and one section in Summer. The recommended UTA-to-student ratio for the project is 1 to 25. The class size for CS2 is typically 60 students.

2.2 UTAs' Training

The department provides two parts of training to prepare UTAs for their roles and duties. The first part is a zero-credit online training course created by the UTA coordinator, which is completed before the first classroom interaction. The second part consists of a weekly instructor training on the class organization, structure, and course contents. Figure 1 illustrates the UTAs' roles in and out of the classroom, making training crucial for preparing them to carry out their responsibilities.

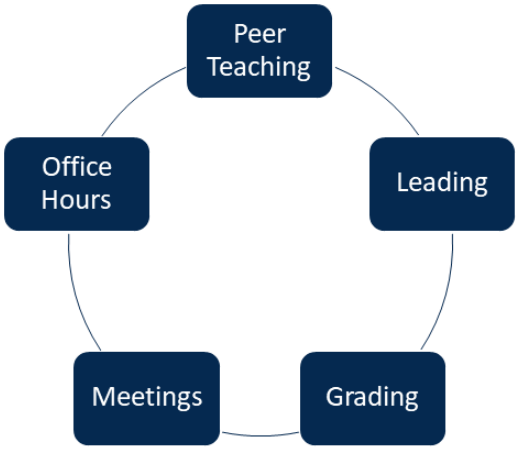

Figure 1 - UTAs roles and responsibilities

The online, zero-credit training course is designed to make UTAs aware of non-technical teaching aspects and the dynamics of the classroom environment. The course covers fundamental aspects such as FERPA (Family Educational Rights and Privacy Act) basics, Cybersecurity, and Kognito, a practice-based digital learning tool to improve mental health and well-being in educational settings [11]. Emphasizing the importance of soft skills, the training equips UTAs

with social abilities for interacting effectively with students and recognizing potential challenges students may face. This is crucial given that UTAs often engage with students in their age group.

Professors are actively involved in preparing UTAs, holding weekly meetings to ensure readiness for leading lab sessions, and imparting skills to manage the class. The training focuses on sensitizing UTAs to non-verbal cues that students may exhibit when facing difficulties but are hesitant to communicate. For instance, if students are visibly struggling to understand a problem or program, indicated by head shaking or expressions of frustration, UTAs are encouraged to move around the classroom, paying attention to individual or group cues. This proactive approach ensures that quieter students receive support, promoting a comfortable learning environment.

In addition to the training, faculty members supplement the UTA's preparation by providing appropriate rubrics for each assignment. Moreover, to maintain consistency and enhance communication, one faculty member has created a video on grading in general, fostering a cohesive approach to the grading process among UTAs. The comprehensive training and ongoing support system aim to empower UTAs with subject knowledge and essential teaching skills for a prosperous and inclusive educational experience.

3. Research Method

This section discusses the research methodology for the funding organization program that employs undergraduate Teaching Assistants (UTAs) to improve our institution's first three programming courses. The study employs a mixed-method approach [8] consisting of both quantitative and qualitative data collection to comprehensively analyze the program's impact on student learning and perceptions of experiences.

The study aims to investigate the effectiveness of the UTA program, assess student performance, and understand the dynamics of the classroom environment in answering the following research questions

***RQ1**: What may be the effect of structured departmental initiatives involving UTA participation on undergraduate CS students' persistence?*

***RQ2**: How do UTAs appear to function in one class setting to create more inclusion, comfort, and productive engagement in a way that could contribute to positive course outcomes?*

In the observed class setting, UTAs (Undergraduate Teaching Assistants) function by fostering a sense of inclusion, comfort, and productive engagement among students. Through video recording observation, we identified instances where students exhibit signs of comfort, particularly those indicative of productive engagement. For instance, Figure 2 shows two students volunteering to stand up and explain their programming codes to their classmates, indicating the classroom environment's positive comfort.

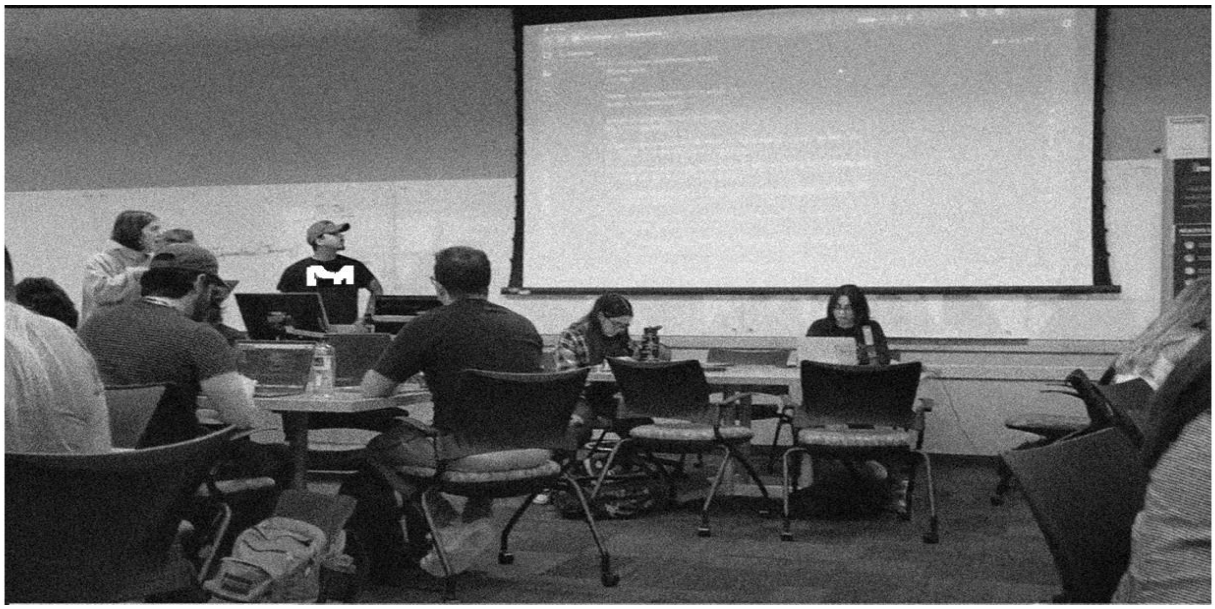

Figure 2 Students volunteered to get up and explain their codes on the board.

3.1. Quantitative Method

In the quantitative phase of this research, data was collected to assess the UTA program's overall impact on student performance. The data included student demographics and grades, with academic plans obtained from the registrar's office following the project's Institutional Review Board (IRB) regulations. These student records helped in understanding the background and characteristics of the students. The study tracked the enrollment patterns of students, specifically if they were taking the programming courses in sequence or if there were any deviations from the prescribed course order.

The quantitative analysis identifies the UTA program's impact on student outcomes. The school received the grades from the institutional data as permitted by the IRB (Institutional Review Board) and performed the analysis. It determines success rates (percentage of students who scored a C or above) for those students who took CS1-BP (Best Practices) and those who did not across all sections of courses. It is interesting to understand which students pass or fail the courses. The analysis helped assess the UTA program's overall effectiveness in improving student success rates, which was also one of the state metrics for public institutions where the study occurred.

3.2 Qualitative Method

In the qualitative phase, the research explored the experiences and perceptions of students, faculty, and UTAs. The main data collection method was classroom video recording coupled with the lead author’s field notes of the classroom observation. Video recordings of classroom sessions were captured to gain insights into the classroom dynamics and interactions between UTAs and students. These recordings provided a rich source of qualitative data. Researchers took field notes during classroom observations to document observations, interactions, and noteworthy events. These notes provided context and detail to complement the video recordings.

Data collection setting

This study's first data collection setting was for an introductory programming course in Java. The course had one hundred and sixteen students, with four UTAs running the laboratory session, and was recorded for about sixty minutes. Figure 3 displays the lecture portion of a CS1 class.

Figure 3 – Lecture session in an Active learning classroom environment

4. Findings

4.1 Quantitative findings

Preliminary results from quantitative data analysis have already shown improvements in student grades and retention rates. The method accounted for the percentage of CS1 students passing the next course, CS2, and then CS3. The intended broader impact is implementing a similar intervention for higher-level computer science courses.

The result's analysis, which stemmed from the data of the University Institutional Research office, provided a comparative overview of CS1, contrasting the utilization of UTAs (BP) from Fall 2021 to Spring 2023 versus the conventional course structure without UTAs. BP implementation started in Fall 2021; thus, the impact could not be discerned until enrollment in Spring 2022 and beyond. Accordingly, CS3 results would be available in the Summer of that year for students who initially enrolled during the BP rollout.

For the study, success rates are the percentage of students who scored a C or above in CS1 and enrolled in CS2. The numbers in Table 2 compared the success rates for those students who took CS1-BP (Best Practices) and those who did not, across all sections of the courses. The exact process applies to CS2, continuing to CS3.

Table 2. CS1 and CS1-BP Success rates in CS2 and CS3 comparison

COURSE (ALL SECTIONS)	SEMESTERS	STUDENTS WHO TOOK CS1-BP (UTAs)	STUDENTS WHO TOOK CS1
CS2	Spring 2022-Spring2023	463/559 (83%)	648/913 (71%)
CS3	Summer 2022-Spring 2023	300/329 (91%)	352/442 (80%)

The study is in progress, but the numbers highlight the challenges and successes in our computer science curriculum. It is encouraging to see the difference in success rates in the courses with the best practices initiative, which may indicate students' better understanding and grasp of the materials.

4.2 Qualitative findings

The following qualitative fieldnote summary is the result of observing a video recording of CS1 classroom observations.

> *Professor - student interactions*
>
> *Students are sitting at oval tables in groups of five to six. Although the class is mixed and not all students are visible on camera, it is apparent that there are more male and fewer female students in the class. Students are paying attention during the lecture. They follow (as assessed by head movement or gaze) the instructor, writing on the whiteboard and walking around the classroom. Sometimes, a student will look at their phone, although it is not clear from the observation alone whether the student is using their phone to look up information about the lecture or for something less academic. The instructor explains the concept of "Class" vs. "Instance" and then "Global" vs. "Static" data. He talks and stops to pose questions. The classroom provides space that allows the instructor to move in between tables and interact with each group, see what they do, and allow them to voice their answers or questions. In a large class like this, as if a traditional classroom is used often, students who sit in the back may need help but be missed or even ignored, instructor movement means more professor student / engagement. When the instructor uses the example of using one bus to drive everybody home versus giving everyone a car to go home and asks about the pros and cons of the two approaches, there is more talking and interactions in the class, first around the table and then across the table.*
>
> *UTA - student interactions*
>
> *After the lecture, the instructor announces the start of the lab session. There is an informal minute break where everyone stands up and stretches their legs, uses the bathroom, or gets a sip of water. Some students move around the room to talk to their peers with their laptops in their hands. Other students use their cell phones, while others use the shared computer on the table. Then, four UTAs (three male and one female) emerge from the back to the front of the classroom. They are chatting with each other. Then, one of the UTAs uses the podium computer and starts the projector. The lab's structure was that UTAs spread around the classroom and assisted students with their coding practice. Students would raise their hands to get the UTAs' attention.*
>
> *Instructors also train UTAs to be proactive, ensure the group dynamic is going smoothly, and initiate questions if the group or an individual member has challenges.*

Figure 4 - UTAs walking around the students' tables and helping students.

Figure 4 shows two female and two male UTAs, and the instructor interacted with students at each table as they collaborated on coding and problem-solving tasks. Our observation noted that the students' table conversation and facial expressions reflect comfort. Students' comfort positively impacted their learning outcomes and academic success. The video showed that when students actively participated in learning activities, understood concepts, and applied knowledge effectively, they experienced productive comfort. This indicates that having UTAs in the classroom helps create an environment where students feel empowered to engage meaningfully with course content.

4.3 Limitations

Our current method utilized a camera view of an entire classroom and brought challenges in the following five UTAs in a class of more than 100 students. We had challenges separating the findings by gender—although women and men are visible on screen, it is hard to distinguish gender and separate the results with limited camera quality.

5. Conclusion & implications \ future works

The pilot program is a work in progress that started in Fall 2021. The study is essential since CS1 is a make-or-break step for students. It especially influences female students to stay in the major or change. We found that the active learning environment and the use of UTAs have increased the number of students taking CS2, among the study's success measures. We will conduct more classroom video recordings and analysis and class observation by the researchers to dig more into the impact of Undergraduate Teaching Assistants (UTAs) on underrepresented students in an Introductory Computer Science (CS1) course. One of the female UTA students who was a UTA from Fall 2021 to Summer 2023 is currently pursuing a Ph.D. in Computer Science, and she

attested her UTA position as among the factors to her decision to become a researcher and future college professor. We intend to interview and follow some UTAs for future studies formally.

Some literature indicates that women possess a shared sense of belonging in computing and may be at greater risk of leaving or becoming disinterested in the field unless they feel supported. The environment is correct [2]. The UTA strategy will promote mentoring relationships that increase women's sense of belonging and improve persistence in the major. Researchers point to peer and faculty relationship development as a primary contributor to a sense of belonging.

We plan to share the findings of this project with UTAs and computer science educators and administrators, especially those interested in learning strategies to broaden participation in CS (Computer Science) by innovating CS1. So, for our following observations, we will set a camera in a classroom section and focus on students and UTAs' interaction at one or two tables.

Acknowledgments

This material is based upon work supported by the Center for Inclusive Computing at Northeastern University. Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Center for Inclusive Computing.

References

[1] "Women and Information Technology by the Numbers," NCWIT - National Center for Women & Information Technology (2020).

[2] M. Kargarmoakhar, M. Ross, M. Weiss, M. Georgiopoulos, S. Lunn, Z. Hazari, K. Christensen, and T. Solis, "Understanding the Experiences that Contribute to the Inclusion of Underrepresented Groups in Computing," in IEEE Frontiers in Education (FIE), Uppsala, Sweden, 2020, DOI: 10.1109/FIE44824.2020.9274113.

[3] D.T. Spaulding, J.A. Kennedy, A. Rozsavolgyi, and W. Colón, "Outcomes for Peer-Based Mentors in a University-Wide STEM Persistence Program," Journal of College Science Teaching, vol. 49, no. 4, pp. 30-36, 2020.

[4] H. Pon-Barry, B.W.-L. Packard, and A. St. John, "Expanding capacity and promoting inclusion in introductory computer science: a focus on near peer mentor preparation and code review," Computer Science Education, vol. 27, no. 1, pp. 54-77, 2017, DOI: 10.1080/08993408.2017.1333270.

[5] D. Mirza, P.T. Conrad, C. Lloyd, Z. Matni, and A. Gatin, "Undergraduate teaching assistants in computer science: a systematic literature review," in Proceedings of the 2019 ACM (Association for Computing Machinery) Conference on International Computing Education Research, July 2019, pp. 31-40.

[6] V.O. Amatari, "The Instructional Process: A Review of Flanders' Interaction Analysis in a Classroom Setting," International Journal of Secondary Education, vol. 3, no. 5, pp. 43-49, 2015.

[7] C. O'neal, M. Wright, C. Cook, T. Perorazio, and J. Purkiss, "The impact of teaching assistants on student retention in the sciences: Lessons for TA training," Journal of College Science Teaching, vol. 36, no. 5, p. 24, 2007.

[8] J.W. Creswell, A concise introduction to mixed methods research. SAGE Publications, 2014.

[9] H. Danielsiek, J. Vahrenhold, P. Hubwieser, J. Krugel, J. Magenheim, L. Ohrndorf et al., "Undergraduate teaching assistants in computer science: Teaching-related beliefs, tasks, and competences," in 2017 IEEE Global Engineering Education Conference (EDUCON), April 2017, pp. 718-725.

[10] Center for Inclusive Computing, accessible via https://cic.northeastern.edu/, 2019.

[11] Kognito, available at https://kognito.com/.

[12] D. Barto, C.W. Bird, D.A. Hamilton, and B.C. Fink, "The Simple Video Coder: A free tool for efficiently coding social video data," Behav Res Methods, vol. 49, no. 4, pp. 1563-1568, 2017.