Interventions for Increasing Belonging and Inclusion in Undergraduate Computer Science Classrooms

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Abstract

Undergraduate study of computer science is a common pathway into computing professions; however, attraction and retention of students from underrepresented groups is a long-standing problem. Higher education is in the middle of a well-documented "leaky pipeline," and the reasons for the dismal diversity statistics in computer science are wide-ranging and reach beyond the college classroom experience. Evidence has shown that Culturally Responsive Teaching (CRT) results in positive learning outcomes and feelings of belonging and inclusion, leading to stronger retention of students from underrepresented groups. This work details efforts across our department to incorporate three components of CRT into introductory and advanced courses: using diverse assets; encouraging identity connections; and structuring meaning-making. Our objective was to create and implement instructional materials that reflect a range of cultural perspectives, help students to express their unique identities in course activities, and craft opportunities for reflection on learning and connection to one's lived experience. We provide a repository of resources and discuss in more detail several examples of course materials targeted at these objectives. In addition to general lessons learned, we present survey results showing that students from underrepresented groups in courses using these materials indicated an increased sense of belonging. Their responses showed statistically significant improvement in their belief that computer science could better help them understand themselves, and in considering themselves a "computer science person."

CCS Concepts

• **Social and professional topics → Computer science education**; *Model curricula.*

Keywords

diversity, inclusion, belonging, Culturally Responsive Teaching

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1 Introduction and Related Work

Computer science is one of the least diverse fields of study, and the profession as a whole has been characterized as having a "leaky pipeline," a well-documented phenomenon that has a number of potential causes, including lack of opportunities, unfair treatment, and workplace culture [9]. An underlying component of this problem is that individuals in underrepresented groups generally indicate feeling a much lower sense of belonging in technical fields as a whole [26]. The "need to belong" is a fundamental human motivation, and it develops over time through sustained, positive interactions [4]. Hagerty et al. provide a widely cited definition of sense of belonging, stating that it "...is defined as the experience of personal involvement in a system or environment so that persons feel themselves to be an integral part of the system or environment" [11]. Creating more inclusive environments, in which people from both majority and non-majority groups find opportunities to become "integral," is a logical pre-condition to belonging, and both are keys to student success on many levels.

Fostering a sense of belonging in students has been identified as a predictor of motivation, self-confidence, academic engagement, academic success, and psychosocial success [7, 20, 22], and researchers continue to work toward a better understanding of how this feeling is defined and measured [8]. In their 2022 review of the related literature, Taff & Clifton found a need for increased discussion of the "specifics" of pedagogical approaches from which to build a more inclusive higher education ecosystem that leads to a stronger sense of belonging for all students [25]. To that end, a recent study provided support in developing computer science courses for high school teachers, finding that female role models, collaborative work, and relationships played a significant role in female students developing a stronger sense of belonging [17]. Bowman et al. identified "encouragement" and "role models" as factors that foster a sense of belonging in students from underrepresented groups [5]. Lehman et al. found that persistence of women in computing majors relates to "self-confidence, sense of fit, and in-class experiences." They suggest that this sense of fit, or sense of belonging, can be positively impacted by peer interactions and community building in the classroom [13]. Furthermore, interventions and training for developing a sense of belonging students have been frequently studied in K-12 students and in introductory CS courses in universities. Facilitator training has been shown as an effective method for helping students develop a sense of belonging, indicating that in-classroom interventions can be worthwhile and productive [14, 15]. Finally, negative impacts on the development of students' sense of belonging are also an area of active study [1, 2, 16]. While the above research makes positive strides in understanding and improving student experiences in this area, persistent gaps in the pipeline to STEM careers shows that there remains a pressing need for continued work [23].

Culturally Responsive Teaching (CRT) is one possible path to improving student outcomes and feelings of inclusion and belonging in the classroom [6, 10]. The goal of Culturally Responsive pedagogy is to center the students' identities in the learning process and to intentionally connect course content with students' lived realities. There are many strategies for meeting these goals, from creating curricula specifically for outreach to a targeted population, to using a variety of teaching methods to appeal to various students, to educating faculty on the cultural practices of underrepresented groups. Implementations of Culturally Responsive Teaching in middle schools have shown an increase in confidence in underrepresented groups; however, students showed decreased interest over time [18]. Additionally, teachers implementing these principles have communicated a need for more training and resources [24]. While these interventions and training sessions have yielded positive effects on students, there is a need for broader and more consistent applications, along with additional pedagogical materials and supports.

This work focuses on course-level CRT interventions of three general types: those providing a wide variety of perspectives on course content, those that encourage students to express their unique identities through the course work, and those that help students reflect on how their in-class experiences connect to the rest of their lives. We report here on the experiences and impacts of applying CRT strategies in both introductory and upper-level undergraduate CS courses, and provide a repository of materials for achieving these goals. Additionally, our research includes analysis of results from a survey instrument designed to investigate whether implementing these specific CRT goals impacts students' sense of belonging, specifically in underrepresented, or non-majority groups in our computer science courses.

2 Goals: Culturally Responsive Teaching

Our project's goals were to create, assess, and distribute course materials that implement best practices for inclusive teaching in Computer Science classes at all levels of our curriculum. We identified three broad areas of Culturally Responsive Teaching [6, 10] on which to focus:

- **Diverse Assets:** *Instructional materials should employ a diverse range of images and cultural perspectives within course content.* For our courses, we looked for readings that represent diverse perspectives on course topics, and images and examples that highlight diverse populations. We also identified social issues facing marginalized populations that can be incorporated into curricular materials and discussions.
- **Identity Connections:** *Courses should provide an opportunity for students to connect with new course knowledge from their unique cultural perspectives.* We developed open-ended assignments and projects to allow students to explore matters of personal interest. We also created course materials designed to encourage students to express their unique identities, experiences, and strengths.
- **Meaning Making:** *The learning experience should value the education of the whole individual.* We incorporated student reflections on learning into course materials to encourage them to connect their academic experiences and efforts to their lives as a whole. We also worked to provide opportunities for students to share experiences with one another in supportive ways.

With these goals in mind, we began by finding existing resources we could leverage, as well as crafting new course materials to pilot in the classroom.

3 Course Applications

Here we present two aspects of our course applications of Culturally Responsive Teaching. First, we detail curated and developed materials related to each of the goals outlined in Section 2. Next, we outline four case studies from our classroom experiences in implementing CRT curricular approaches and materials. These are selected to represent a range of course levels and intervention types.

3.1 Materials

Our team worked to catalog course materials that implement the above ideas for ready use both in our courses and in those of other CS educators. These materials include resources available online for widespread use, existing materials created by the team but not previously shared, and new materials created to meet needs identified during the project timeline. The following sections provide a high-level overview of the types of materials we cataloged and/or created. Note that while an item may be listed as an example of a particular category in CRT, most can fit within more than one area. For example, an open-ended project that helps students connect their unique perspectives and identities to course content can also be an opportunity for meaning making, as activities of this nature connect to the "whole individual." A full repository of these resources is available at https://eloncs.github.io/ibics/.

3.1.1 Diverse Assets.

- Resources for highlighting famous computer scientists of various identities, particularly those that are underrepresented in the field.
- Videos created specifically by and for diverse populations to introduce topics or as motivation.
- A free online text "Critically Conscious Computing" [12].

- Lesson plans for discussing ways in which AI can both help and hinder equity.
- An online Inclusive Language Guide from the APA for easy reference to current terminologies [3].

3.1.2 *Identity Connections.*

- Open-ended projects in which students can express themselves creatively through computation.
- A repository of blog prompts asking students to read and reflect on the societal impacts of technology.
- Example projects in data science that invite students to explore problems facing marginalized communities as well as those of personal interest.

3.1.3 *Meaning Making.*

- A collection of reflection questions added to course quizzes to promote meta-learning.
- Resources for adding "ethical reflections" to common CS1 lessons [19].
- An active learning lesson in which students discuss in groups their "dream AI" and try to convince others of its positive impact.
- Surveys that can be periodically given in any course to help students reflect on their learning process, their experiences overcoming challenges, and how they can change to find more success.

3.2 Case Studies

Next we present four case studies describing the implementation of a selection of the materials described in Section 3.1. These courses range from the introductory level (CS1, CS2, and Data Science & Visualization), to advanced (Artificial Intelligence). Together, these cases represent a diverse range of both student characteristics and course-level goals for CRT informed pedagogy.

3.2.1 Meaningful Art in CS1. We found that many of our current course materials could be changed in relatively minor ways in order to meet our CRT goals. For example, in our introductory class (CS1) we have often used making art with Python's "turtle" graphics package as a first assignment. Students learn simple commands to get the turtle to move around the screen, drawing a picture as it goes. The assignment allows students to draw whatever they wish, as long as it meets some basic specifications (use at least three colors and three shapes, for example). We changed the instructions of the assignment to ask the students to draw a picture that tells us something about themselves. In the comments of the code, they were asked to write a sentence telling why they chose that particular drawing.

The assignment, as originally written, has many positive traits: it is fun for students and open-ended to allow for student choice and expression. However, editing the assignment in this way did make a difference. Before, many students would make simple drawings, and every semester there were several students who would draw a house, because it is generally the first thing they think to draw that uses several different shapes and colors. The new assignment instructions, however, got students to think more intentionally about what they wanted to draw as a connection to their identities. The drawings were generally more intricate, even though the technical specifications were no different. Students submitted pictures (and explanations) like: the beach (because it made them happy), two sports logos (because parents root for opposing schools), and a purple heart (in honor of a family member). We learned that simply making explicit what we wanted the students to get from the exercise had a positive impact, as students created more diverse and nuanced imagery that helped them connect their technical skill development to their identities and experiences.

3.2.2 Learning About Diverse Computer Scientists in CS2. The second intervention revolves around exposing students in a CS2 classroom to accomplished members of the field who come from diverse backgrounds. The idea, colloquially called "Famous Fridays," is to give more students an opportunity to see people who look like them being recognized for their work in computing. Representation is a key component of belonging [17], and this activity aims to allow as many students as possible the chance to see themselves represented as an important part of the community.

Each Friday, we began class with a quick 5-10 minute history lesson about an influential person (or persons) from computer science. We introduce each person to the class through a short discussion and give the students resources to explore their background further. We chose people ranging from the early history of computer science, think Ada Lovelace, Alan Turing, and Grace Hopper, to more modern people who may be early in their careers but are making important contributions, like Joy Buolamwini, Reshma Saujani, and Andrew Ng. In our application of this idea, some "famous computer scientists" may be less famous in the classic sense of the word, and some may do work *related* to computer science but are not considered computer scientists themselves. The key aspect of this activity is to find people from different backgrounds who are doing interesting work related to computing. We considered characteristics like gender, sexual orientation, race, ethnicity, academic background, and country of origin for selection. However, the possibilities are wide-ranging, and there is no single criterion or checkbox required for inclusion. Some of the featured people have a story that allowed us to highlight the breaking down of an existing barrier or prevailing through difficult circumstances.

During the final installment of the series, we helped the students in the classroom imagine themselves as future famous computer scientists by showing a word cloud of all their names. A moment of confusion followed by a moment of excitement flowed through the room as students began to realize the names they were seeing as their own. In a sign of the times, this was followed by many students taking a snapshot of the word cloud with their phones. At this point, we revealed (or reiterated) the reason for the whole series of Famous Fridays - to emphasize that each one of them belongs in this classroom and in this field. While computing has a past that looks overwhelmingly white and male, the future has room for, and need of, *all* people.

CS2 is an important point in the CS undergraduate path for this type of intervention. Students have completed the introductory course and are beginning to look ahead to the rest of their studies and future careers in the field; however, many do not have a clear picture of what that future can and will hold. At this point, seeing faces and backgrounds that mirror their own can bring a sense of confidence and comfort that computer science is a place where they belong and where they can make important contributions.

3.2.3 Examining Social Problems Facing Marginalized Communities in Data Science & Visualization. In our curriculum, Data Science & Visualization is an introductory course with no prerequisites. Enrolled students range from first-years to seniors, with prospective and selected majors from across the full spectrum of university departments. The course content is designed to be accessible and achievable to all students, from those studying the liberal arts, to those with strong STEM backgrounds and interests. Any course with data at its core has the potential to address a very wide variety of problems through the identification of a related data set that will also be sufficient for technical skill development. As such, we identified this course as an excellent candidate for achieving our CRT goals by using data science to examine problems facing marginalized communities in the United States.

Students in this course complete several longer-term assignments in which they apply the concepts they learned through daily labs to a larger problem. In order to connect their data science skill development to the study of problems facing local, marginalized communities, we chose to craft one assignment around the topic of gentrification. The development of the light-rail line in Charlotte, NC has led to gentrification in several historically black neighborhoods [28]. In this assignment, students used PolicyMap to collect data for several neighborhoods in proximity to the light rail and one which is not (as a control) [21]. Many students looked at how racial demographics and household income changed over time, finding that the data clearly supported reports on gentrification in these areas. As one of our learning outcomes, we asked students to carefully reflect on how one might use the process of data science to tell different types of "stories," and many could easily identify that some might argue that these changes *improved* neighborhoods, making the overall outcome positive despite changes in the historic demographics of these areas.

This example represents a curricular change that does take a significant amount of time to develop. In order to create consistency throughout the semester, we added course-level objectives related to the use of data science to explore these types of problems. We also needed to scaffold activities leading up to the larger assignment, such as adding a daily lab activity in which students learned to use PolicyMap to gather data. Future work will involve adding more opportunities for student discussion and reflection, and increasing the time available to work in class and in groups to provide stronger support for students at all levels. While this was not a simple intervention, the nature of this course lends itself to integration of important social topics. Furthermore, the potential, and hopefully positive impacts of students connecting technological subjects to problems facing society has wide reach considering the diverse backgrounds and interests of those who enroll.

3.2.4 Dreaming of an Imaginary Agent in Artificial Intelligence. Artificial Intelligence (AI) is an advanced course in our departmental curriculum. The typical student enrolled in AI is a junior or senior CS major, although CS minors often take this course alongside their major studies. At the start of the semester, we added a new, seminar-like activity to better engage our students in building community within the classroom and connecting course topics to their personal interests and motivations.

We first covered the foundational elements of intelligent agents and their environments, including vocabulary for agent components such as actuators, sensors, and performance measures. Students then formed small groups and were assigned the task of imagining an intelligent agent they would like to see in the world. Each group's goal was to develop a short presentation detailing all the relevant components of their "dream AI," prepared with a venture capitalist audience (their instructor) in mind. In addition to fully describing their agent, they needed to explain its most important aspects and why investors should fund their project over any of the others.

This activity was easy to implement, as it connected seamlessly to course topics that were in active discussion. More significantly, students were *very* energized and engaged in their brainstorming discussions and presentation preparation. In fact, every member of every group spoke during their presentation even though this was not required, which showed that everyone was excited about their "dream AI," and motivated to succeed in their investment pitch. The "winner" of our imaginary funding was the "Breakfast Robot." Not only did this group clearly detail how the robot would function within the constraints of the classical agent and environment definitions we covered, they were passionate about its purpose. All agreed that a customized and delicious breakfast "on demand" would be an excellent addition to their lives. In fact, we brought the Breakfast Robot, and other ideas from that day, into many subsequent discussions as we covered different aspects of intelligent agents and systems. Doing so reinforced concepts and made them more interesting by returning to student-imagined examples. While the instructor brought the academic content forward and provided structure for group discussion and imagination, it was the *students* who made it both meaningful and memorable.

4 Assessment

To evaluate how classroom interventions affected student feelings of belonging and inclusion, we administered a survey at the beginning and end of the 2024 spring semester. The survey, described in more detail in our prior work [27], was verified as exempt through the IRB process. Students across 16 sections of a variety of upper- and lower-level CS courses had an opportunity to provide feedback, both in courses with targeted CRT-related interventions as well as in courses with no interventions. Taking the surveys was neither required nor incentivized in any course. This effort resulted in 227 responses for the the pre-survey and 110 responses for the post-survey. The following analysis focuses on the 76 distinct responses from students who completed both the pre- and post-surveys. Of these, 35 responses corresponded with intervention courses (46%). Across all included responses, 63% of students were CS majors, 73% identified as white (only), 63% of students identified as male (only), and 29% identified as female (only).

Our analysis targets student responses to 15 Likert-style questions in common between the pre- and post-surveys, which are scored on a 1 to 5 scale, from disagree to agree. Table 1 shows these questions along with the mean change from the start to the end of the semester. Results are grouped by whether students were in a course section that included a targeted, inclusion-oriented intervention ("Int.") or not ("No Int."). While the number of responses is limited (n=35 and 41, respectively), the Wilcoxon signed-rank test revealed three statistically significant changes from pre- to post-survey, indicated in Table 1 with bold and an asterisk. Students in non-intervention courses showed a significant decrease (-0.26) for the question, "Topics in the field of computer science are important to me" (p=0.03). Students in intervention courses showed a significant increase (+0.26) for the question, "I consider myself a computer science person" (p=0.01), as well as an increase (+0.40) for "Computer science classes will help me better understand myself" (p=0.008).

Of particular interest are students who fall outside the white, male demographic group. When we limit our focus to students who were in one of the intervention sections and were not white and male, we are left with 22 survey responses.[1] Among this group, four questions showed statistically significant changes from the start to the end of the semester according to the Wilcoxon test. As among the entire population of intervention course responses, the same two questions relating to being a computer science person and understanding oneself showed an increase. More interestingly, two other questions show significant decrease: "I feel comfortable interacting with computer science professionals" (-0.36, p=0.03), and "I feel comfortable interacting with computer science majors" (-0.41, p=0.02). These decreases are concerning, particularly as they affect a demographic group we especially hope to reach with our inclusion intervention efforts, and suggest that more work is needed in the future.

Survey Question	Int.	No Int.
Topics in the field of computer science are important to me.	0.09	**-0.26***
People like me make important contributions to the field of computer science.	0.09	0.32
I find the field of computer science interesting.	0.09	-0.16
Computer science courses will help me in my future work.	0.20	-0.05
Faculty in the Computer Science department demonstrate respect for individual differences.	-0.03	0.11
Computer science classes will help me better understand myself.	**0.40***	0.00
Computer science classes will help me gain skills that transfer to my other courses.	0.20	-0.05
I feel comfortable interacting with computer science majors.	-0.29	-0.11
I feel comfortable interacting with computer science professionals.	-0.17	-0.05
I have the potential to succeed in a computer science class.	-0.14	0.21
I expect to make important contributions in my computer science class or classes.	-0.14	0.26
I have the potential to make important contributions in the field of computer science in the future.	0.17	-0.11
I consider myself a computer science person.	**0.29***	0.11
I have what it takes to become a computer science professional.	0.11	-0.11
I tend to do better than the average student in STEM subjects.	0.09	0.21

Table 1: Mean changes in Likert score from pre to post survey for courses with and without an inclusion-oriented intervention. Statistically significant changes are indicated with bold and an asterisk.

5 Conclusions & Future Work

Connecting computer science curricular content with the students' lived experiences seems like a daunting task at first. Not only is it uncomfortable for many instructors to consider opening the door to discussions of social and cultural issues, but we may fear it could detract from core learning objectives. However, we did not find this to be the case. We found that with relatively minor changes we were able to translate the goals of CRT into our classrooms and see a significant impact. More time-intensive changes (as described in Section 3.2.3) were also successful in showing that one can introduce socially relevant topics and still achieve the technical goals of a CS course. In summary, we have learned the following as a result of this work:

- **There is no need to sacrifice course content to improve inclusion.** None of the courses in our study reduced their learning objectives because we are not "adding" CRT content; rather, we are improving the existing way we teach this content.
- **Using CRT does not require having large-group discussions on controversial matters.** We recognize that these types of discussions can be very beneficial to students and can help implement CRT principles; however, we also recognize that not all faculty are comfortable with this type of class activity. While some of our changes resulted in class discussions of social issues, the majority did not. Faculty can start with materials that do not invite in-class discussion and work up to the more in-depth materials as they see fit. Even the smallest change that encourages students to better connect the course content with their lives is worthwhile.
- **It helps to make the meta-goals explicit.** In our CS1 course, we added learning objectives to the syllabus that

[1]We have opted to include Asian male students within this analysis group. Our institution is majority-white, and only one student identifying as male and Asian is represented.

reflect the non-technical goals we have for students, such as "To express yourself using code," and "To persevere in problem-solving even when you are 'stumped'." These goals were restated in the course assignments and assessed by reflections on those assignments.

- **Student reflections should be required, but do not need to add to the grading load.** Our experience is that students do not take the extra step of reflecting on their work unless it is both assigned and "counts." However, reflections do not need to be read in detail or graded to be beneficial. We gave credit for reflections simply by completion, recognizing that that the personal engagement of a student with their own learning experience is inherently meaningful and worthwhile.
- **Our team saw success, even though we have a variety of backgrounds in CRT and diversity issues in general.** The course materials presented here can easily be adopted by anyone teaching related courses, even with no prior knowledge of CRT. We hope that by creating a repository of resources, we lower the barrier for any CS faculty to improve inclusivity and feelings of belonging in their classrooms.

Our future plans are informed by both our classroom experiences and survey results. First, we hope to grow our resource repository to meet the needs of each course in our curriculum. We also plan to more fully implement the principles of CRT by expanding and clarifying our goals. The process of surveying our students resulted in some surprising trends that will shape our future work. Courses with CRT interventions, as opposed to those without, showed a significant increase in student agreement that they saw themselves as "computer science people," and that their courses helped them them understand themselves better. This gives us an early indication that our work is positively impacting students' sense of belonging. However, our analysis of responses of students in courses with interventions who did *not* identify as white and male showed significant decreases in their comfort in interacting with computer science professionals and CS majors. This tells us that while we have positive motivation for continuing and expanding this work, we need to increase our focus on building a supportive community for students from underrepresented groups.

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