Attitudinal Trajectories in an Online CS1 Class: Demographic and Performance Trends

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ABSTRACT

In this research, we investigate the trajectory of attitudinal change towards computer science among students in an online CS1 class. We perform this investigation to address several trends in modern computer science education. First, as computer science increasingly becomes a required class for all majors, how do students' first experiences with the subject impact their attitudes? Second, as online education continues to expand, how does enrolling in CS1 online specifically affect audiences that may be marginalized in both CS classes and in online learning environments, such as women and underrepresented minorities? Third, can we intervene to improve attitudes towards computer science, especially among those marginalized audiences? In this research, we poll students in an online for-credit CS1 class four times to observe the change in their attitudes towards computer science over time and intervene with some students to try to improve their perception of computer science. We find that attitudes towards computer science improve with initial exposure, that women's attitudes towards CS begin less positive but follow the same trajectory, and that mid-semester regression in attitudes toward computer science may predict eventual struggles to perform well in the class.

CCS CONCEPTS

• Computing methodologies~Online learning settings • Social and professional topics~CS1

KEYWORDS

Computing attitudes, CS1, online learning

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1 Introduction

Over the past several years, computer science has increasingly become a required subject for non-majors [37, 43]. It has also increasingly been taught online, with the surge in online degree programs from providers like FutureLearn and edX.org led by degrees in computing and related fields [27, 33]. These two trends coincide with preexisting differences in access to CS education based on race, ethnicity, gender, and socioeconomic status [8, 11, 31, 44, 48]. These developments have raised questions about how computer science education changes as we transition to different audiences and modalities.

Significant research has been devoted to exploring the experience of non-majors in computer science classes [12, 21, 22, 45, 52], as well as the comparative experience of online students [24, 28]. While some has examined achievement, a second common question is regarding students' attitudes towards computer science based on their experience in the class [12, 29, 39]. In this work, we contribute to this research by examining the attitudinal trajectories of students in a university-level online CS1 class taken primarily by non-majors. We evaluate students' attitudes towards computer science four times during the term, then separate trends based on prior CS experience, eventual class performance, gender, and racial or ethnic minority status. We also perform a controlled experiment aiming to improve attitudes towards computing especially among underrepresented minorities and women. We find several trends in attitudinal trajectories, as well as promising, though not conclusive, results from the controlled experiment.

2 Related Work

This work examines attitudes toward computer science, especially among non-majors, women, and underrepresented minorities in their first CS class.

2.1 Attitudes Towards Computing

In this work, we employ a standardized inventory for assessing attitudes towards computer science, the Computing Attitudes Survey (CAS) [19]. This inventory has been used in several studies interested not only in performance in computing, but also in dispositions [4, 15, 36, 50], although other inventories have been used as well [35, 49, 51]; we selected CAS due to prior familiarity and due to its development specifically in the context of a CS1 course, similar to our environment.

Past research on attitudes towards computing in general has found, for example, that women were "less interested and in computers and less confident than males" [42], a finding corroborated elsewhere [5, 7] as well as in this work. Other work has similarly found differences in attitudes based on race and ethnicity [3]. These types of inventories have also been used to monitor for changes in attitude through experience with a CS course [14].

2.2 Marginalized Audiences

The gender and racial divides in computing are well-documented, and numerous solutions have been tested to improve participation rates among marginalized audiences in CS education in both formal [10, 16, 30, 31] and informal [17, 40, 41, 47] contexts.

Most pertinent to our work here has been research emphasizing the importance of role models in reaffirming the belongingness of women and underrepresented minority students. Many of these efforts have been very proactive, such as efforts to pair women and minority students with real-life mentors [1, 9, 34, 38], especially in the context of recruitment and retention [2, 6, 13, 16, 18, 23, 46]. While desirable and beneficial, these types of efforts are difficult to scale; in the class under evaluation in this work, there were 66 undergraduate women, posing a challenge for finding individual mentors. We thus build on other more scalable efforts to communicate broadly the important roles women and underrepresented minorities have played in CS history [20].

3 Study Context

This study takes place in the context of an online for-credit CS1 course offered at the Georgia Institute of Technology. The course was taught in Python, presupposed no prior computer science knowledge, and ran for 17 weeks. While enrolled in the course, students watched online lecture videos, completed online problem sets with live feedback, and took asynchronous tests with a digital proctoring solution. A fuller description of the course context can be found in [24], [26] and [28].

The student body for the course (249 students) was approximately evenly split by gender (51% men, 49% women). 17% of the students in the class self-identified as coming from a racial or ethnic minority group. In measuring prior CS experience, we use the distinction illustrated in [25]: 51% of students reported no prior CS experience; 28% reported prior expertise (that is, successful completion of a CS course in the past); 12% reported prior experience (that is, an unsuccessful attempt at a CS class); and 8% reported informal prior experience. 10% of students were CS majors; of the other 90%, the most common majors were Business (17%), Industrial & Systems Engineering (16%), Biology and Biochemistry (14%), and Neuroscience (7%).

4 Methodology

Students were asked to complete four surveys throughout the semester, during the 1st, 5th, 9th, and 17 weeks of the semester. This pacing was selected to accommodate the class's existing survey pace, where they seek early feedback in the form of the 5th-week survey and avoid survey fatigue by skipping a potential 13th-week survey. As part of these surveys, students completed a validated instrument for assessing attitudes towards computing, the CAS [19]. The CAS has 25 prompts, each of which can contribute a score from -1 to 1 to a student's overall attitude score (1 if they agree with how an expert would respond to a prompt, -1 if they disagree, 0 if they are neutral). Students' attitudinal scores may thus vary from -25 to 25. Surveys were required for a nominal part of course credit (1% total); students could opt out of having their survey responses considered for this observational study.

As noted later, students also had the opportunity to consent to an additional experimental study testing an intervention to improve attitudes towards computing especially among women and underrepresented minorities. Students who opted into the study and were assigned to the Control group received the same experience as those who opted out of the experiment.

In total, 161 students opted into the observational study and completed all four surveys (including correctly passing the attention-check question on each survey). Of these 161 students, 71 also opted into the experimental study. 34 of these 71 students were assigned to the Control condition, while 37 were assigned to the Experimental condition. The observational study includes those 124 students that received the Control material and completed all 4 surveys, whether because they opted out of the experimental study (90 students) or because they opted into the study and were assigned to the Control group (34 students).

5 Observational Results

We divide the results of this research into four broad buckets. First, we investigate the overall trends, in order to set something of a baseline regarding students' attitudes in computer science. Then, we break out those attitudinal trajectories by prior experience with CS, by eventual success in the course, and by gender, racial, and ethnic identities.

In order to monitor for lurking variables among the trends, we first charted the relationships between gender, minority status, prior CS experience, and eventual grade in the class. These results are shown in Table 1.

Table 1. Number of students in the observational study at each intersection between gender, minority status, prior CS experience, and eventual grade received.

	Men	Women	URM	Non-URM	A	B	<B
Expertise	22	12	2	30	31	3	0
Experience	5	6	1	6	6	2	3
Informal	5	6	3	8	7	1	3
None	26	42	12	54	42	19	7
A	47	39	9	72			
B	8	17	7	18			
<B	3	10	2	8			
URM	48	50					
Non-URM	7	11					

A number of trends worth keeping in mind moving forward emerge in these numbers. First, women and underrepresented minorities were more likely to enter the course with no prior CS experience. Second, students with prior expertise were unsurprisingly more likely to receive A's than any other group. Third, women and underrepresented minority (URM) students were less likely to receive A's than men and non-URM students, respectively. These trends are relevant insofar as it is unclear if differences in performance and attitudes in this course will be owed to differences in gender and race/ethnicity, or if they are due to prior experience which carries a demographic component.

5.1 Overall Trends

First, we document overall trends observed throughout the course. These trends are shown in Figure 1. Throughout these charts, we add extra spacing between weeks 9 and 17 to correctly represent the passage of time, but points indicate when surveys were actually taken.

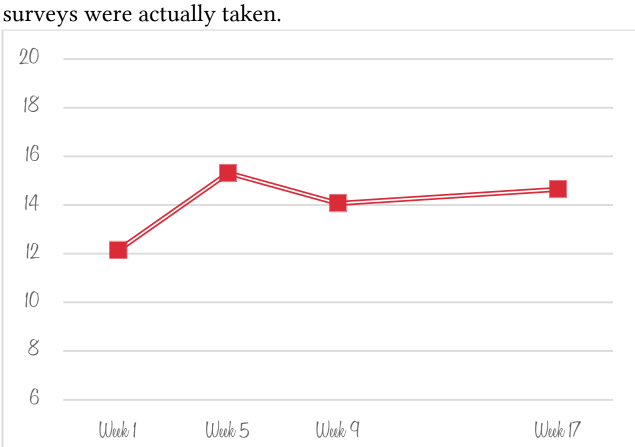

Figure 1: Scores on the CAS for all students in the observational study on each of the four surveys (n = 124).

The overall trajectory sees students starting with a moderate positive attitude toward CS at 12.15, which increases with statistical significance ($t = 3.56$, $p < 0.001$) by week 5. It then diminishes a bit in weeks 9 and 17; both week 9 ($t = 1.97$, $p < 0.05$) and week 17 ($t = 2.45$, $p < 0.05$) retain statistically significant improvements compared to week 1, albeit weaker ones. The overall trend is thus that participation in the course leads to a moderate improvement in attitudes toward CS, which arises early in the course.

5.2 Experience Trends

Our first subdivision of the data occurs by level of prior experience. Figure 2 shows these trends.

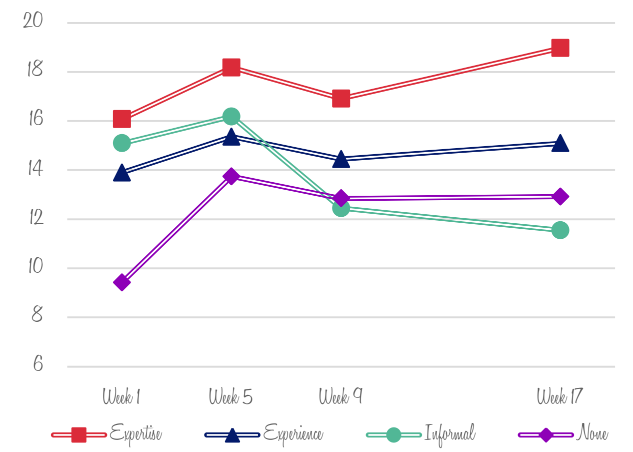

Figure 2: Scores on the CAS on each survey by level of prior CS experience. n = 34 for Expertise, 11 for Experience, 11 for Informal, and 68 for None.

Notably, students with any level of prior experience enter the course with more positive attitudes than those with no prior experience ($p < 0.05$ for all three comparisons). From there, students with prior expertise, prior experience, and no prior experience follow a similar trend to the overall trend, rising over the first quarter of the course before levelling off. For those with prior experience and prior expertise, these changes fit the pattern but are not themselves statistically significant. For those with no prior experience, a statistically significant improvement ($p < 0.01$ for all three comparisons) relative to start-of-course attitudes is observed at weeks 5, 9, and 17. Although the informal trend looks different and negative, the sample size is too small and the standard deviation in scores too high to be significant.

We thus observe that students with no prior CS experience specifically saw a statistically significant improvement in their attitudes towards CS as the semester progressed.

5.3 Performance Trends

Third, we are interested in the extent to which attitudes at in-semester survey points can be used to predict students' final course performance, following with existing work on finding higher- and lower-performing students earlier [32]. It is unsurprising that students with more positive attitudes toward the subject generally perform better in the course, the specific shape of the trends (shown in Figure 3), however, is interesting.

Students who would go on to receive A's in the class began the course with slightly more positive attitudes than those who would receive Bs or below, although this difference was not statistically significant. From there, all three groups of students experienced near-identical jumps in their attitudes over the first 5 weeks, gaining ~2.5 points each (due to sample sizes, this was only statistically significant for those who went on to receive A's). While students who would receive A's maintained those positive attitudes, those that received Bs or below then saw a precipitous drop. These students' final attitudes were lower than their attitudes at the 5-week mark with statistical significance (though not statistically significantly lower than their start-of-course attitudes).

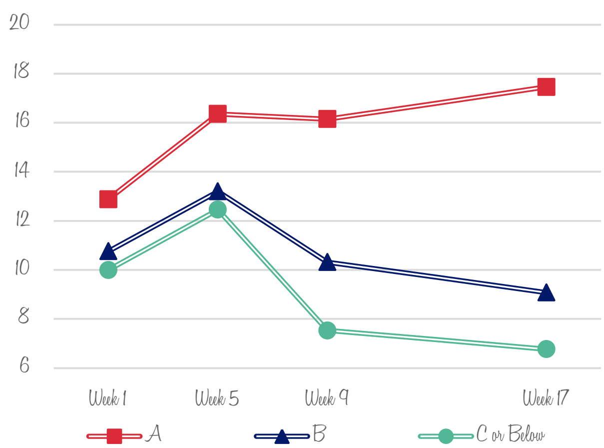

Figure 3: Scores on the CAS on each survey by grade ultimately received in the class. n = 86 for A, 25 for B, 25 for B, and 13 for C or Below.

The most notable part of this trend is that the initial jump in attitudes was mirrored across all eventual performance levels. The design of this course covers the most difficult topics (conditionals, loops, functions) from weeks 5 to 9, suggesting the escalating difficulty in the course material is playing both a pivotal role in determining students' grades and attitudes.

The trend that students who ultimately perform better have more positive attitudes towards computing is not surprising; the trajectory itself also mirrors the fact that students obtain greater clarity about their grade as the semester progresses. These comparisons are useful, however, to provide context to the following demographic trends.

5.4 Demographic Trends

Our first demographic trend concerns gender-based differences in attitudinal trajectories. Figure 4 shows these differences.

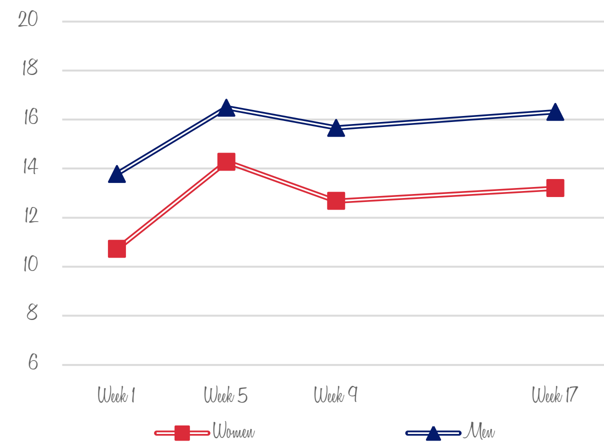

Figure 4: Scores on the CAS on each survey by self-reported gender identity. n = 66 for Women, 58 for Men.

Both men and women demonstrate the same overall attitudinal trajectory, with men offset +3 points on average at every stage. These differences are statistically significant ($p < 0.05$) at weeks 1, 9, and 17, although not week 5 ($p = 0.06$). This trend has a likely obvious interaction with trends in prior experience; women were more likely to have no prior experience, and both those groups are more likely to begin with less positive attitudes. More significantly, though, is the finding that participating in an online CS course does not have a differential effect on women. Concerns have been raised that the toxicity that can emerge in online environments can have a particular negative effect on women in online classes; here, however, that does not appear to be the case. While the online class was not successful in removing attitudinal differences between men and women, it also did not exacerbate them.

Secondly, we also differentiate these trends based on minority status. Figure 5 shows these trends.

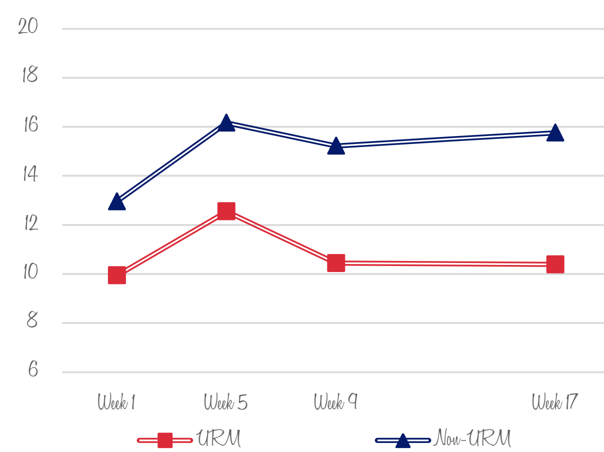

Figure 5: Scores on the CAS on each survey by self-reported racial or ethnic identity. n = 18 for URM, 98 for Non-URM (8 chose not to disclose).

Like gender, both URM and non-URM students follow a similar attitudinal trajectory, rising from week 1 to week 5 then declining again. However, the decline among URM students was more pronounced, leading to no statistically significant improvement in attitudes among URM students; non-URM students, on the other hand, did experience a statistically significant improvement in attitudes ($t = 2.66$, $p < 0.01$). These diverging trends lead to a statistically significant difference in end-of-course attitudes ($t = 2.67$, $p < 0.01$) that was not present at the start of the course ($t = 1.80$, $p = 0.07$). These trends are what would be expected from an audience coincident with diminished course performance, but it is not clear which factors cause which: are URM students struggling more in the class, leading to lower grades which lead to less positive attitudes? Or is the course material less inclusive to URM students, leading to less positive attitudes which lead to lower grades?

5 Experimental Intervention

These studies hypothesized that there are interactions between gender, minority status, and attitudes toward computer science. The observational study above demonstrates some of these effects, such as the different attitudinal starting points between men and women (potentially due to prior experience) and the different trajectories among URM and non-URM students (potentially due to course performance).

We also created an intervention aimed at improving attitudes toward CS among women and underrepresented minority students. We wrote biographies for 40 prominent people in CS—16 historical figures, 16 current leaders, and 8 faculty at our institution—deliberately chosen to represent a diverse sampling of prominent individuals in computing, including 20 women and 20 members of URM (including 10 URM women). For this term, we selected 14 biographies (7 women, 7 members of URM) and added their profile to the course (two profiles at the end of each of 7 chapters of course material) along with a photo; we required students to answer 2 questions about each biography.

5.1 Methodology

Students were offered the chance to opt into an experiment testing this new material. No incentive was offered for participation; students were instead informed that the new material would replace existing material, and thus there would be no additional work involved in participating in the study. Students in the Experimental group received the material described above, while students in the Control group received descriptions of significant moments in computer science history and descriptions of other CS classes offered at the institute; notably, neither of these topics discussed any individuals by name, and the approximate volume and number of questions was the same as in the Experimental group. 117 students opted into the study. 58 were assigned to the Experimental group receiving this new content, and 59 were assigned to the Control group receiving the old content. Of these 117, 71 completed all four surveys (34 in the Control group, 37 in the Experimental group).

5.2 Results

We first analyze the differences in attitudinal trajectories based on treatment. The Experimental group appear to receive a greater initial increase to their attitudinal score, although the differences are not statistically significant for any of the three weeks ($p = 0.08$, 0.08, and 0.44 for weeks 5, 9, and 17 respectively). Figure 6 shows these trends.

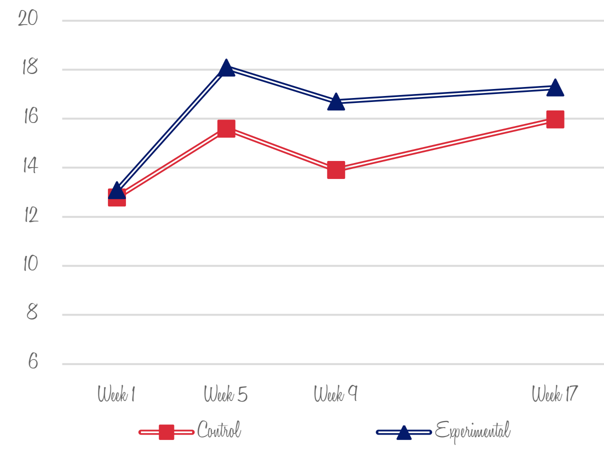

Figure 6: Scores on the CAS on each survey by assignment to either the Control or Experimental condition. n = 34 for Control, 37 for Experimental.

We then break these trajectories out by gender and URM status. Figure 7 shows gender-based trends. The shape matches that of the overall trends from Figure 6 (unsurprisingly, given the 48 of the study's 71 complete participants were women). These trends were encouraging but not statistically conclusive ($p < 0.1$ for weeks 5 and 9). We take this as evidence that this type of initiative is worth further study as a mechanism for improving women's attitudes toward computer science.

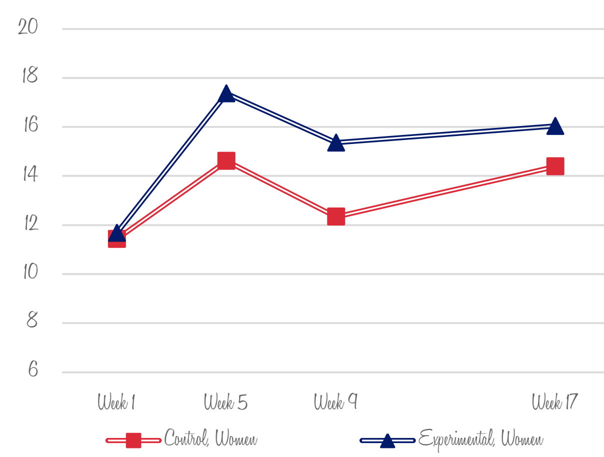

Figure 7: Scores on the CAS on each survey by gender and assignment to either the Control or Experimental condition. n = 23 for Control Women, 25 for Experimental Women.

Due to the low sample size, trends for underrepresented minority students (shown in Figure 8) are less conclusive.

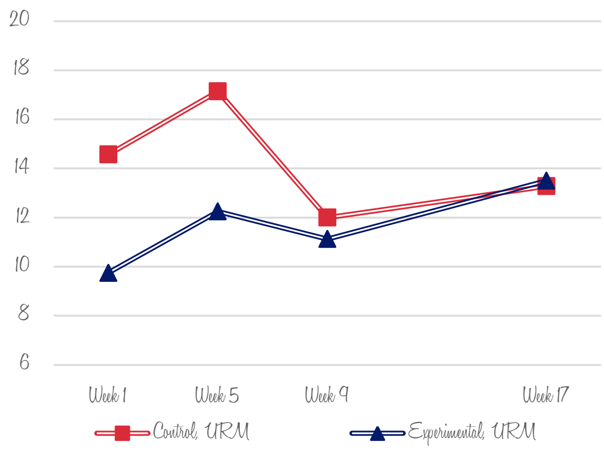

Figure 8: Scores on the CAS on each survey by URM status and assignment to either the Control or Experimental condition. n = 8 for Control URM, 7 for Experimental URM.

Most significantly, we observed a statistically significant ($t = 2.182$, $p < 0.05$) difference in initial attitudes towards computer science, which narrowed and disappeared over the course of the study. Students in both treatments closed the study with equal attitudes towards computing, despite the fact that students in the Experimental group began with significantly less positive attitudes. While this shows that URM students receiving the Experimental material experienced a greater increase in attitudes towards computing, the low number of participants in each group leaves this largely inclusive, except again as an encouragement for future research on this type of intervention.

6 Conclusion

These disparate trends contribute to an overall view of attitudinal trajectories in this online CS1 class. We note that exposure to computer science appears to improve students' attitudes toward the subject, as all students' attitudes improve upon initial exposure, and these improvements are most extreme among those with the least prior CS experience. We find that women and underrepresented minorities enter with less positive attitudes toward computing than men and non-URM students respectively, but women follow the same attitudinal trajectory; this indicates that participation in an online class does not appear to be exacerbating attitudinal gender differences, nor does it appear to resolve them. With regard to underrepresent minorities, there is a more pronounced difference in trends, where URM students' attitudes do not show any overall change, while non-URM students' attitudes show the documented improvement; it is unclear, however, the extent to which this is due to difference in performance, or if in fact it is the *cause* of differences in performance.

Regardless of the reason, these findings demonstrate the need to improve attitudes toward computing especially among women and underrepresented minorities. Toward this end, we performed an experiment testing the role that exposure to diverse role models in computer science may improve these students' attitudes. The results were promising, but not conclusive; there is evidence of the potential of this approach, but that evidence stops short of conclusive endorsement.

6.1 Limitations

Some limitations of this work are clear; it takes place in the context of only one CS class without a comparison to evaluate the extent to which these trends are specific to this university, to online classes, etc. It is for this reason that we specifically examine differences among subgroups rather than make broad claims regarding students' experiences in CS1 in general.

More specifically, our observational study has a clear limitation: one third of students in the observational study are those that opted into the experimental study but were assigned to the Control condition, while two-thirds are those that did not opt in at all. This means that any differences in the *kinds* of students that opted into the experiment will magnify the apparent traits of the students who opted out, as they are disproportionately represented. To check for this, we checked for trends in the kinds of students that opted into and out of the controlled experiment, but we found no notable differences.

6.2 Future Work

This work has identified trends in attitudes toward computer science based on gender and minority status and shown the potential of a lightweight approach to improving attitudes among those marginalized groups. Future work, both by ourselves and others, should focus first on ascertaining the extent to which these trends are general to CS classes or specific to our context, and second on evaluating further the potential of this approach to improving attitudes toward computing. Could a greater number of biographies, a more individualized curation of content relevant the particular student, or a more open-ended assessment of that knowledge lead to even greater outcomes? Additionally, there is a parallel question: could exposure to a diverse set of role models in computing also change the perception of non-marginalized populations on who "belongs" in computer science, thus creating a more inclusive community?

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We would like to note that beyond the first author, the authors of this paper are listed in alphabetical order; the relative contribution of each subsequent author is the same.

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