Overcoming Misconceptions About Computer Science With Multimedia

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ABSTRACT
Preconceived ideas about computer science may discourage students, especially women and minorities, from pursuing study in the field. Many of these common, but negative stereotypes are misconceptions. We address these misconceptions in multimedia courseware developed for a CS0 or CS1 course covering a breadth of topics in computer science. Experimental results show that the multimedia overcomes negative stereotypes, including a couple that are more pronounced for women. We discuss implications of these results for computer science curricula.

Categories and Subject Descriptors
K.3.2 [**Computer and Information Science Education**]: Computer Science Education, Curricula.

General Terms
Experimentation, Human Factors.

Keywords
Computer science education, introductory courses, CS0, CS1, misconception, women, user interface design.

1. INTRODUCTION
A number of preconceived ideas or stereotypes about computer science and professionals in computer science are common today among the general public, including students of all ages. Some of these ideas are misconceptions which present a negative image of the field, and may discourage some students, especially females and minorities, from pursuing a course of study or career in computer science. The number of women entering computer science and information technology has been declining, while the demand for professionals in these fields has grown [5][6][7].

The CIMEL (*C*onstructive and *c*ollaborative, *I*nquiry-based *M*ultimedia *E*-*L*earning) project is attempting to increase interest in computer science while improving learning in CS0/CS1 courses through the use of interactive, multimedia courseware [3]. Version 1 of the courseware complements two textbooks, *The Universal Computer: Introducing Computer Science with Multimedia* [2] and *A Multimedia Introduction to C++* [1]. Figure 1 shows a sample screen capture. Sample content and documentation are available at www.cse.lehigh.edu/~cimel.

The multimedia interface includes personae representing professors, a teaching assistant (shown above), a librarian, and students, who are diverse with respect to gender and ethnicity. They explain and discuss concepts through audio, optional text boxes (one is shown), and graphical images and animations (the buttons above are also animated). Interactive quizzes, collaboration, and internet exploration tools actively engage the learner, and different options for viewing the material (audio versus text boxes, a "Just the Facts" mode with text and reduced graphics) allow the student to customize the environment.

The first chapter in both textbook and multimedia includes a section dealing with misconceptions about computer science. Our hypotheses were: 1) students taking a first semester course in computer science still have many negative stereotypes about the field, 2) effective multimedia can change student attitudes, and 3) effective multimedia can especially help overcome misconceptions that may be more common for young women, such as "Computer scientists work alone at their computers." We designed an experiment which measures students' attitudes prior to viewing the multimedia, and again after completing it, and then compared the results. The results are very promising. We plan follow-up studies to see if these effects endure, and also to see whether they can be duplicated with students in sixth grade.

2. MULTIMEDIA CONTENT
The multimedia begins with a brief section (about ten minutes) introducing the idea of the universal machine as a general purpose computer, as well as the distinction between actual and virtual machines. (Subsequent sections go into more detail, including an interactive simulation of a Turing machine.) The second section starts with an Afro-American woman professor and an Afro-Asian male student dialoguing about the field of computer science. Then comes the screen shown in figure 1, which presents six common misconceptions: "Computer science is for nerds," "Computer science is for math whizzes," "Computer science is about computer hardware," "Computer science is about writing programs," "Computer science is about application programs," and "Computer scientists work alone at their computers." Each of these buttons go to different screens, which include videos of a diverse group of professionals and students describing their personal experiences, which counter each misconception. A drag and drop exercise at the end of the section reinforces the main points made in the videos.

Audio, video, graphical images, simulation, text, and an interactive quiz are all used to convey and reinforce the material [9][11][12]. These varied media target different learning styles. For example, narration provided by the professor, TA, and student can be delivered via audio to sensory learners, while those who

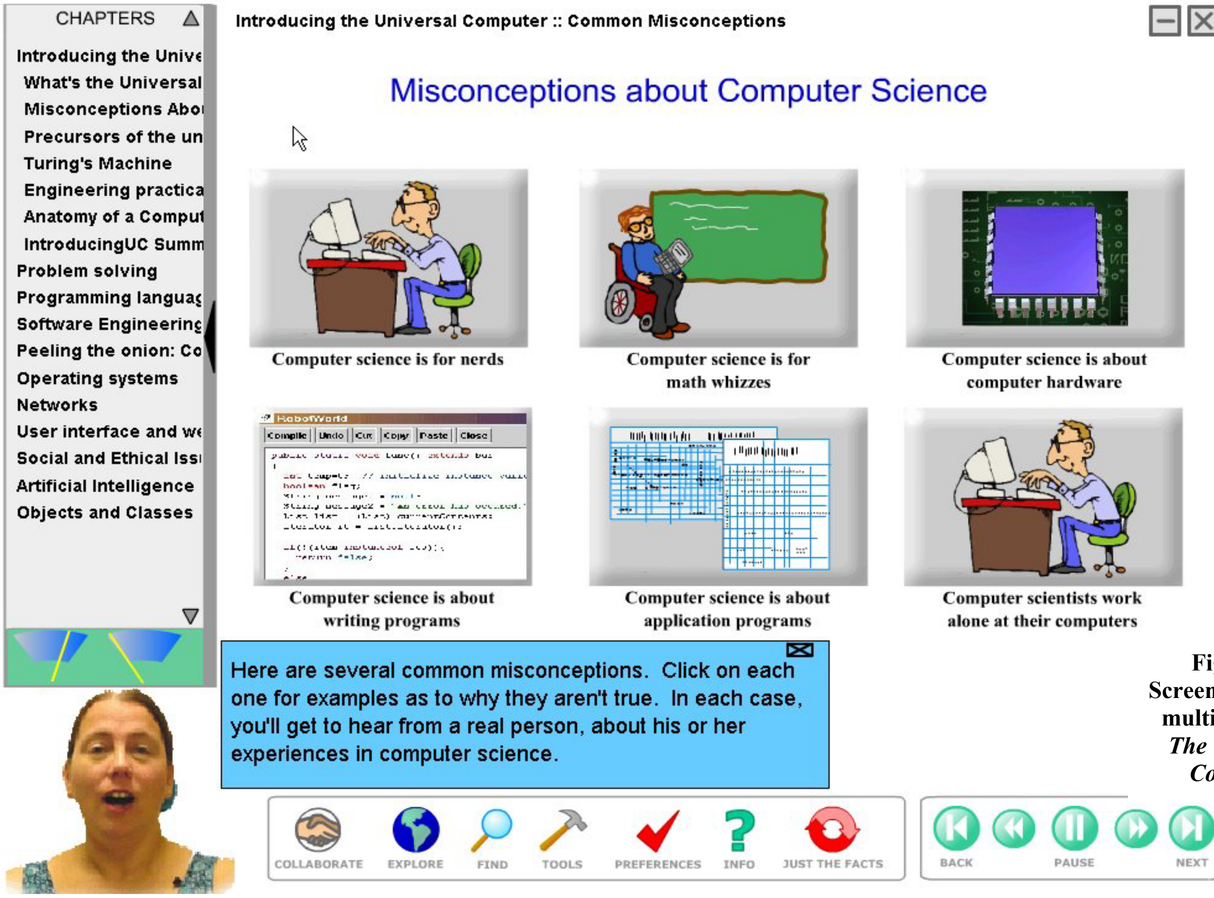

Figure 1: Screen capture of multimedia for *The Universal Computer*

prefer reading can display text boxes. Text is not shown with audio by default as according to Mayer's study [8][10]. Previous studies have shown that CIMEL multimedia helps graduate and upper level undergraduate students learn concepts in software engineering [4], and also helps students in a first semester course learn Java programming using BlueJ and an objects-first approach [4]. The videos of real people in the field give a more credible and personal viewpoint on the misconceptions about computer science. Women and minorities are included so that diverse students can more easily identify with them and their viewpoints. Finally, the interactive exercise at the end of the section reinforces the major points by actively involving the student in reviewing the concepts. It verifies the student's understanding and provides immediate feedback on incorrect responses [4].

Our testing used the multimedia alone, in a laboratory setting, though we believe it can also be used in conjunction with classroom discussion. The multimedia reaches more students with different learning styles. The videos essentially bring six guest speakers, diverse in gender, ethnicity and experiences, into the classroom, right at the beginning of the course.

3. EXPERIMENTAL DESIGN

55 undergraduate students enrolled in two introductory computer science courses (Survey of Computer Science, a CS0 course for non-CS majors, and Introduction to Computer Science, a CS1 course with more time to be spent on C++ programming) participated in the experiment, held the first week of class as part of their activity in a multimedia computer lab. The participants completed a demographic survey (including age, gender, ethnicity, major, and prior experience using computers). Two-thirds of the participants then took a pre-test of ten questions, in which they indicated their level of agreement (on a scale of 1 to 5) with ten statements about computer science and computer scientists. (We wanted to determine if the pre-test might have an effect, by comparing the results of those who took the pre-test with those who did not.) All of the students then completed the multimedia, using random user ids affixed to their questionnaires. The multimedia recorded user activity to a server. After completing the multimedia, all participants filled out the post-test, consisting of the same ten statements as the pre-test, in a different order:

1. Computer scientists write programs all day.
2. Computer scientists get to work with lots of interesting people.
3. A strong math background is needed to succeed in computer science.
4. Many computer scientists have poor social skills.
5. Good verbal and written communications skills are important for a successful career in computer science.
6. Computer scientists spend all their time sitting in front a computer.
7. Computer scientists study how to make computers easier for people to use.
8. Computer scientists need to understand other fields in order to make computers do what their users need them to do.
9. A career in computer science would be dull and boring.
10. Most computer scientists spend a lot of time building newer and faster hardware.

4. DATA ANALYSIS

In Table 1, each pretest mean is the mean value of 38 answers for each question, and each post-test mean is the mean value of 55 answers for each question. All but three items (7, 8, and 9) are significantly different from the pretest to the post-test and all in the expected direction—multimedia has the positive effect of overcoming these misconceptions ($p<=0.01$). The mean scores for the questions on the pretest showed that for most of the questions, the misconceptions identified in the multimedia did exist. The most strongly exhibited misconception was that strong math skills are needed to succeed in computer science. The next were "Computer scientists spend a lot of time building hardware," "…spend all their time sitting in front of a computer," "…do not get to work with interesting people," and "Computer scientists write programs all day." Two statements that scored well (did not strongly exhibit misconceptions) were "Computer scientists need to understand other fields" and "Computer scientists make computers easier to use."

Table 1 Pretest of 38 students and Posttest for 38+17 students

Statement	Pretest Mean	Posttest Mean	Mean Post-Pre	Significance (p)
1. Programming	2.71	1.97	-0.74	0.001
2. Interesting people	3.24	3.82	0.58	0.001
3. Math background	3.84	2.45	-1.29	0.001
4. Social skills	2.61	2.05	-0.56	0.001
5. Communication	3.50	3.92	0.42	0.005
6. Time at computer	2.92	2.18	-0.74	0.001
7. Easier to use	3.97	3.84	-0.13	0.418
8. Other fields	4.16	4.37	0.21	0.160
9. Boring career	2.37	2.16	-0.21	0.088
10. Hardware	3.00	2.45	-0.55	0.001

5=Strongly Agree; 4=Generally Agree; 3=Sometimes Agree; 2=Generally Disagree; 1=Strongly Disagree Maximum possible score was 5.

To eliminate the possibility that the pretest influenced student responses on the posttest, we compared mean posttest scores of those who took only the posttest to those who took both. Only one question (3) showed a significant difference, which was small. The pre-test does not seem to bias the post-test, leading us to believe that the significant effects noted above must be due to what the students learned from the multimedia.

Most interesting was a comparison of results for males and females (Table 2). 40 respondents were male and 15 were female. On most questions, the females scored higher than the males on both the pretest and posttest, and showed a greater gain for those questions where the pre- and post-test differences were significant. On two questions, "work with interesting people" and "spend a lot of time building hardware," females scored significantly lower on the pretest than males, but showed a much larger gain on the posttest (see rows 2 and 10 in Table 2, $p<.01$ in both cases).

Table 2 Pre-test means of 9 female and 29male students and Post-test means for 9+6 female and 29+11 male students

S	Female			Male		
	Pretest Mean	Post-test Mean	Mean Post-Pre	Pretest Mean	Posttest Mean	Mean Post-Pre
1	2.22	1.44	-0.78	2.86	2.14	-0.72
2	**2.89**	**3.89**	1.00	**3.34**	**3.79**	0.45
3	3.67	2.11	-1.56	3.86	2.55	-1.21
4	2.22	1.78	-0.44	2.72	2.14	-0.58
5	3.67	4.33	0.66	3.45	3.79	0.34
6	2.67	2.00	-0.67	3.00	2.24	-0.76
7	3.78	3.78	0.00	4.03	3.86	-0.17
8	4.33	4.33	0.00	4.10	4.38	0.28
9	2.33	2.11	-0.22	2.38	2.17	-0.21
10	3.22	2.00	-1.22	2.93	2.59	-0.34

5=Strongly Agree; 4=Generally Agree; 3=Sometimes Agree; 2=Generally Disagree; 1=Strongly Disagree Maximum possible score was 5.

We also looked at other breakdowns of the data based on demographics. 20 students were enrolled in the Survey of Computer Science (non-majors) course, and 35 were enrolled in the Intro (majors) course. 25 were computer science majors. Skill levels ranged from prior coursework and/or experience (33) to first course (7). 46 were Caucasian; other ethnic groups represented were too small to be statistically significant. 41 were 18 or 19 years old, and 13 were 20 to 21. There were 35 freshmen, 7 sophomores, 6 juniors, and 7 seniors.

Of these groups, only two showed any significant difference: age and class. The 18 to 19 year olds had more correct perceptions on the posttest than the 20 to 21 year olds did. Freshmen had a higher total mean score for both the pretest and the posttest than seniors. In fact, as class status rose, total mean scores for both the pretest and posttest declined.

The multimedia software records user interactivity. Every student in the experiment did the drag and drop exercise. 67.3% of students were not able to drag all counter-arguments to the correct stereotypes on the first attempt, though all were able to complete the exercise after more than one attempt.

5. DISCUSSION

The data for the entire group clearly show a significant improvement for seven of the questions on the survey. It so happens that the three questions which do not show significant change were those that were addressed only incidentally by the multimedia. For example, the multimedia did not explicitly address a misconception that explicitly stated that computer scientists only studied computing and did not need to understand other fields, although one of the professionals in the videos talked about working closely with her users to build systems that helped them do their jobs better. Also, two of these questions (7 and 8) also scored well on the pretest, so there was little room for improvement (i.e., these are apparently not misconceptions). The students did not exhibit strong misconceptions about these statements before viewing the multimedia, and so the multimedia did not change their opinions significantly. The question about computer scientists making computers easier to use may be somewhat vague; students may think of computer scientists making a specific task easier to do, or may not relate the statement to developing intuitive user interfaces.

Statement 3 ("A strong math background is needed to succeed in computer science") had the greatest improvement of all. It correlates directly with the "Computer science is for math whizzes" misconception. (It also had the lowest initial score, indicating that most students believed that a strong math background is needed to succeed in computer science.) It is interesting to note that this finding comes on the heels of a recent issue of the *Communications of the ACM* (September 2003) with several articles devoted to the necessity of a strong math background for computer science. Curriculum developers may want to consider the impact of their convictions (or biases) on students entering the field. Could CS curricula put more explicit emphasis on the formal requirements of computing (i.e., symbolic logic, algorithmic proof, etc.) than mathematics per se?

The statements showing the second and third highest gains, "Computer scientists write programs all day" and "Computer scientists spend all their time sitting at the computer," also correlated directly to explicitly-stated misconceptions in the multimedia. These findings also have a bearing on computer science curricula, which by and large emphasize programming in the first several courses. We think computer scientists need to take another look at the recommendations of *Computing Curricula 1991* and *Computing Curricula 2001*[1] by introducing a breadth of knowledge areas in the first computer science course.

The mostly higher posttest scores for the female students than for the male students may be an important clue about how to widen the "incredibly shrinking pipeline" for women coming into computer science [5,6]. The lead author has observed that female students tend to stay longer in multimedia lab than males, and that *all* unsolicited favorable comments about the multimedia come from female students. The two questions on which the women had the lowest pretest scores and showed the greatest gains both relate to social aspects of computing—working with interesting people and spending a lot of time building hardware. When we showed an earlier prototype of the misconceptions section at a workshop of K-12 teachers and teaching fellows, they strongly recommended that we address another misconception that they believe is especially common for young girls. So we added a button/video interview for "Computer scientists work alone at their computers," expressly to address this issue. We are encouraged to find that this material can have a significant impact on young women first learning about computer science.

The differences between younger and older students could be explained in several ways. One possibility is that the multimedia targets beginning undergraduate students, and hence more sophisticated students may find it less appealing.[2] But this theory does not explain why both the pretest and posttest scores decreased with age and class standing, which leads us to a more troublesome hypothesis: that undergraduate education may be reinforcing negative stereotypes, making it more difficult to modify common biases. This possibility is a serious concern which warrants further investigation.

Even after the initial discussion, animated button, and video interviews, two-thirds of the students needed multiple attempts to complete the interactive drag and drop exercise, yet all were able to do so with multiple attempts. The exercise reinforces the concepts they learn from the earlier material, reducing the likelihood of incorrect interpretations of the material.

These results confirm feedback from students and teaching assistants from previous versions of this course, telling us that first year students have a hard time seeing how what they are learning in a first year course relates to "the real world." The people talking on the videos are all from real life and convey experiences that are contrary to common stereotypes. We therefore plan to incorporate more "real world" videos in future versions of the video, with professionals describing experiences in particular fields covered in the book and multimedia.

6. FURTHER INVESTIGATIONS

This study looked at the immediate influence of the multimedia. We plan to re-administer the posttest to the same students at the end of the semester, to determine whether there is a long-term effect, in the context of the entire course, using *The Universal Computer*. We hope that the multimedia continues to engage the students, especially female students, giving them a broader perspective of the field.

Since we do not have enough data for minority students, we think it would be a good idea to conduct a follow-up study with a larger number of students from underrepresented groups, perhaps at other universities and/or community colleges.

The negative correlation between class standing and total mean scores on both pretest and posttest warrants further investigation. First, we may need to determine if similar result are observed with a larger group of upper-level undergraduate students in computer science. If the pre- and posttest scores of a larger group show the same results, an investigation into the possible reasons should be undertaken. If factors in the environment of the computer science

[1]Tucker, Allen B., et al., *Computing Curricula 1991: Report of the ACM/IEEE-CS Joint Curriculum Task Force*, ACM Press, New York, 1991 took a strong position recommending a breadth-first approach to introducing computer science. *Computing Curricula 2001* (www.computer.org/education/cc2001/steelman/cc2001/chapter7.htm) backs away a bit. "Even though the *Computing Curricula 1991* report argued strongly for a broader introduction to the discipline, the majority of institutions continue to focus on programming in their introductory sequence." Nevertheless, the new report notes that a "breadth-first" approach can "provide a more holistic view of the discipline. Many computer science educators have argued for a "breadth-first" approach in which the first course considers a much broader range of topics." At Lehigh, we cover both breadth and programming (C++) in one CS1 course, *with the help of the multimedia*, with less emphasis on programming in a CS0 course.

[2] An earlier multimedia work, *The Universal Machine*, whose interface featured a space ship with a cartoon character asking questions or giving advice, gives more sophisticated, primarily male students the false impression that it targets a "juvenile" audience. So we gave the interface of *The Universal Computer* to more generic design and use personae that look like "real" people, in order to avoid this problem. We still use a modified version of the older interface with *A Multimedia Introduction to C++*.

department or the structure of the curriculum are promoting any of the negative misconceptions, they need to be identified and addressed, especially if we want to retain women within the field. As Camp observes, “the computing community cannot sit back and assume that as the numbers of students rises, the percentage of women students will automatically rise and that the "[incredible shrinking pipeline] will take care of itself." We must take direct action to attract and retain more women to computing at all points in the pipeline (i.e., K-12, undergraduate, graduate, faculty and industry).” For this reason, we think it is that it is important that we try to use or adapt the multimedia for use not only in the first year of college, but even earlier in the pipeline. The middle school years, when many girls are probably developing negative stereotypes that turn them away from computer science, may be the most crucial.

Two of the authors are also involved in another NSF-sponsored project in education, the Lehigh Valley Partnership for G4-12 Teaching Fellows. The goals of this project are to promote science, math, engineering and technology (STEM) education in grades 4 through 12, and especially to encourage women and underrepresented minorities to pursue further study in the sciences. Teams of graduate and undergraduate students in several science disciplines (including computer science) are working with local schools to provide inquiry-based learning experiences, mentor students, and develop technology-based instructional materials. One team is using parts of the CIMEL multimedia to enhance lessons in sixth grade technology classes. One of these lessons is an introduction to computer science that addresses common misconceptions, using the same multimedia discussed in this paper. Students will view the multimedia in conjunction with classroom discussion, and complete the drag and drop quiz at the end. We will measure student attitudes before and after the lesson through a survey similar to the one used in this study.

7. CONCLUSIONS

Our results strongly support these hypotheses: 1) students taking a first semester course in computer science still have many negative stereotypes about the field, 2) effective multimedia can change student attitudes, and 3) effective multimedia can especially help overcome misconceptions that may be more common for young women, such as “Computer scientists work alone at their computers.” Further investigation is needed to determine whether these results persist and whether similar effects may be found in other populations, including minorities and students in middle or high schools, where the pipeline for women and minorities is more critical. There are also implications for computer science curricula in general, including the importance of dealing with misconceptions in a first semester breadth course, in order to overcome misconceptions (assuming they *are* misconceptions!), such as “Computer science is for math whizzes” or “Computer scientists write programs all day.”

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