Multimedia for Computer Science: from CS0 to Grades 7-12

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Abstract: The pipeline for women and minorities entering CS/IT is shrinking. Using a combination of multimedia e-learning and mentoring, we seek to widen the pipeline in both first year college courses and grades 7-12. We are developing multimedia that complements a new first semester Computer Science (CS0) textbook. For grades 7-12, we plan to establish outreach teams consisting of undergraduate and graduate student Teaching Fellows, teachers and administrators, faculty members, and industry professionals. This year, two outreach teams will adapt multimedia designed for CS0 for use in middle schools. Preliminary results show that the multimedia promotes learning of Java programming "objects first," for both undergraduates and high school students. One outreach team will adapt these Java materials for use in a high school. Another team will adapt multimedia introducing the field of CS for use in a middle school, seeking to clear up common misconceptions about Computer Science.

Introduction

The pipeline for women and minorities entering computer science (CS) is shrinking, at a time when the projected demand for IT professionals is growing (Camp, 1997, 1999, Cohoon, 2002). Camp's findings imply "that 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)" (Camp 1999).

Our ongoing project, building on previous results that we report here, will take direct action at all points on the pipeline. Using a combination of multimedia e-learning and mentoring by experienced students and industry professionals, we seek to widen the pipeline in both the first year college CS courses as well as grades 7-12. We believe some of the pressures inhibiting the pipeline are fairly obvious:

1) Young people have widespread misconceptions about computer science and what computer scientists do.
2) Middle and high school teachers are generally ill-prepared to teach CS and may themselves reinforce the same misconceptions.
3) Insufficient exposure to suitable role models in IT and CS for women and minorities.
4) Parents/guardians of underrepresented minorities also lack exposure to CS and thus are ill-prepared to motivate their children to pursue education and career opportunities in IT.

This paper describes how our approach will address these problems, and preliminary results.

Approach

The CIMEL project has been developing new interactive multimedia for computer science courses, starting with upper level courses in software engineering and more recently for first year courses in computer science. New multimedia and textbook materials for CS0 are under development and evaluation; a first edition will be published for use at other colleges and universities next fall. One of the goals of a new NSF project (expected to start in the summer of 2003) will be to adapt these multimedia materials for use in grades 4-12. Multimedia is no panacea, though, without teachers who know how to make effective use it. We are establishing outreach teams that will include undergraduate and graduate student Teaching Fellows, grades 4-12 teachers, Lehigh University faculty members, and industry professionals to promote learning in selected Lehigh Valley public schools. Two of these outreach teams will begin working to incorporate inquiry-based instruction and materials for use in middle schools and develop multimedia instructional materials to facilitate learning in CS and IT.

Constructive, **I**nquiry-based **M**ultimedia ***E-L*****earning (CIMEL project)**

CIMEL, a multimedia framework for *C*onstructive and *c*ollaborative, *I*nquiry-based Multimedia *E-L*earning supplementing undergraduate computer science courses, began in October 2000. Since then, we have developed and evaluated a user interface and content for upper level and introductory courses in computer science (Blank et al. 2002a, Blank et al., 2002b). Documents and a prototype are available at http://www.cse.lehigh.edu/~cimel. Figure 1 shows the user interface and a sample screen.

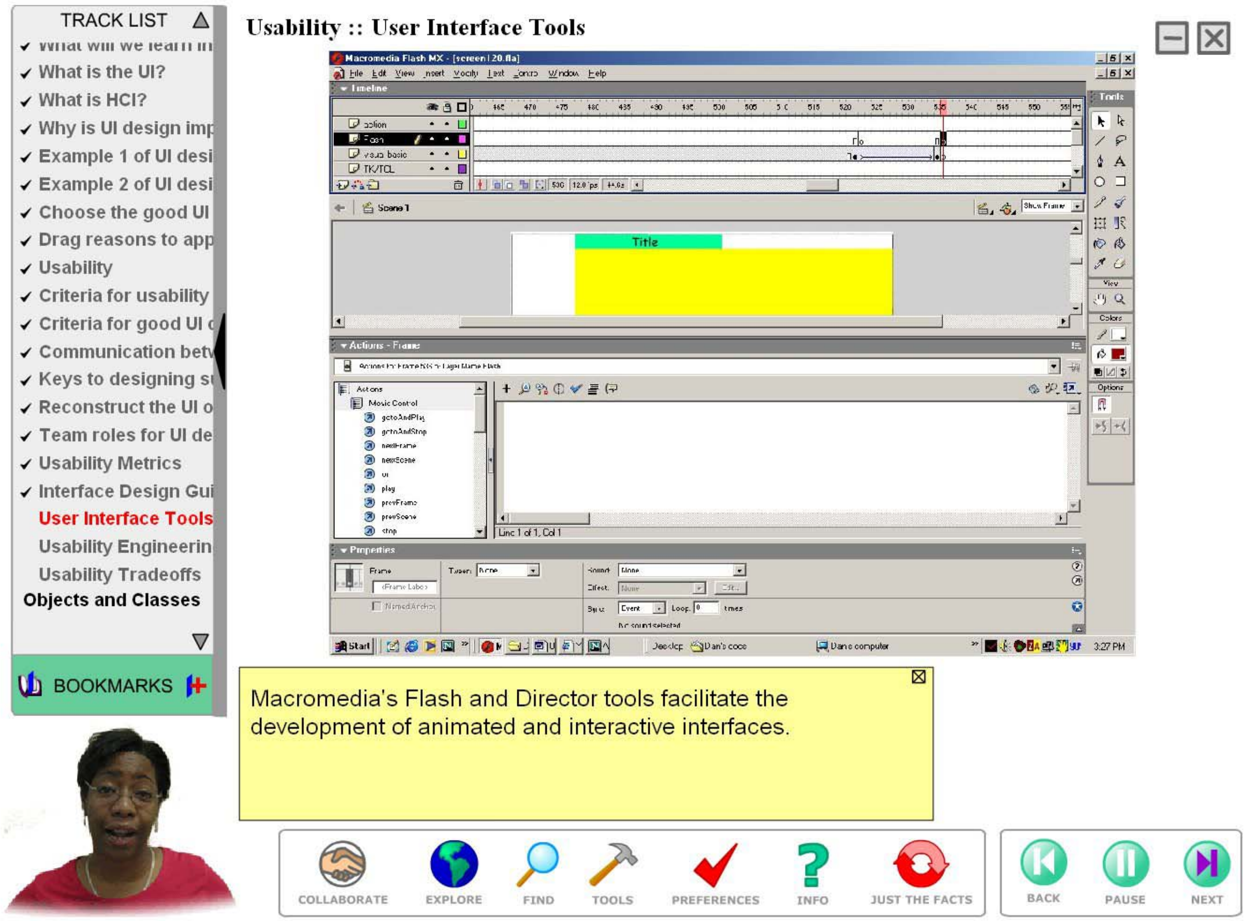

Figure 1: Screen Capture from CIMEL multimedia

- Multimedia personae model a diverse community of teachers and learners. The personae currently include two professors (one shown on the lower left), a teaching assistant, a reference librarian, and three students. In addition to graphical images, they speak in audio and/or text boxes. Personae model students and instructors studying material together, working through interactive exercises, and suggest exploratory research on relevant topics using online information.
- The icons at the bottom give learners access to various tools, including the COLLABORATE and EXPLORE (emerging trends) tools under development for this project, as well as the BlueJ and JavaEdit programming environments developed elsewhere. The PREFERENCES icon lets the user adapt the environment according to his or her personal learning style, including turning text boxes or audio on/off, toggling auto-advance or wait for next page, setting the timing rate where there is no audio narration, volume control etc.

Multimedia content is being developed to complement a new textbook, *The Universal Computer: Introducing Computer Science with Multimedia* (Blank, Barnes and Kay, McGraw-Hill/Primis, 2003). Chapters in the new book include: Introducing the Universal Computer, Problem Solving *Before* Programming, Programming Languages and their Translators, Software Engineering, Computer Architecture, Operating Systems, Networks and Security, Analyzing Algorithms, User Interface and Web Design, Social and Ethical Issues, and Artificial Intelligence.

When we say that the multimedia complements the textbook, we mean that it presents parallel content, enhancing learning either before or after students read the book. The professor persona presents didactic material, with student personae occasionally asking questions, for a few screens at a time, followed by interactive screens in which a professor or teaching assistant guides the learner through quizzes, constructive or inquiry-based learning exercises. All interactions may be recorded to a tracking database, which we currently use for evaluation purposes.

While our approach is to present enough didactic material in the multimedia that it can be a standalone learning experience, interactivity is frequent and rich in CIMEL content. Personae provide feedback to all responses, which are in turn logged to a web-based tracking system for evaluation purposes. Experimental evidence, focus groups, surveys and student interviews make it clear that student learning is roughly proportional to the richness of interactivity. A design goal of CIMEL is to facilitate diverse student learning styles to keep the multimedia effectiveness for a broader audience (Blank, Sahasrabudhe & Heigl, 2002).

Interactive quizzes and constructive exercises help students learn by doing. Personae provide feedback guiding a student through each exercise. Because the multimedia supplies feedback to all user interactions, right or wrong, students can learn whether or not they know the answers. *Constructive* exercises are much more complex, challenging a learner to build solutions to problems by dragging pieces of structures into place, incrementally.

A goal of the CIMEL framework is to offer students ways to go beyond the knowledge presented in the course work, by exploring current research trends. Providing students with opportunities to explore the research literature related to a course gives them a better appreciation for the fundamentals presented in the courses, as well as a perspective of where technology is headed. Learning how to do research is also a valuable skill for lifelong learning. *Inquiry-based* exercises facilitate learning by doing research. For example, after studying abstract data types for collections, the professor persona asks the student to investigate the design of similar ADTs in the most recent JDK. The following screen is a follow-up exercise about what has learned from the inquiry-based activity.

As part of the CIMEL project, we have developed an advanced inquiry-based learning unit that teaches students how to detect emerging trends in computer science research (Roy et al., 2002). An emerging trend is a topic area for which one can trace the growth of interest and utility over time (Kontostathis et al., 2003). For example, XML is a technology that emerged in the mid 1990s. Through the detection of emerging trends, students see the role that current topics play in course-related research areas. A multimedia unit explains the utility of emerging-trends detection with an interactive tutorial and assignment. An experimental evaluation conducted using the multimedia tutorial in an undergraduate Programming Languages class revealed that students achieved significantly greater precision in detecting emerging trends when using the methodology implemented in the multimedia tutorial (Roy et al., 2002). As a component of this project we plan to deploy an emerging trends tool that will support inquiry-based exercises adapted for middle and high school students in selected information technology subject areas.

Experimental results

With both full audio narration and JUST THE FACTS summaries, as well as interactive, constructive and inquiry-based learning exercises, CIMEL facilitates learning for students with different learning styles (Blank et al, 2002b). Experimental evaluation shows that the multimedia has a significant effect on learning, both in objective tests and homework assignments, for graduate students learning how to design abstract data types in a course on Object-Oriented Software Engineering (Blank et al., 2002a) as well as for undergraduates learning the same material in an upper level undergraduate course on Software Engineering (Blank et al., 2002b).

In the fall of 2002, we began experimental evaluation of material introducing Java in a first year course in Computer Science (CS1). This time, we tried introducing Java using an objects-first approach and BlueJ (Kölling, 2001). Earlier, we had developed material introducing Java with a traditional, syntax-first approach, starting with a "Hello, World" program, then presenting classes in a second chapter on Java. After the first author presented material from the second chapter at a SIGCSE workshop on BlueJ (March 2002), other participants convinced him that a syntax-first approach is problematic for Java, because it puts too much emphasis on distracting details, such as the signature of a `main` method. With the BlueJ environment, it is possible to get students started immediately with classes and objects. A pedagogical heuristic: students learn best what they learn first (and repeatedly). A corollary for Java: classes and objects are what students need to learn best. We therefore redesigned the chapter on classes and objects so that it would parallel the first chapter of a new textbook introducing BlueJ (Barnes & Kölling, 2002).

In the fall of 2002, we conducted an experimental study, investigating whether our new multimedia enhances learning of introductory concepts in Java and object-oriented programming. Specifically, we compared how well students in a CS0/CS1 class learned from the first chapter of the textbook, *Objects First With Java – A Practical Introduction Using BlueJ* versus our corresponding multimedia. Seventy-six students were randomly divided into two groups. One of the groups took an online pre-test of 20 questions. Then, half of the students in each group were randomly assigned to one of two groups, one using the text and BlueJ, the other using multimedia and BlueJ. All the students then took a post-test. Later the group that used the text and BlueJ was given access to the multimedia, and the group that used multimedia and BlueJ was assigned to read the book. A second post-test was given to all students. Thus the design of this experiment, based on the Solomon Four-Group Design, is:

R	O_1	X	O_2		O_3
R	O_1		O_2	X	O_3
R		X	O_2		O_3
R			O_2	X	O_3

Where R indicates random assignment, X indicates exposure to the multimedia tool, O_1 is the pre-test, and O_2 and O_3 are the two post-tests. This experiment allowed us to determine whether there is a testing effect, i.e., whether scores on the post-test are improved merely through practice on the pre-test. It also tested examined differences between the multimedia and text groups on the first post-test and a second time on the second post-test.

Taking the pre-test had no effect on the scores of the post-test. For the group getting the pre-test, the mean post-test was 13.44, while the mean for the group not exposed to the pre-test got a mean of 13.46, an insignificant difference (t = .043. df = 72.05, p = .966). Thus taking a pre-test does not result in a higher score on the post-test due to a practice effect. (We exploited this result in the design of a subsequent experiment, reported below).

Students made significant gains from pre-test to post-test, with both the textbook and the multimedia, but they learned more from the multimedia. Scores on the first post-test were higher for those using the multimedia (mean of 14.50) than those using the textbook (12.46), a significant difference (t = -3.337, df = 76, p<.001). Moreover, the multimedia adds to what they learn from the textbook. Students using the textbook first, then using the multimedia improved their scores on the second post-test (12.46 to 15.40), a significant improvement (t = -6.527, df = 34, p<.001). We infer that the multimedia helps students learn conceptual material better than if they were exposed only to the textbook. On the other hand, there was little improvement for students using the multimedia first, then the textbook (from 14.73 to 15.13), an insignificant difference (t = -.993, df = 29, p.<.329). Thus it doesn't seem to matter whether the students are exposed to the multimedia before or after reading the textbook.

Our tentative overall conclusions are that first year students can learn Java "objects first" using BlueJ, and that interactive multimedia helps. We then conducted another study to determine whether we would get similar results when giving the same materials to high school students. Twenty-six Students That Are Ready pupils (grades 10-12) participated in an experiment to learn about object-oriented programming and Java. Half of the students were randomly selected to use the textbook, *Objects First with Java*; the other half of the students used multimedia software. All of the students were asked to take a pre-test before starting the assignment (we were no longer concerned about a practice effect). After completing their assignment, they were instructed to take the post-test.

As with the undergraduates, the high school students improved their scores, though with smaller margins. High school students using the textbook showed modest improvement (5.31 to 7.62, t=-3.290, df=12, p=.006) as did those using the multimedia (from 3.23 to 9.08, t=-6.619, df=12, $p \leq .001$). The gain from pre-test to post-test was greater for students using the multimedia, averaging a gain over three points higher than the text group (t = -3.137, df = 24, p = .004). These results suggest that the multimedia improves learning more than using a textbook.

We are nevertheless concerned that the mean scores for high school students are much lower than those for undergraduates. We attribute this difference to maturity and motivation. Undergraduates understood that their work counted towards a course grade, while S.T.A.R. students participated on a voluntary basis; many of them expressed a lack of interest in the subject matter during the study. It is possible that high school students will perform better in a classroom situation, and also if they were prepared by previous materials and context. A goal of our project will be to incorporate public school use of multimedia in a richer context of outreach teams with teaching fellows.

Plans for Grades 7-12

Discussions with computer science teachers in local middle and high schools confirm what we believe are national trends: teachers are ill-trained to teach computer science (typically having taken one or two college courses in CS or information technology), women and underrepresented minority students quickly lose interest in the subject (one high school reports having just one girl out of 125 students in computer science elective courses), there is a lack of awareness among grades 7-12 education about what computer scientists actually do (they don't just code or hook up CISCO networks!), and there is considerable interest in using multimedia to enhance awareness.

This spring, we will establish outreach teams consisting of undergraduate and graduate student Teaching Fellows, grades 4-12 teachers and administrators, Lehigh University faculty members, and industry professionals to promote learning and to strengthen partnerships between Lehigh University, neighboring school districts, and local industry. The outreach teams will work together to incorporate inquiry-based instruction and materials in G4-12 curricula, to develop multimedia instructional materials to facilitate learning in computer science and information technology, and to learn from one another through the open exchange of knowledge, ideas, and experiences. Target public schools for this project, in Allentown and Bethlehem, Pennsylvania, have high percentages of underrepresented minority students and students from low income families. In addition, the recruitment and selection processes are tightly integrated with existing outreach programs at Lehigh and partnerships with institutions with large enrollment of women and underrepresented minority students to ensure that several Teaching Fellows will be well diverse.

We plan to begin by adapting one or two "breadth of computer science" chapters currently under development for *The Universal Computer* for use in middle schools. One unit, corresponding to the first chapter of the book, will introduce computer science (available at http://www.cse.lehigh.edu/~glennb/um/1intro.pdf). One of our goals is to overcome misconceptions about computer science, ranging from "computer science is about nerds staring at computer screens" to "computer science is about writing programs." We will also develop inquiry-based learning exercises offering students ways to go beyond the knowledge presented in course work, by exploring current research trends exercises and user interface design problems that expose students to "real world" examples.

Conclusion and plans for evaluation

The vision of this project is to increase STEM undergraduate and graduate students' awareness of and interest in public school education by partnering them with teachers to develop and enhance the STEM curriculum. It is expected that this activity will increase the number of women and underrepresented minorities involved in STEM education and careers by exposing students in public schools to hands-on, inquiry-based, and problem-based learning experiences. We plan formative evaluation to gauge our progress, including surveys, interviews and focus groups, and summative evaluation to determine the impact of our program on school students, teachers and teaching fellows. In particular we will document and track the number of women and underrepresented minorities recruited to serve as teaching fellows, the demographics of students participating in the programs, semi-annual pre-test/post-tests to determine whether student have learned targeted content (such as misconceptions about CS) and whether the new materials and work of the outreach teams have increased their interest in STEM careers, particularly IT.

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