Overview of issues in computer science and recommendation for teaching Computer Science Classes

An Innovative Approach to Introductory Computer Science Courses

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Abstract
This report proposes a new approach to introductory computer science courses by suggesting a 3D graphic programming environment called Alice. The overall drastic decline in the CS enrollment is mainly caused by strong stereotypes and gender-based issues. In addition to the social issues, programming languages’ intricacy adds unnecessary confusion and frustration to the freshmen undergraduate struggle in computer science courses. In order to teach the students the basic concepts behind programming it is suggested to implement an interactive programming class using the Alice program for middle school students. The Alice program’s easy and fascinating design, combined with the successful research study conducted by Caitlin Kelleher and with Alice summer camps for middle school students at Calvin College, prove that schools will benefit from adding this class to its curriculum.

Background
In our technology-dependent world, computers and everything connected with them are of significant importance. Our extensive usage of computer technology suggests a greater dependence on computer science and a growing need for professionals who will develop and operate it. According to the Bureau of Labor Statistics “nearly 75% of tomorrow’s jobs will require use of computers” (as cited in “Technology facts”). Because computer and programming skills are becoming so essential, especially for business and sciences, it is crucial to provide necessary Computer Science (CS) education for everybody.

In her doctorate thesis proposal, Caitlin Kelleher indicated that even those who will learn the basics of programming but will not choose to pursue a career in a computer-related field will still benefit from programming experience. To some extent every student will have to work with computers or interact with computer scientists, programmers and engineers. Basic programming skills and knowledge about how to create a program will be very valuable for students who will have to work with computer professionals. This knowledge will contribute to their successful communication and productive work (2003, p.3).

Significance
According to Harry Henderson, in the last decade the number of people needed to fill computer jobs, such as Computer Scientist, Database Administrator or System Analyst, roughly doubled. However, in 1998, computer industry executives stated before Congress that 300,000 jobs were not filled “due to the lack of qualified workers” (1999). As presented by the Bureau of Labor Statistics, “the US economy is expected to add 1.5 million computer and information related jobs by 2012, while the country will have only half that many qualified graduates” (as cited in Computer Science Teachers Association, 2006).

A survey carried out by the Higher Education Research Institute (HERI) reveals that “the percentage of incoming undergraduates among all degree-granting institutions who indicated they would major in CS declined by 70 percent between fall 2000 and 2005” (Vegso, 2006). This decline is also deepened by the decrease in the enrollment of females, who are roughly half of the population. According to the American Association of University Women Foundation “women receive less than 28 percent of the computer science bachelor’s degrees, down from a high of 37 percent in 1984. Computer science is the only field in which women’s participation has actually decreased over time” (as cited in “Technology facts”).

To help prevent further exacerbation of this appalling trend, computer education should start at an early age. As stated by Mary Moss, principal of Mott Hall II School in New York, “middle school is a critical point in a student’s academic career. Computer use makes learning interesting and gives students skills needed to be successful in high school and the work world” (Fung, 2005).
Purpose
This report is intended to discuss the issues in CS and to suggest the implementation of an innovative 3D graphic programming environment called Alice.

Sources and Limitations
This report uses U.S. statistics and information from accredited educational websites. Specifically focused on Alice, this report doesn’t cover other possible programs or teaching approaches that are used in the U.S. or other countries.

Overview
After presenting a formal definition of Computer Science, this report will discuss the most common issues regarding CS and highlight how the Alice program can help to invert these problems and benefit schools.

Computer Science and Related Issues

Definition and Significance of Computer Science
The concise and clear definition of Computer Science was given on the web-page of the School of Computer Science in South Africa:

Computer Science is concerned with the study of problem solving with computers. It is a field that tries to deal with questions like:
- How can we use computers to solve certain problems?
- What makes some problem solutions better than others?
- How do we verify that we have a correct solution to a problem?
- What problems can and can’t be solved by a computer? (2006)

Computer Science is one of the youngest and most rapidly developing sciences. Computers, software and the Internet are becoming an increasingly important, almost necessary, part of our daily routine. Kelleher indicated in her work that “8 of the 10 fastest growing occupations between 2000 and 2010 will be computer related” (2003, p.2). As Wanda Dann, Stephen Cooper and Randy Pausch (2006) point out “if you were born tomorrow you might be interacting with a computer from your very first day to your very last.” They explain that the computer chip, which is used on the band around a newborn’s ankle at the hospital, allows tracking the baby’s location at all times. On the last day, one will probably have “a computer monitoring … vital signs.” The authors further show that life expectancy will be a lot longer due to the computer aided technological advances, such as “computer-controlled brakes and airbags in our cars, and computer modeling that allows us to design new drugs to fight diseases like AIDS” (p.3).

It is impossible to underestimate the role CS plays in any aspect of one’s life. Without exaggeration, computer science is the ultimate tool for the development of future research and technology.

Current Issues Regarding Computer Science
Nationwide there has been a dramatic decrease of CS undergraduates. Below are the most significant factors that have contributed to this trend.

Stereotypes. According to the Merriam-Webster Dictionary Online, one of the meanings of the word stereotype is “something conforming to a fixed or general pattern; especially: a standardized mental picture that is held in common by members of a group and that represents an oversimplified opinion, prejudiced attitude, or uncritical judgment.” It is astounding and very upsetting how many different stereotypes people have about computer science and its scientists.

The main stereotype is a very strong “perception that computer technology is primarily for certain individuals” (Hanson, 1997; Butler, 2000). There are plenty of other fields, like music or art, where the person is expected to have a “talent” or specific skills to perform well in the selected major; however, one cannot be born with a set of computer science skills or talents. Mathematical background and interest in sciences are the favorable skills for those planning to major in computer science; yet, one doesn’t have to be Einstein to become a computer scientist.

Another common stereotype is an incorrect picture of a computer scientist. As Figure 1 shows, a computer programmer is portrayed as a weird-looking, out-of-this-world kind of person with very thick glasses, who locks himself (notice, it is never herself) in a small dark room where he sits in front of his beloved computer screen for several days and nights in a row forgetting about sleep, food and showers.
Fig. 1: Misconceptions about computer scientists and their working conditions Source: Laurie Williams presentation “Debunking the Geek Stereotype with Software Engineering Education”

Despite the ridiculousness of this so-called “geek stereotype” and a perceptual change that “geeks” are not merely nerds but very useful experts, for a lot of young people who are choosing a career this sort of image is repulsive and may deter them from entering the CS field.

Gender issues. A drastic difference between male and female enrollment and a decrease in the number of female students enrolled in CS are of a major concern. Because females are underrepresented in computer science a historical and “cultural bias that technology is a ‘male’ domain” (as cited in Butler, 2000) remains true. Maria Enderton (2003) highlights the importance of this issue in her honors thesis:

“History is filled with instances of men (and sometimes women) characterizing woman by emotion and man by reason, and therefore, by intellect. These “superior” reasoning talents of man then also imply heightened mathematical and scientific abilities, including computer science abilities. (...) The belief, accurate or not, that women have a diminished reasoning ability has serious implications in various spheres of life. One such sphere is the realm of computer science” (p.3).

As Figure 2 indicates, from six selected academic disciplines, computer science was the only field with a steadily decreasing number of women earning bachelor’s degrees.

Fig. 2: Percent of bachelor’s degrees earned by women in selected fields, 1966-2001

Source: Computing Research Association http://www.cra.org/info/education/us/women.html Note: According to NSF, data are missing for Bachelor’s and Master’s degrees granted in 1999 because “detailed national data were not released for the academic year ending 1999 by the National Center for Education Statistics.”

Stereotypical careers combined with a historical tendency for men-scientists, don’t play in favor of women who would like to be involved in CS. Prejudges and discrimination against the females who choose the computer science path exacerbate a double challenge they face: the complexity of computer science and the necessity to fight unfairness and prove that women can succeed in this field. Thus, the trend presented in Figure 3 is not accidental -- less and less undergraduate females choose a career in CS.

Fig. 3: Portion of the CS degrees granted to women, 1966-2003.

Note: According to NSF, data are missing for Bachelor’s and Master’s degrees granted in 1999 because “detailed national data were not released for the academic year ending 1999 by the National Center for Education Statistics.” Adapted from CRA http://www.cra.org/info/education/us/women.html

The decrease in the total number of women graduating in CS is more dramatic than the decrease in the total number of CS degrees granted to men even though there is no real difference in women’s abilities to do math and science. The following information is taken from “A Guide for parents grades 4-7: Science can take her places” supported by the National Science Foundation:

* In mathematics, there was virtually no difference in scores between girls and boys in 4th, 8th, and 12th grade (1990 through 2005).

* In science, the results fluctuated: in 1996 there was no gap between 4th or 8th grade girls and boys; boys scored slightly higher in 2000. In 12th grade, boys scored only slightly higher in 1996, and the gap narrowed further in 2000 (Ride, 2006, p. 5).

Keeping in mind that computer science is concerned with the study of problem solving, the exercise conducted at University of Hawaii at Hilo in the Introductory to Computer Science course shows that females can naturally outperform males. During this exercise the students were divided into male and
female groups that were asked to plan a party. The female groups outpaced male groups presenting fast, concise and detailed solutions.

Butler indicated in her research an obvious gender difference in the attitudes toward and the use of computers. Several studies indicated that "boys tend to prefer games, essentially random play, and girls seem to prefer goal-oriented computer use." Also girls usually lack previous programming experience and prefer "group work and collaboration to working alone" (as cited in Butler, 2000). Because CS is currently dominated by males the gender differences in teaching CS courses are not taken into close consideration.

Complexity of programming languages. This is the most important obstacle for the first semester college freshmen with no previous programming experience. Most programming languages, such as C++, Java and Action Script "tend to drag the focus of the course away from solving problems using a programming language toward interface design" (Chan et al.). Most of us will not immediately notice the difference between the C++ commands presented below:

Incorrect: if (variable1 = variable2)
{
variable1 + 1;
variable2 = variable2 + variable1 - 3)
}

Correct: if (variable1 == variable2)
{
variable1 ++;
variable2 = variable2 +
(variable1 - 3);

A mere typo, misspelling or omission of a semicolon, which should end every program command, can cause the program to "crash" or not work correctly. This adds unnecessary complexity to the CS course and is often a major source of students' frustration, which may cause them to drop the class or not take any more of the CS courses.

C++ is considered as the "industrially relevant language, leading students and some educators to believe that learning C++ contributes significantly to employability upon graduation" (Chan et al.). However, its obscurity doesn't aid in understanding of the basic concepts and unnecessarily complicates the problem solving process.

These are one of the most important and common issues in computer science. Overcoming these problems can visibly change the current situation in CS attracting more students and making it easier to understand the basics of programming.

Alice --A Tool To Solve Computer Science Issues

What is Alice?

Alice is a graphic programming environment that allows students to learn the concepts behind programming by creating 3D virtual worlds and animating characters. Developed by Carnegie Mellon University, this software revolutionizes traditional approaches of teaching object-oriented programming by allowing the visualization of abstract concepts.

Why is it called Alice? The book "Learning to Program with Alice" explains that it is not an acronym and it doesn’t denote anything. The system was called Alice "in honor of Charles Lutwidge Dodson, an English mathematician and logician who wrote under the pen name Lewis Carroll. Carroll wrote Alice’s Adventures in Wonderland and Through the Looking Glass. Just like people who built Alice, Lewis Carroll was able to do complex mathematics and logic, but he knew that the most important thing was to make things simple and fascinating to a learner" (Dann, 2006, p.7).

Alice is a graphic programming environment that allows students to learn the concepts of programming by creating 3D virtual worlds and animating characters. Developed by Carnegie Mellon University, this software revolutionizes traditional approaches of teaching object-oriented programming by allowing the visualization of abstract concepts, as shown in Figure 4.
Fig. 4: 3D world animation that visually represents the concepts of an object and an array. This particular animation demonstrates the concept of permutation of the items inside the array. Source: Created by Yekaterina Khartonova, 2006.

Why Use Alice in Middle School?

According to Butler, middle school is a turning point for boys and girls, which is definitely the case with computer science (2000). According to the researches the “seventh grade was the point at which boys increased their use of computers compared with girls” (as cited in Butler, 2000) and “by eighth grade, twice as many boys as girls are interested in pursuing science, engineering, or technology based careers. … By late high school many girls have already opted out of the math and science classes that would make it possible for them to pursue a mathematical or scientific major” (as cited in Kelleher, 2003, p.4). This is also the time when middle school students are not yet inhibited by various social stereotypes and are enthusiastic about learning.

Last but not least, successful experimental study of using Alice with middle school students at Calvin College (“Alice activities…” 2005) and in Kelleher’s research projects allows us to believe that making Alice part of the curriculum will establish even more positive results.

Why Use Alice At All?

If a graph could say “I love you,” if it could sing a child to sleep, then from this struggle I might find some benefit to reap.

But all this wishful thinking only serves to make things worse, when I compare my dearest love with your numeric verse.

For if mathematics were a language, I’d succeed, I’d scale the hill. I know I’d understand, but since it’s not, I never will.

This poetry suggests a great new approach to the settled concepts of sciences, in our case, to the intricate concepts of computer science. These verses show how much inspiration one gains when something that is complex is represented in a familiar tangible way. This is exactly what the Alice program does. Allowing a programmer to focus on the concepts behind programming, the Alice program uses intuitive commands in natural language. It is much easier to read and understand a command that says “Object move forward 1 meter” than to comprehend the same statement in C++ that says “Object.xVar = Object.xVar + 1;”. Figure 5 shows the Alice program’s appealing graphic interface and gives a brief explanation of the main interface areas.

The main reason for using the Alice program is that it can overcome some of the problems that discourage students from taking CS classes. Having identified the major issues in CS we can see how teaching with the Alice program can address these topics.

Stereotypes -- Eliminate ignorance. Stereotyping is natural when people do not have current and valid information about the subject. Because CS is a very technical field it is very hard to explain what it is about, without sounding like a “geek.” Because Alice presents CS concepts through visual objects the students are able to explain the most complicated ideas using every-day terms and examples. For instance, to explain all possible permutations the student can just run the animation mentioned in Figure 4, which will visually demonstrate number rearrangement.

Gender issues -- Flexibility in usage. The Alice program, uses the concept of storytelling, which is very attractive to all students in general. As a form of self-expression the Alice program allows role-playing, which is one of the main ways that teenagers develop “their own identities” (Kelleher, 2003, p. 12)

Complexity of programming languages -- Alice is syntax-error free! The most common and frustrating part of most programming languages is syntax error, occurring when the student mistypes something. Alice’s drag-and-drop graphic environment makes students’ programs virtually free of syntax errors by a letting the student use the mouse and drag the “rounded-rectangular tiles that represent commands” (Kelleher, 2003, p. 10) into the programming area.
Fig. 5: A screen shot of the Alice system; each interface area is labeled. Descriptions of each area are below.

1: The object tree displays a list of objects in the current Alice world and allows students to select objects.
2: The details area displays the properties and methods … for the currently selected object.
3: The scene editor displays the 3D world and allows students to place objects and navigate through the virtual world
4: Students can build animations … by dragging program tiles from the details area.
5: Students use behaviors to associate methods with events such as mouse clicks.


Advantages of Having Programming with Alice Class

Benefits for the students
- An interesting and fun class
- Better preparedness for CS introductory courses
- Higher academic performance in college
- Scholarship opportunities
- Job opportunities and career advancement

Benefits for schools
- Reputation as a school “in-tune” with the latest information and technology
- Reputation as a good school for college preparation
- Successful alumni

Benefits for the United States
- Increase CS enrollment
- Have better prepared college freshmen
- Remain the leader in technology

REFERENCES


Conclusion / Recommendation

The decline of Computer Science professionals suggests that we should improve computer education. Middle school representing a watershed in the students’ development and perceptions is the best time for teaching introductory computer science class using the Alice program. I recommend the implementation of this program for Spring 2007 at Parker School. This program’s proven simple and fascinating approach to programming will attract students’ interest and increase CS enrollment at Parker School and at the university level.


