Robots as Recruitment Tools in Computer Science: The New Frontier or Simply Bait and Switch?

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Abstract

There is little doubt that the use of robots in introductory classes is an effective way to spark an initial interest in Computer Science and recruit students into our classes, and subsequently recruit some of them as Computer Science majors. But when the semester is over, the vast majority of our students are unlikely to see robots in the classroom again until they take advanced courses in AI or Robotics. It is time for those of us who are proponents of the use of robots in Introductory Computer Science to start thinking seriously about how we are using robots in our classes, and how to sustain the interest and enthusiasm of our students as they move on to more traditional courses.

While the focus of this paper is on the use of robots in Introductory Computer Science courses, my goal is to initiate a more general discussion on the use of any sort of cool new technology (tangible or not) into both undergraduate and K-12 education. These technologies successfully attract students to study subjects that we ourselves are deeply engaged in. But we need to discuss as a community what happens when our individual classes conclude and the rest of their studies commence.

Introduction

We have clearly made it past the tipping point in the use of robots in the classroom. Seymour Papert & Mike Paterson had students playing with physical Logo turtles back in 1971[Feurzeg], but it is only more recently that robots have genuinely become as affordable (or perhaps it would be more accurate to say, just as expensive) as many college textbooks. While there are those who work towards the integration of robots across the undergraduate Computer Science (CS) curriculum, the recent explosion of work in this field has been in elementary courses for majors and non-majors.

At some level this can be thought of as simply an extension of the use of traditional non-electronic manipulatives in K-12 schools. According to Jean Piaget, children are limited to thinking about things in terms of perceptions and concrete experiences until adolescence. [Driscoll] Thus with younger children, one would imagine that the use of physical manipulatives to teach mathematics, for example, would be essential. In fact, regardless of grade level, the use of manipulatives in mathematics classes generally (but not always) results in better performance, as well as higher scores on retention and problem solving tests. [Clements & McMillan]

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The Need to Recruit More Students to Computer Science

Across the country, the number of Bachelor's Degrees in Computer Science and Computer Engineering is down. [Zweben] While there are obvious factors like the dot com bust that may explain much of this trend, some also suggest that the advent of No Child Left Behind, and specifically the fact that Computer Science is not an area that students are tested on, may be a factor. Anecdotal reports suggest that computer studies are down:

> "Here are some of the things kids at Garfield/Franklin elementary in Muscatine, Iowa no longer do: eagle watch on the Mississippi River, go on field trips to the University of Iowa's Museum of Natural History, and have two daily recesses ... Creative writing, social studies, and computer work have all become occasional indulgences." [Meier & Wood]

More locally, the demographics for the annual high school programming contest held at Rowan University have been changing:

- One regional high school that used to regularly win our contest had all of their programming classes cancelled.
- Another school had all their programming classes cancelled and the freed computers reassigned to No Child Left Behind remedial work.
- One teacher left her high school to teach at a community college because all of her classes were cancelled. [Provine]

These changes are occurring at the same time that the US Bureau of Labor Statistics is projecting that many of the careers in Computer Science fields are growing. [BLS]

Clearly there is a need to attract more students to Computer Science, and if it is not happening in our schools it may be up to us to introduce the field to our Freshmen. Furthermore, as a Computer Scientist, I personally feel an urge to evangelize about the subject that I myself am so deeply interested in. So how do we capture and maintain student interest?

The Science of Interest

While the result seems obvious, it is worth noting that educational psychologists have found that the degree of interest a person has in a subject has a powerful influence on his or her ability to learn the material. [Hidi & Renninger] So assuming that robots do increase student interest, our gut instinct to incorporate them into our classes is indeed scientifically valid. So what exactly is interest, and how can we create, maintain, and sustain it?

[Hidi & Renninger] developed a four-phase model of how a person's interest develops and matures based on empirical studies of interest & learning. The four phases happen sequentially, and the length and character of each phase is influenced by a variety of factors:

- **Phase 1: Triggered Situational Interest.** Some sort of event or information, almost always external, initiates interest.
- **Phase 2: Maintained Situational Interest.** This comes after phase 1 and involves focused attention either over an extended period of time or recurring, and some level of persistence. This phase is almost always externally supported.
- **Phase 3: Emerging Individual Interest.** This phase is "characterized by positive feelings, stored knowledge, and stored value." While this interest is generally self-generated, it requires some continued external support.
- **Phase 4: Well-Developed Individual Interest.** Again this is characterized by positive feelings, and an increase in stored knowledge and stored value over phase 3. Phase 4 is typically self generated, but can benefit from external support.

For example, consider two students, Alice and Bob[1]. Both have just graduated from high school, they had similar grades and SAT scores, and no experience with robots or computer programming. Both attend an advising session for undeclared majors the summer before their Freshman year at Our State U, where several faculty members try and recruit them for their classes. Among the classes advertised is an introductory programming class in which students will do much of their programming on small robots. Alice and Bob both watch the professor giving the demonstration. They both find it interesting and both add the handout the professor provides to their ever-growing pile of material they have collected.

After returning to their homes that evening, both Alice and Bob sift through the material they received that day. When Alice gets to the robot programming handout, she thinks about the light-following task the professor demonstrated. She has never really thought about programming before, but the demonstration was kind of cool, and while it seemed quite magical at first, she found the logic behind how the robot followed the light quite satisfying and attractive. She pulls out her laptop and heads over to the URL the professor provided. After some web surfing, she decides to sign up for the course.

In contrast, when Bob sees the robot programming handout, he briefly recalls the various demos in a positive light, but then quickly tosses the paper into the recycle bin and continues on to the others.

Alice and Bob both have a Triggered Situational Interest in robots and computer programming. They are attentive and interested in the professor's demonstrations. But only Alice moves on to Phase 2, a Maintained Situational Interest, which hopefully may progress to Phase 3 as she takes the class in the Fall.

[1] This case illustration is modeled on one from [Hidi & Renninger]

But what then? If Alice decides to become a CS major, she will see a lot more programming, but she will not have the opportunity to see any robots in her classes until she takes an advanced elective in her Junior or Senior year.

Using Robots Across The Undergraduate Computer Science Curriculum

Klassner and Anderson have presented approaches to using robots in seven core areas across the CC2001 curriculum from Programming Fundamentals and Programming Languages to Architecture and Operating Systems. [Klassner & Anderson] On the one hand, this seems to be the ideal solution to the problem of how to help Alice continue to develop her interest in robotics and computer science. But there are some other factors that we should consider.

First, while I personally find robotics one of the most exciting areas in computer science and perhaps Alice will too, robots are not for everyone. If Bob were to find a different path to the CS major, it is not clear that he would see the addition of robots to several of the required courses in his major beneficial. Indeed, he might even find the recurrence of robots irritating. Perhaps an alternative theme (tangible or not) would be of greater benefit to him. Or perhaps he would benefit from a more traditional approach.

Furthermore, it seems likely that the success of a robots-across-the-curriculum approach depends as much on the quality of instruction as on the quality of the robot or the curriculum. Indeed, according to [Huetinck & Munshin], "The most significant influence on the successful use of manipulatives is the quality of teacher-conducted instruction in their use."

While I can imagine that one or two enthusiastic and skilled instructors at a small institution could incorporate robots into many of their classes (and thus into much of the curriculum), it seems less likely that this would work at most larger institutions.

Finally, if an institution really does embrace a robots across the CS curriculum approach, that may impose a more strict sequencing of courses than may currently be in place. If a student does not successfully complete their algorithms and complexity (using robots) course, should that prevent them from taking operating systems (using robots) the following semester? Will students who transfer to the university from other schools be able to enter the major? What about students who decide after their Freshman year that computer science is actually the major for them, is there any hope that they will be able to complete the program in four years?

Robots in Introductory Computer Science Courses: First, Do No Harm

We are beginning to recover from the shock that was dealt to the educational robotics community when Fagin and Merkle presented results that indicated that the use of robots in an undergraduate core computing course actually *reduced* the test scores of students [Fagin & Merkle]. They concluded that the fact that students in the robot sections of their course had limited access to work with the robots was a key factor, and that had a simulator been available the results might have been different. This conclusion is supported by [Huetinck & Munshin] who emphasize that in the use of traditional manipulatives, it is important to allow the students to have hands-on time with the manipulatives. If, due to cost or time constraints, students are forced to rely on teacher demonstrations, the benefits of using the manipulatives are reduced.

More recently, [Summet et. al] from Georgia Tech & Bryn Mawr reported on their work with a CS1 course that incorporated robots in which each student had their own personal robot that they could use whenever they wished. Their initial data suggest that the robots do no harm.

Personal robots that students can either purchase or borrow or the availability of a simulator does seem to be one key factor in the success of introductory courses that use robots. We do, however, need to be careful that our attempts to make the equipment affordable do not result in reducing either its pedagogical value (because of technical limitations) or even its perceived value to students. [Huetinck & Munshin] point out that some excellent manipulatives can lose their value in a high school setting simply by the addition of cute pictures. In one example, students were much more willing to work with white, black, and gray cubes than similar multicolor cubes which they viewed as too childish.

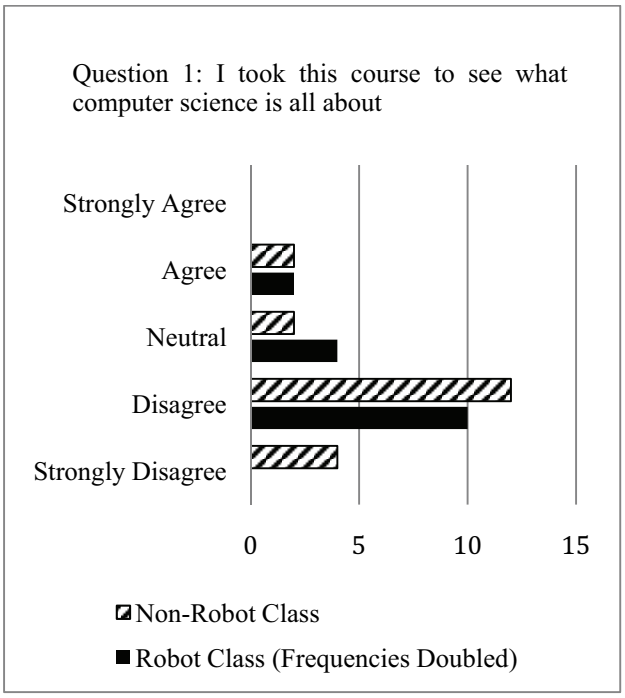
In my own introductory and advanced classes that use robots, the majority of the students seem to have a positive regard for the variety of robot platforms I have used (including the Handy Board, Lego Mindstorms, and IPRE/Scribblers). However, a few have dismissed the robots as toys that have no intellectual value.

Robots in Introductory Computer Science Courses as a Recruitment Tool

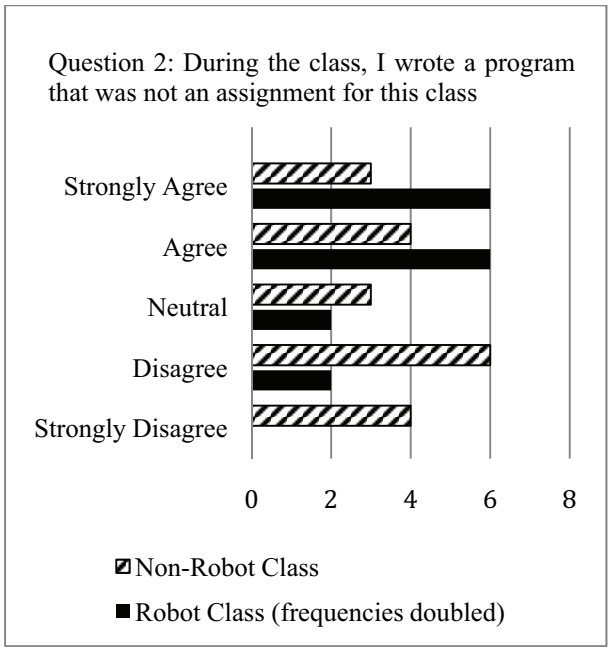
My own preliminary work seems to suggest that the use of robots in CS courses for non majors may be a good way to attract them to the field and possibly the major. [Kay] In a pilot study, I compared students in one robot and two non-robot sections of an introduction to programming course for non-majors. The number of students in this pilot study was quite small: 20 out of 44 students in the traditional classes and 8 out of 10 in the robot class chose to complete the final survey; however the results do feel compelling.

The graphs that follow are from questions administered at the end of the semester. In these graphs, the robot data frequencies have been doubled for visualization purposes. In other words, 3 students in the robot section are illustrated as 6 on the graph so that the classes are easier to compare.

Question 1, below, shows that students in both the robotics and non-robotics sections seemed, alas, to be equally unmotivated by the desire to learn more about Computer Science.

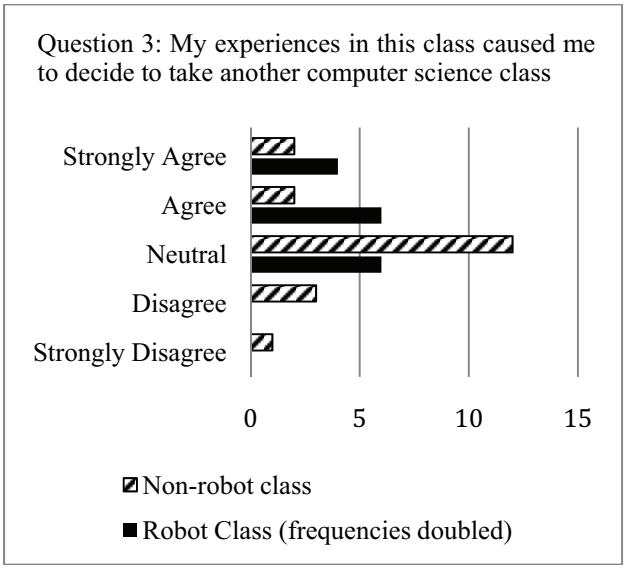


The results for question 2 are more interesting and make one wonder whether robots might indeed motivate students to work more outside of class.



Did the robots attract the students to further studies in computer science? When asked whether the experiences in their respective classes caused them to decide to take another computer science class, 5 of the 8 students in the robot course reported yes, while only 4 out of the 20 students in the traditional classes reported yes.

BINGO! Or maybe not. I like to think that I am an effective teacher and that some of my students will make it to the phase 3 emerging individual level of interest by the end of my Introduction to Programming Using Robots course. But interest in what? Programming? Robotics? Computer Science? Something else? If students in my course sign up as CS majors have I misled them about what to expect in future courses? Is this a case of bait and switch?



One might argue that any introductory-level course for non majors will provide an incomplete view of the fullness or complexity of the field of study. At Rowan University, we offer three flavors of Introduction to Programming: the traditional course, a course that uses more scientific examples (designed to fulfill the programming requirement for some math, science, and engineering majors), and the course that uses robots. All three of these courses spend a full semester teaching a very limited syllabus – at a minimum instructors are expected to cover the fundamentals of conditional statements, loops, and functions. A student who finds any one of these introductory courses accessible and interesting may be overwhelmed by the pace set in our CS1course for majors. Or the student might not be able to succeed in the rigorous mathematics curriculum that we require of our majors. Or the student may simply be disappointed that CS is not as interesting as they thought it might be. Then again, perhaps they may discover a love for everything that is Computer Science.

Conclusions

I continue to be a strong advocate for the use of robots in Introductory Computer Science Courses, and yet I find myself in a quandary. On the one hand, I find the use of robots in my introductory courses exciting, interesting, and fun for both me and my students. I believe that in time we will discover that this approach does indeed improve the performance of students in our classes, rather than simply not harming them. In addition, it seems as though there is a level of personal responsibility in the choice of college major that I have ignored so far; surely a student should take the time to review all of the requirements for a given major and consider carefully whether they are making an appropriate choice. An interesting introductory course should simply serve as the entrance point to further research.

But I must admit that this was not how I selected my own majors as an undergraduate, and I am confident that the majority of my students do not use this approach either. And so, while I do not see the full integration of robots across the curriculum as the solution, I feel the occasional twinge in my gut that there is something we as educators are missing. Perhaps we are doing our students a disservice by starting them out with a cool new gadget they can hold in their hands and play with, and subsequently moving back to a keyboard and mouse. Or perhaps the fact that many students are purchasing these devices means that they will continue to use them after the course finishes.

I wish I were able to conclude with a more satisfying answer. As an individual, I can continue to take on a few of the students who are most excited by robots and help them maintain and develop their interest. But I continue to believe there must be better solutions that support more students. I hope that this paper stimulates a further discussion among those of us who use robots or other types of electronic tangibles in our introductory classes, and that together we may come up with some new ideas.

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