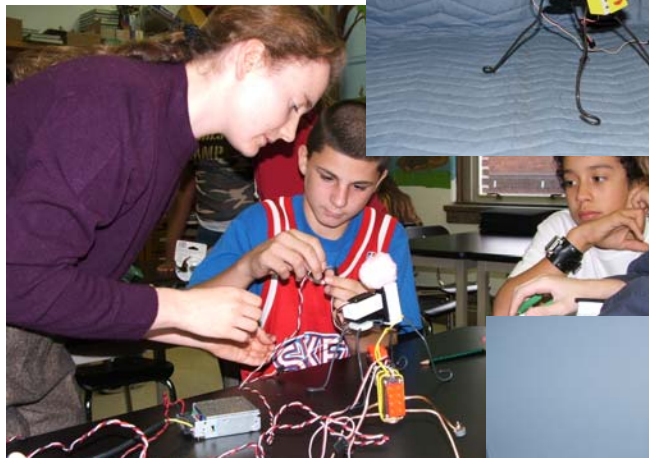


Under Represented Populations in Science and Technology: Robots for Science Education

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The Division of Science Resources Statistics of the National Science Foundation (NSF) reports that as of 1999, only 15.7 percent of students enrolled in engineering undergraduate programs in the United States were members of under represented minority groups. The same report revealed that the number of women receiving bachelor's degrees in computer science between 1990 and 1998 has steadily declined each year [1]. Young women, non-whites and those coming from low socioeconomic backgrounds are not choosing to study the physical and technological sciences. The cause for this gender/racial gap is unclear, but these under represented populations run the risk of being left behind in our technology-driven society.

Diversity in most environments is critical to success. The dominance of non Hispanic /white males in the fields of science and engineering has created a homogenous population of technological scientists. The "untapped genius" that lies within other portions of the population may hold vital pieces of information about an infinite number of undiscovered truths. With the current push for new scientific discoveries and improved technologies in the international market place the United States needs to tap into every available resource in order to remain competitive.

Innovative changes in the traditional science curriculum may lure more young women, students from low socioeconomic backgrounds as well as racial and ethnic minorities into the fields of science and engineering.

Science instruction with the implementation of robotics could provide these under represented populations with the needed impetus. Robots offer the opportunity for creative expression, problem solving and constructionist learning [2, 3, 4, 5]. The sometimes tedious subject matter in mathematics and computer programming are deeply imbedded in the novelty and kinesthetic nature of the robot. For example, a child who dislikes sitting still for a mathematics lesson might focus entirely on the math skills needed to program a robot that will move in a desired manner. Introduction to robotics at a young age could open doors and pique the imaginations of all students; encouraging diversity in the fields of science and technology [18].

If female, low socioeconomic status (SES), and racial minority students are shown to exhibit positive attitudes towards robotics then perhaps science instruction with the implementation of robotics would provide these under represented populations with the needed inspiration. Furthermore, if working with a robot at school could produce improvement in student attitude towards science and technology then everyone would benefit.

Attitude and motivation are important factors for school aged children. Nora Sabelli, senior program director in the Directorate for Education and Human Resources at the National Science Foundation explains that, "We know that motivation plays an extremely important role in education, playing while learning increases the time spent on the task, an important predictor of retained knowledge" [6]. Young people with favorable attitudes towards a learning tool are more likely to use that tool in a constructive manner and spend more time on task.

Iguana Robotics expects to find that students exposed to robotic enhanced education, will be inspired to study higher level science coursework and then pursue careers in

science and engineering fields. It is also predicted that test scores for all students will improve due to increased motivation.

Theoretical Rationale

Constructionist learning is a powerful, visceral kind of learning according educational theorists such as Seymour Papert [7] and Mitchel Resnick [8]. Deeply rooted in Piaget's theories, *Constructionism* is an adaptation of the educational theory, Constructivism, J. Bruner's theory that learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge [9]. *Constructionism* (*n* not *v*) focuses on the physical building of meaningful objects while learning [7]. According to Bers et al,

“Robotics naturally addresses the four basic tenants of *Constructionism*: 1) learning by designing meaningful projects to share with the community, 2) using concrete objects to build and explore the world, 3) the identification of powerful ideas that are both personally and epistemologically significant, 4) and the importance of self reflection as a part of the learning process” [4].

Although there are many variations of *Constructionist* approach, some more radical than others, the basic tenets of the theory are based soundly in the research findings of Piaget. While Piaget did not specify tout the glories of robotic enhanced education, his ideas about the importance of hands-on learning, student autonomy in learning and playing while learning seem to support the use of robots in classrooms. It is not surprising that Seymour Papert was a student of Jean Piaget [30].

Seymour Papert, arguably the seminal thinker for technology use and learning, modernized educational theory with his popular book, *Mindstorms: Children Computers and Powerful Ideas* [10]. Papert's belief that computers would revolutionize education was perceptive and accurate. Iguana Robotics, Inc. is not proposing that robots replace teachers and take over the classroom, glaring out at children with an icy stare and ruling with an iron fist (literally). The suggestion is that robots could be incorporated into every classroom as an educational tool, much like a computer, to facilitate learning in a kinesthetic way. Perhaps robots could be considered a “computer” for those learners who prefer tactile/hands-on learning [18]. If the idea seems far-fetched, recollect what we all thought about the use of the PC in school classrooms a mere 20 years ago. In the 80's, proponents argued that computers were an expensive technology and involved concepts too advanced for most teachers, let alone school aged children. As it turns out, they were wrong. Today most children exhibit computer skills well beyond their parents'. Seymour Papert saw the limitless educational possibilities that a computer held. Papert's views about computers could apply to robots as well.

The use of robots in an educational setting offers students multiple modes of learning. Individuals have preferred ways of gathering information due to biological and cultural differences (Gardner 1991; Gardner 1993). Not all students easily retain information from the oral lecture style used in the traditional classroom. Some individuals are kinesthetic learners and learn best by doing while visual learners need to see a diagram or chart in order to fully understand. For example, in the neuroscience classroom, classic conditioning might be explained through an oral discussion, a diagram on an overhead projection and then physically demonstrated with a robot. The kinesthetic nature of the

robot adds another level of understanding for diverse learners. This three part approach allows students to understand the topic on many levels and with multiple senses.

Empirical evidence

Robotic enhanced instruction is currently being used in classrooms across the country and has been receiving praise from authors and editors of numerous journals for many years. There is much anecdotal evidence found in trade magazines and professional journals to support that the robotic experience offers students opportunities for high order thinking, creative expression and discovery learning [3, 11, 12]. These types of learning experiences have been shown to motivate learners regardless of location, socioeconomic status, or gender [6, 5, 20]. Weinberg reports that, "Robotics provides a unique learning experience (since) robots are a physical embodiment of computation. The students receive strong, visceral feedback from physically experiencing their work" [13]. One problem lies in the lack of published, quantitative research reports on the subject of robotics as subject matter for the classroom. Iguana Robotics Inc. hopes to help fill this void in educational research with our Educational work and subsequent publications.

The following research reports seem to support the hypotheses that robotic enhanced science curriculum can improve student attitude, motivation, and learning outcomes.

Wagner's [5] ground breaking study showed that robots offered students a superior means of learning complicated concepts such as logic-problem solving and programming. Wagner's study compared the impact on student science achievement and problem solving as a result of instruction using robotics, a battery-powered manipulative, or a traditionally taught science class. Classrooms (N=15) of fourth, fifth, and sixth graders of which there were males (N=244) and females (N=209) participated in the study. The study consisted of two treatment groups and one control group. Treatment groups received a week of instruction using robots or battery powered manipulatives. The control group from each grade was given the traditional lesson, a week in duration. The study found that students in the robotics group had higher scores on programming and logic-problem solving than did the battery-powered group. Both experimental groups scored higher than the traditionally taught science class. Wagner's results show that a robot offers more to students than mere technological novelty.

C. Massey, at the University of Pennsylvania has just completed work under a National Science Foundation grant entitled: "Agents for change: Robotics for girls" (expired Dec. 2003 [14]). Massey and her highly qualified team have developed school-based, and informal education projects and curriculum materials for middle school students. The target of the project, just completing its third year, is to use robotics as an organizing theme to provide hands-on experiences and interesting applications that will appeal to female students as well as their male classmates. Massey's project worked with students in urban and rural areas and with students from low income and racially diverse backgrounds.

Descriptive research was conducted by Iguana Robotics' Education director, J. Rogers [15] to assess middle school student attitudes towards robots, technology and science. The subjects were two classrooms of sixth grade students (N=53) and eighth grade students (N=74). Observational checklists were completed to examine student behavior in the science classroom. A Likert-type questionnaire consisting of 20 items was administered to students to obtain their perceptions towards robotics and technology, and

to explore gender differences in their responses. Finally, interviews were conducted with female middle school students (N= 8) to obtain in-depth information on their perceptions and attitudes towards robotics, technology and the sciences. Results showed that middle school students exhibited positive attitudes towards robotics, careers in robotics, science and technology, and that female students held more positive attitudes towards careers in robotics than their male counterparts.

Garrison [17] came to conclusions similar to Rogers' in a 1993 doctoral study focusing on intrinsic motivation. The study compared intrinsic motivation found in fifth grade students (N=68) while working with a physical robot or a computer simulated robot. Both methods of delivery were found to motivate students. Interestingly, the study revealed that female students were significantly more motivated than their male classmates.

Buck [16] makes the argument that perhaps young girls are not interested in science because the traditional science curriculum is designed by "White, Western, Males." A study was conducted by Buck to explore adolescent girls' ideas and feelings about the contemporary structure of middle level science instruction. The qualitative study investigated the opinions of science teachers (N=11) and female 7th and 8th grade students (N=51) from various locations across the continental United States. In small interview/focus groups consisting of four to six female students, issues were discussed such as favorite science topics, comfort level in science classrooms and curiosities about the physical world. The study revealed that adolescent girls strive to make a connection to science. They saw how science helped them to better understand themselves and their world, but they seldom found such correlations in contemporary science classrooms. Teachers interpreted the girls' request from an assimilative perspective by seeking ways to help the female students "fit" into the existing structure of science education. Teachers did not attempt to change their science curriculum.

Empirical and theoretical evidence seems to support the use of robotics as an invitation to girls and under represented minorities into science, technology, and engineering. The absence of these groups from the physical and technological sciences could be due to a lacking in the traditional science curriculum and an expectation for these under represented groups to simply "fit in" [16, 21, 22]. If changes in the traditional science curriculums could be made to better meet the needs of all students then these under achieving and under represented populations would no longer be "left behind." It is well known by teachers that when positive attitude and motivation can be established in the classroom, learning outcomes will improve. Most students are motivated by robotics and robots [5, 14, 12, 13, 14, 15, 18, 20]. Therefore it is probable that robotic enhanced science instruction can improve test scores as well as inspire a diverse population of students.

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