Robots in Education

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INTRODUCTION

The new paradigm in engineering education demands hands-on training of the students using technology oriented projects. The roots of this approach can be traced back to the work of **Seymour Papert** in 1970s when he built a programmable turtle with a reflective light sensor (Papert, 1971). His ideas ultimately lead to the educational theory of **constructionism** (Papert, 1986 and Harel & Papert, 1991). According to this theory, students learn very effectively when they are involved in the creation of an external object that lives in the real world. Learners use this object to think with, and to relate ideas of, their subject of inquiry (Bourgoin, 1990). From an educational point of view, the theory of Papert can be linked to the **constructivist** theory of Jean Piaget (Paiget, 1972). According to this theory, learning comes from an active process of knowledge construction. This knowledge can be gained through real life experiences and linked to a learners' previous knowledge. The concept of turtle was evolved further at MIT and became the famous **Programmable Brick** by **Fred Martin** who also developed new learning environments and methodologies based on this concept (Martin, 1988 and Martin 1994). The unusual idea put forward by the Brick, at least at the time of its invention, was the incorporation of the "design" work into the learning process. Students were not only users in this case, but were actively involved in the design process, while solving their problems (Martin, 1996a). The 'Brick' was later adopted and incorporated by the LEGO MINDSTORMS kit (RCX in 1998 and NXT made available in 2006). The use of the name "MINDSTROMS" can also be traced back to the book by Seymour Papert (Papert 1980). Versions of these Bricks for economically challenged communities have also been proposed recently (Sipitakiat, et al, 2004).

The **active learning** methodology (Harmin and Toth, 2006) uses this philosophy of involving students in their own learning through class discussions and group problem solving and proves to be effective at least in certain cases. Robots have become a major player in this area and have been employed in improving the quality and level of student learning, ranging from primary schools to graduate level. As pointed out by Resnick and Martin (Resnick and Martin, 1990), "Creatures built from Electronic Bricks fall on the fuzzy boundary between animals and machines, forcing students to come to terms with how machines can be like animals, and vice versa". In engineering courses incorporating connectionism approach, the students are asked to design and program a robot for a specific task. They also work in small teams and help and learn from each other.

However it is important to know what is currently available to an educator so that he/she can develop the required skills, abilities, attitudes and values in students. In this article we identify some of the major research centres working in the area of education utilizing robots and discuss some of the robotic kits now available to educators. We also comment on the famous robotic competitions worldwide.

BACKGROUND

Many researches have tried to include a project-oriented approach to the teaching of engineering subjects. This approach has the benefit of allowing students to seek information on their own while developing a well defined product. The use of robots in enhancing the quality of education at a university level has been discussed by many authors (Takahashi et al, 2006, Gage & Murphy 2003, Matsushita et al 2006). Students from school to undergraduate level have been involved in microcontroller based robotic projects. They can design, build and test their robots themselves and that helps them later in their education. Mukai and McGregor (Mukai and McGregor, 2004) have gone to the level of teaching control to eight graders in public schools.

Robots can help educators in teaching and learners in learning various branches of basic sciences. This is in addition to their obvious use in engineering courses. Mathematics (Algebra, geometry, matrices, calculus), Physics (electricity, force, Newton's laws, momentum, rotations and angular momentum) are few examples (Yousuf et al., 2006). Their connection to biology comes through understanding and linking of human sensors to robotic or electronic sensors. Bratzel (Bratzel, 2005) uses engineering principles to teach physics and physical science by incorporating LEGO robots. She introduces, in chapters of increasing difficulty, concepts of motion, forces, fluids, stability, work and energy, etc. Bratzel has also correlated the activities in her book with the national science content (in USA) standards for grades 5-12, and hence makes for a good choice for educators at that level.

The purpose of integrating robotics is not just to create excitement among students but to use this excitement to help them in learning what they find difficult to learn using conventional methods. All the educators want to develop certain abilities, values and attitudes among their students. Some of the international accrediting organizations, like the Accreditation Board for Engineering and Technology recommend the use of a "**competency-based learning**" methodology for course development (Earnest, 2005 and Criteria for Accrediting Engineering Programs, 2006). The core of this system is that all activity (in the classroom, laboratory or projects) must be focused on pre stated competencies by using structured learning objectives. This system also demands the evaluation to be based on the competencies developed by the students. This can only be done by looking at concrete evidence (e.g., electrical or mechanical systems developed, software, technical reports, etc). Once again, the use of robots provides the educator with well defined competencies to be evaluated precisely.

EDUCATIONAL ROBOTS

We divide this part into subsections discussing various aspects of the main theme. Since each of these subjects is sufficiently broad in itself, we concentrate on a few representative cases only.

Research Groups in the Area of Educational Robotics

This is an area of immense activity and the number of research groups active in this area is extremely large. Almost all the robotic research groups have an interest in the educational aspects of the subject. Many have tried to involve their own undergraduate students into the process and have gained new and deeper insights into student behaviour and learning.

Massachusetts Institute of Technology

MIT has been active in the area of robotics for a long time but it was in 1989 that Fred Martin (Martin 2001) started a worldwide movement in educational robotics by introducing his now famous undergraduate design contest. This was also the launching of the corresponding robot "brain" called the Handyboard (Handyboard). It is now being used by educators worldwide together with the Interactive C language to program the system (Butler et. al., 2006). This system is powerful enough to have industrial applications. The work of Fred Martin was continued later with Mitchel Resnick's Life-Long Kindergarten group (Kindergarten Group). This work was partly sponsored by the LEGO Group and became the foundation for the LEGO MINDSTORMS Robotics Invention System (to be discussed later).

NASA Robotics Alliance Project

The Robotics Alliance Project is an initiative of the **NASA**, the National Aeronautics and Space Administration in USA. It is based on the idea that NASA is going to need many more robot engineers for its space endeavours in the future and the only way to have quality engineers in the future is to invest in their training (RAP). Hence the project starts at the level of K-12 and does it through a variety of robotics programs, competitions and curriculum development. Their web site offers links to curriculum resources starting from primary to doctoral level. It also lists some of the major robotic competitions, and internship opportunities for students, etc. NASA also provides video and webcast archives for educators.

Carnegie-Mellon University

The robotics institute at the **Carnegie-Mellon University** is one of the largest of its type and has various projects with an educational impact. The CREATE project, which is an acronym for Community Robotics, Education and Technology Empowerment (CREATE) has research programs in curriculum design for teaching robot programming at the secondary school level and