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Robots in the classroom - tools for accessible education

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Keywords

Robots, Educational Technology, Access, Students with Disabilities

Abstract

In this paper we describe some of the current and envisaged uses of this broad collection of technologies referred to as robots, within education. This is firstly from the general perspective but then with an emphasis on the benefits they bring to school and university students with disabilities.

Introduction

Robots have found widespread application in industry and are beginning to increasingly find applications in diverse roles within education. There are many definitions of what constitutes a robot and numerous designs, configurations and types reflecting their broad range of applications. The authors here take a free definition and within the scope of this paper we consider: manipulators; robot vehicles; automated and remote controlled devices; and robots that might exist only in software.

Possible roles for robots in education

With robots and related automated process having increasing role in industry they are becoming an object for study in their own right in technology and engineering courses at secondary school and university level. However in this paper we mainly consider the wider role of robots more generally in key elements of the learning process.

Robots are a great aid to the teaching of especially maths and physics because of their power to capture the imagination of many younger people. Thus they can be employed to elucidate often difficult abstract concepts. With the robot as the focus of the discussion of a wide range of topics can be brought to life: Newtonian mechanics; measurement; task planning; programming; mathematical formulation of a problem; optimisation; limits; etc. Giving something physical in the 3-dimensional "real world" can help many students grasp the fundamentals of a topic more quickly than just using paper/white board and pen. The robot as well as assisting in conceptualisation of a problem provides an environment for experimentation. Possible solutions can be programmed into the robot and then its behaviour observed to see if it conforms to that which the student expected. There is then opportunity for iteration towards a correct solution to a particular problem. Thus the power of discovery in effective learning can be readily facilitated through the use of a robot as a teaching aid.

Simple robotic vehicles have been successfully used at both school and university level by both the departments represented by the authors of this paper. At the Open University a simple robotic buggy that can be controlled over the World-Wide-Web has been configured to mimic the NASA Mars Buggy and used extensively with school groups [URL 1.]. This was an extension of a remotely controlled robot in a maze that was developed specifically in response to the control technology elements of the English/Welsh National Curriculum for 11-12 year olds [Whalley 1992]. Similarly at the University of Reading autonomous robot programmable "insects" have been used at both school and university level and are more fully described under **Experiences with Robot Insects in Education** below.

Robots have traditionally been programmed by complex high or even low level computer languages, which would tend to mitigate against their use within education. There are

several robot programming languages that have been developed specifically for educational use (e.g. *LOGO as used with the Lego Dacta system). However even these may be overly complex and constrained by the need for precise syntax for many younger or less able students. An interesting approach to address this has been taken and an international group of researchers working in evolutionary robotic design. They have successfully demonstrated the use of evolutionary robotic approaches to enable children to design for themselves a range of simple robotic behaviour such as collision avoidance, line or wall following, etc. for Lego based mobile robots [Lund, et. al. (1998)]. The same problem has been addressed differently in the work at the Open University. In brief their approach is based on the use of a simple object-oriented control language integrated with a role play and storyboard techniques to enable the children in the creation of their own programmes [Whalley 1992].

Robots can be an expensive technology with costs ranging from about 100 ECU to 10,000 ECU. Since the use of robots in education is still in its infancy there are difficulties with staff training, technology reliability and a lack of quantitative studies showing the educational impact. Most work reports anecdotally that there is an educational benefit, but there is usually no reliable measure of what factors are causing the benefit.

However the authors see robotics as an increasingly available and affordable technology that can address needs of teachers and learners in established areas of the curriculum. They are not attempting to support a technology push approach to hi-tech learning environments. A survey of any set curriculum for education from the ages of 8 upwards readily yields key opportunities for the application of robotics to those with experience of the pedagogic advantages of approaches based on these technologies.

Work of Seymour Papert

Seymour Papert, a founding father of this field, supports an approach to learning in the classroom which he calls 'constructionism', opposed to the traditional style of 'instructionism' [Papert, 1993]. By this he means that children will do best by finding or 'fishing' for knowledge by themselves. Improvisational, self-directed, 'playful' activities should simulate the more 'natural' way in which children seem to learn outside the classroom. Instead of a one-way and top-down transmission of knowledge from teacher to child (the behaviourist/objectivist approach), appropriate learning environments ('contexts'), could be used as 'personal media'. This could, according to Papert, empower the child to develop a different relationship to knowledge in a new style of learning, which can account for personal variation in learning styles.

In the mid-1960s Papert developed at the MIT AI-Lab with his colleagues the programming language LOGO, a computer language especially designed for children. This is now widely used in control and robotic activities in the classroom. He also went on to develop a programmable computer-sketching device, called a 'Turtle' to introduce mathematical concepts of geometry and shape. Again this has become a widespread technology.

Particular roles for robots with disabled students

Educational applications for robots hold particular promise for students or pupils with disabilities in two main ways:

- The robots can be enabling in themselves – students being facilitated to undertake a wide range of tasks that would be otherwise denied them because of their disabilities
- Accessible interfaces to educational robots can lead to disabled students having equal participation with peers in robot based learning activities

The potential for robots facilitating learning by experiment has already been stated. This approach has added value for the disabled student who may be reduced to an observer role in many conventional student experiments. Provided the appropriate computer interface is available most disabled students can initiate the experiments themselves.

Robot Manipulators in Special Education

A fully integrated, robot aided, science education programme for students with disabilities was developed by Howell [Howell, et. al. (1994)]. This work was based on a commercial robot (the RTX from OxIM, UK) and focused on developing teaching material based on the US science curriculum for Junior High School students. Examples of teaching material included experiments in biology, where seeds were grown under different conditions, and physics where properties of materials were tested.

Harwin and Gosine [Harwin et. al. (1986), Gosine et. al. (1990)] carried out similar work, which had a greater focus on the interface between the person and the robot. This system was also based on the RTX robot and children with special needs were evaluated in a structured teaching environment. Tasks undertaken in this system ranged from illustrating basic concepts such as block play, problem solving and sequencing tasks, through to simple chemistry experiments, and making and eating simple desserts. An observation of this system is that once the individual was familiar with the interface, they were prepared to experiment, both with the robot and with the environment. One example is that when time for free play was allowed, one student experimented with pouring water from one container to another discovering how water flowed and getting splashed in the process - this proved to be a powerful learning experience.

This illustrates a strong advantage of a robot-based system compared to a software simulation in that the real world has many more interacting factors that cannot be illustrated by a computer. Further it is a demonstration of the robot equalling access for students with special needs to the same equipment used by their peers.

A programme of work has recently been begun, led by the Open University, towards developing a flexible learning environment based on remote controlled experimentation. Key objectives for this work are to develop an experimental facility that will enable the active participation of disabled students in science education alongside their peers and to provide a facility that supports the practical elements of science education at a distance. An important feature of this work is that from a standard personal computer students are able to design and configure experiments that they then conducted at a remote laboratory. Robot manipulators and other related technologies have a key role here [URL 4].

As well as the approach of linking robot assisted exercises to a formal syllabus the advantages of a robot being available for free play or exploration should be noted. Students with severe physical disabilities may have missed much from such experiences in their pre-school lives because of their inability to interact with their environment and the objects within it in a controlled fashion (e.g. playing in the bath). Thus, robots can have a key role in replacing the informal learning received by most children as they play.

Mobile Robots in Autism

One of the authors is studying how to use interactive, mobile robots as therapeutic devices for children who have difficulty in co-ordinated interactions with the environment and other people [Dautenhahn 1999]. The project Aurora (Autonomous robotic platform as a remedial tool for children with autism) is using a commercially available mobile robotic platform. The platform itself is seen as a mediator device, i.e. it is intended to encourage

children to interact with the environment. Basic forms of social interaction like attraction and avoidance are elements in the robot's interaction repertoire [URL 3].

Experiences with Robot Insects in Education

Within the Department of Cybernetics at the University of Reading, a set of small robots known as the seven dwarves has been developed specifically for educational use [URL 2.]. These robots have been used extensively in education from the ages of 6 through to post doctoral research over a period of about 6 years. The "dwarves" consist of a 3-wheeled machine, roughly 150mm x 150mm x 150mm driven by 2 electric motors, which can be controlled by the resident software. They also include a set of ultra-sonic sonar sensors by which they sense the world. The way the "dwarves" behave given the sensor information can be fully programmed by the students, at different levels as applicable to the age group. When programmed, the "dwarves" are then set free and their behaviour observed. A lot of fun and educational benefit has resulted from groups of these being programmed and set free to run together. (E.g. groups of student can work together to programme a pair of robots which will follow each other).

The robots thus present an achievable challenge to a wide age range. They are perceived as fun as they travel at speeds up to 1m/sec and can sense obstacles at a distance. The students find that deliberately programming the robots to crash is boring as they only move the once, however programming them to just miss is more challenging and far more enjoyable. Once the students have started to think in a reactive programming way they seem to find it far more intuitive than, for example, programming a sequence of Cartesian commands. The slow response time of the robot of up to 1/10 of a second compared to its speed of up to 1m/sec means the robots' actions are far less deliberate than the students expect and they tend to associate this with character. A robot with a following programme is often described as curious or frightened and often likened to a puppy.

This is an example of a robot-based approach suitable for a wide range of educational circumstances, which can be readily made available to many disabled students by simply providing the appropriate interface to the computer used to programme the robot insects.

Conclusions

Robots have great potential for sound pedagogic reasons within education at all levels. They provide particular opportunities for making accessible, for a wide range of disabled students, practical elements of the curriculum. However the available technology is largely under exploited except by teacher enthusiasts in isolated pioneering centres. If these educational and accessibility benefits are to be realised widely then, alongside further technical development work, activity is required to:

- Raise awareness within the teaching professions as to the potential of robot technology
- Low cost robots and associated software need to be made more widely available
- A wide range of applications need be developed for a common robotic platform so that the investment in the technology is seen to have cost benefits across the curriculum and not just in a few specialised areas.
- Teacher resources that integrate the robotic tools with curriculum material need to be produced, evaluated and marketed

The authors are engaged in all the areas outlined as well as their technical research and development and would welcome exchanges and collaboration from other working in the field.

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URL's for World-Wide-Web References

URL 1: <http://met.open.ac.uk/heronsgate/projects/Mars/buggy.html>

URL 2: <http://cyber.rdg.ac.uk/research/CIRG/>

URL 3: <http://www.cyber.rdg.ac.uk/people/kd/WWW/aurora.html>

URL 4: http://kmi.open.ac.uk/people/martyn/remote_experimentation.html

Commercial products

A few examples of commercially available educational robot systems are listed in the table below. (This is for information only and does not imply any endorsement of assessment of the products by the authors.)

Manufacturer	Product	Brief Notes
Fischer	Fischertechnik - Mobile Robots Kit with Lucky Logic for Windows s/w	Allows students to build autonomous mobile robots. The kit contains an interface, which supports 4 digital motor outputs, 8 digital and 2 analogue inputs. Analogue inputs can be used for light sensors, digital inputs for bumpers (touch sensors) or tilt sensors. Programming is done using a graphical programming system. Suitable for children 12+.
LEGO Dacta	RoboLab (and associated Win/Mac based s/w)	Staged development of complex robotic machines based on series of programmable Lego bricks, which can be built into any Lego, based model. Focussed at procedural programming based on LOGO. Simpler kits also supplied which do not require the computer and related products exist for a "Smart House". Suitable for children 8+.
Valiant	Roamer / Turtle	Widely used programmable mobile robots (Roamer has dedicated s/w, Turtle programmable by LOGO both build on Papert's work). Valiant also supplies kit components from which students can construct their own robots. Suitable for children 6+.