Children, robotics, and education

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Abstract Popular interest in robotics has increased astonishingly in the last few years. Robotics is seen by many as offering major new benefits in education at all levels. Before rushing in to exploit this popularity, educators should ask serious questions about the universality and longevity of the robotics phenomenon. Is it a fashion? To be useful, the energy released by robotics must be sustained and universal, and the means of exploiting it must be systematic. Universities define their own robotics curriculum, but most schools lack both the resources and freedom to do this, and must work within the national curriculum. If it can be shown that robotics has sustained potential in education, it seems inevitable that new ways need to be found to integrate it into the schools curriculum.

Key words. Children robotics education . Edutainment . RoboCup Junior. RoboFesta

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ORIGINAL ARTICLE

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Abstract Popular interest in robotics has increased astonishingly in the last few years. Robotics is seen by many as offering major new benefits in education at all levels. Before rushing to exploit this popularity, educators should ask serious questions about the universality and longevity of the robotics phenomenon. Is it a fashion? To be useful, the energy released by robotics must be sustained and universal, and the means of exploiting it must be systematic. Universities define their own robotics curriculum, but most schools lack both the resources and the freedom to do this, and must work with a national curriculum. If it can be shown that robotics has sustained potential in education, it seems inevitable that new ways need to be found to integrate it into the school curriculum.

Key words Children robotics education · Edutainment · RoboCup Junior · RoboFesta

1 Introduction

In the UK, as in many other countries, interest in robotics has swept across the nation. There are commercial magazines, such as *Real Robots*, there are hugely successful television programs, such as the commercial *Robot Wars* and the Government-sponsored *Technogames*, and many web sites, such as the BBC's site (www.bbc.co.uk/science/robots).

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There is no doubt that many children and adults find robots fascinating (Fig. 1). Sales of affordable robot toys and robot construction sets are reaching unprecedented levels.

Many of us believe that robotics provides a tremendous source of energy that can be used to motivate learning for children and adults alike. However, before rushing headlong into new programs of education, we need to understand exactly what it is that robotics has to offer the educator. We need to resist getting caught up in what may turn out to be nothing more than a passing fad. Here are some of the questions that need to be addressed.

- Do children learn anything from robotics?
  - Social skills and teamwork?
  - Science, technology, engineering, math?
  - Literacy and communication?
  - Art, creativity and design?
- Is this different from other ways of learning?
- Is this popular interest in robotics a fashion, or is it likely to be timeless?
- Are there gender issues to be addressed?
- What is the best way to exploit the potential?

Anecdotally, almost anyone who has worked with children and robots will tell you that it was a great experience, that it was electric, and that the children got a lot out of the experience. Not surprisingly, many of us believe that this enormous interest and energy can be harnessed for educational purposes.

However, before steering our education system too far in the robotics direction, there are some important questions to be asked about the energy that seems to be released when children or adults build robots.

The first question is whether the popular interest in robots is a fashion. Will the passion wane and be displaced by some other activity or toy? Is robotics the hula-hoop of our decade? Will robotics become boring? If it does, then there can be no long-term commitment to teaching *through* robotics.

In principle one could teach science, technology, and mathematics through automobile maintenance. To my

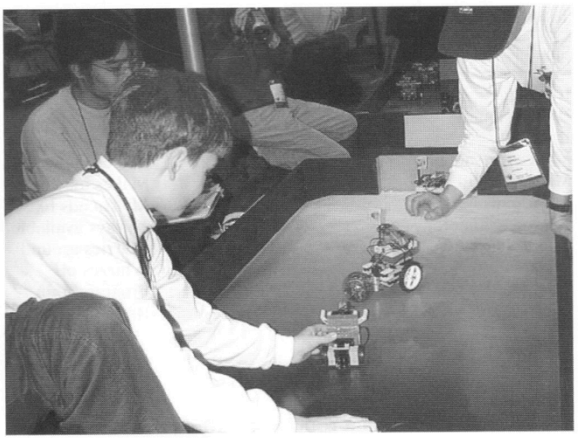

Fig. 1. Robot soccer at RoboCup Junior, Melbourne, 2000

knowledge, this is not done, and yet many of us claim explicitly that these things can be taught through robotics. Where is the difference?

In May 2000 I observed a bus-load of children arrive at the European RoboCup Competition in Amsterdam. They were to spend a Saturday participating in a new children's robot football competition devised by Henrik Lund and Luigi Pagliarini of the University of Southern Denmark, and organized by Ben Kröse of the University of Amsterdam. The children used robots constructed out of Lego Mindstorms, and a simple program interface devised by Lund and Pagliarini. Very quickly they learned how to construct programs using software with primitive behaviors such as "seek the ball" and "go to the center of the pitch."

Building robot football teams is very difficult for adult scientists and engineers. Lund and Pagliarini's ingenious approach simplified many problems by having a special infrared light-emitting ball that the Lego sensors could see. By making the pitch white at one end and black at the other, the robots have a one-dimensional orientation, which can be complemented by the use of touch sensors to give information about the other dimension.

By lunchtime, the children had programmed their robots to play, and during the afternoon a competition was held, and winners emerged. The atmosphere was electric. As I observed these children so passionately engaged with their robots, I was haunted by a question that would not go away: "What are these children really learning here?"

I think this question is fundamental. No doubt if the same group of children had been taken to another event, perhaps a sports event or a scout camp, one might have observed an equally electric atmosphere. Certainly children do learn things at these other events, so what, if anything, is special about robots?

One gain from robotics events seems to be in the *behavior* of the children. Their social behavior seems to change in positive ways. In a study of children participating in RoboCup Junior in Melbourne in 2000,[1] all the 12 teachers interviewed remarked on the teamwork of their children. Apparently boys start listening to each other when they are really motivated to achieve a common goal. And girls *are* different from boys.

Lund and Pagliarini have made great inroads into the gender question. They observed that boys get very engaged in robot wars and robot soccer, but girls do not. After experimenting with children in Scandinavia, they found that girls are not necessarily antirobot, but they approach robotics differently. They devised new, more creative, robotics activities. They then observed that girls like making clothes for their robots, devising dance routines for robots, making robot processions, and so on. In principle, girls and boys could benefit equally from robotics in the classroom.

2 Does robotics enable children to learn?

To answer this question, a distinction should be made between enthusiasm and learning. A distinction can also be made between serendipitous learning and structured learning.

Over recent years, teaching in the UK is increasingly judged by explicit *learning outcomes*. When teaching, we are expected to know our *aims* and *objectives*, and to have *measurable* learning outcomes. To this, many teachers would add less tangible outcomes, e.g., communicating to their students the joy of learning, and the fascination of the subject.

In robotics, the intangibles come free in most cases. Boys, in particular, are fascinated by robots, and are highly motivated to build and experiment with them. But what of the more formal learning outcomes?

In August 2000, I visited a rural school in Australia. The children were spending a technology lesson preparing robots to participate in RoboCup Junior in Melbourne the next week. One of the boys explained how he had built a circuit with an op-amp and some LEDs to make it easier to see what his Lego robot was doing. The previous summer, I explained op-amps to my daughter as she prepared for her physics examinations. For her, the knowledge had no applied context, and she found the whole thing rather abstract and boring. In contrast, the boy had built the op-amp circuit on his own initiative, and he seemed to have the best learning outcome.

To my knowledge there are no definitive studies that show that robotics improves learning outcomes. Most of the information available is anecdotal, and based on particular teachers doing particular things, or particular one-off initiatives reporting good outcomes.

One might ask if there is scope for a formal scientific study to investigate the efficacy of robotics in teaching any particular part of the curriculum. Perhaps some double-blind tests in which some children were educated over a sustained period using robotics when appropriate, with another group having some kind of nonrobotics "placebo" instead.

My belief is that this would be like drug trials in which the difference between the test and placebo groups be-

Table 1. A possible comparison of motivating media for teaching technical skills

	A	D	E	F	M
Robotics	✔	✔	✔	✔	✔
Car maintenance	✗	?	?	✔	✔
Cooking	✗	?	✗	✗	✔
TV stars and soaps	✗	✔	✗	✗	✗
Sport	?	✗	✗	✔	✗
Painting and art	✗	✔	✗	✗	✔
Wood and metal craft	✗	✔	✗	✔	✔
Computer games	✔	✔	✔	✔	?
Meccano	✔	✔	?	✔	✔
Model trains	✔	?	✗	✔	✔
Dinosaurs	✗	✗	✗	?	?

comes apparent so quickly, that the experiment is abandoned, with everyone then receiving the new treatment. Some teachers are already using robotics in their teaching, and presumably they do believe that robotics enables children to learn.

3 How is robotics different for teaching?

How does the use of robotics differ from other ways of supporting learning? What is special about this medium? It is often claimed that robotics can be used to teach science, technology, engineering, and mathematics. I agree, and here are some examples:

A: algebra and trigonometry
D: design and innovation
E: electronics and programming
F: forces and laws of motion
M: materials and physical processes

The question is whether robotics allows such things to be taught more effectively than other media. Table 1 uses the letters in the above list to show a possible comparison between various media to support children's learning. For example, car maintenance might be used to motivate some children. In my opinion there is little explicit algebra and trigonometry involved, little design and innovation, quite a lot of materials and processes, quite a lot about forces and the laws of motion, not much explicit electronics, and probably no programming.

Consideration of other motivators suggests that they do not cover the same spectrum as robotics either. The exceptions are computer games, and traditional Meccano construction kits.

Computers can simulate three-dimensional dynamics very successfully. Although simulations of physical systems can be very realistic, the pedagogic value of robots lies in making them work by using or extending your knowledge to diagnose and fix problems.

Hands-on robotics cannot be simulated at present. Virtual reality may change this, but not in the short term. For now, it is more effective, and probably less expensive, to let children build and experiment with real robots.

Table 2. Pet–robot comparisons

Small pet	Small robot
It's *my* pet	It's *my* robot
Hold in hand	Hold in hand
It's cute!	It's cute!
Makes me smile	Makes me smile
Makes me laugh	Makes me laugh
My friends like it	My friends like it
Always available	Always available
Scurries around	Scurries around
Whizzes off	Whizzes off
Program/train	Program/train
Dies	Breaks

My conclusion is that robotics *is* different because it is so multidisciplinary and involves a synthesis of so many technical things. Of all the motivating media discussed, I think robotics is especially motivating.

4 Is robotics a fashion, or is it permanent?

If robotics were a fashion, its educational value would be limited to a short time window. Although this might provide short-term opportunities, it would not justify the time and effort that many people are putting in to it. Are we wasting our time?

Dolls have been found that date back thousands of years, and they remain very popular with girls *and* boys today. Presumably they satisfy some deep human needs. My view is that robotics also relates to deep human needs, and that the interest in robots is likely to be permanent.

It is possible to speculate that there is something animal-like about small robots. Like small rodents, they are cute, they sometimes whiz off unexpectedly, and they make us laugh. In fact one can find a lot of parallels (Table 2).

In some ways, robots are similar to dolls and pet animals. For whatever reasons, children seem to like both. Perhaps because they are models of other humans and living things? Models that they can experiment with without adult interference and sanction? Generally you must not damage your toys, and you must not be cruel to animals.

I do not think that robotics is a fashion, any more than model trains. Indeed, robots are like superior railway engines: they do not need tracks, they do more interesting things than just move, and they can have a mind of their own. I am convinced that, like dolls, cats, dogs, gerbils, and hamsters, child-friendly robots will be with us forever.

5 Edutainment

Twenty years ago the hardware for building robots was hard to obtain for those lacking know-how and money. Similarly, software for programming chips and electronic components

was extremely specialized and complex. Robotics was an arcane science that was the preserve of university laboratories, and the automotive, aerospace, defense, and other multibillion-dollar industries.

Now, everyone can experiment with robots. You can buy a range of construction kits in your local department store for between $30 and $200. In the UK, a BBC web site gives instructions on building robots that can be bought by mail-order for $30. The newly launched magazine *Real Robots* gives away components that build up into a robot over a period of a few months.

Complex electronic devices that were once the preserve of specialist professionals are now available to everyone as consumer goods in the home. Many purchasers buy these goods for personal pleasure and entertainment.

The same computer that is used for games, home accounts, and surfing the Internet, also has great potential for the education of children and adults. *e-learning* is being seen as a major new force in education and training.

The consumer electronics and software that supports mass entertainment can also act as a platform for education, and so we get the idea of *edutainment*. The term "edutainment" suggests that children can be educated at the same time as they are entertained. Learning becomes a pleasurable activity.

Robotics is an edutainment medium *par excellence*. The hardware is becoming less expensive, and many educators are responding by creating new software development environments and interfaces. There is great potential for robotics to motivate many parts of the curriculum, in ways that many learners will find highly entertaining.

6 Gender and access issues

Only two of the members of my department at the Open University are women. None of the ten full professors in the Technology Faculty are women. So must technology and robotics be the preserve of boys and their fathers?

If it were the case that robotics is only attractive to boys, then only half the population could be educated in this way. This would be a severe blow to our edutainment aspirations.

The work of Lund and Pagliarini[6,7] shows that girls will indeed engage in robot activities. It is no longer necessary to pretend that boys and girls are the same and, not surprisingly, we find that girls relate to robots differently from boys. Thus, the challenge to educators is to consider girls as potential learners who do not follow the usual male clichés of speed, power, competition, and destruction.

The evidence is that girls *do* like designing robots. For example, Fig. 2 shows 6-year-old Grace and her 8-year-old brother Max with the robot they designed and built for the RoboCup Junior dance competition in Seattle in 2001. This robot was made using a Lego Mindstorms kit, to which Grace added wings made of diaphanous material, and a head made from modelling clay.

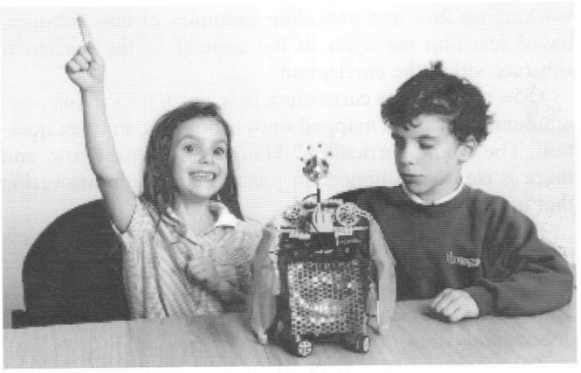

Fig. 2. Girls *do* like designing robots

The attractive feature of robot dance is that it requires no less skill to program than more competitive activities such as robot soccer. The dance robot shown in Fig. 2 won the world championship in its class because its choreography was original, witty, and fun. This shows that robot activities can be devised that are attractive to girls and boys alike.

In the UK, the Government has supported the *Techno-Games* programs produced by the BBC. In this series, children are challenged to build all kinds of machines, including robot rope climbers. Many girls enter these competitions, and they seem to enjoy them as much as boys do.

In January 2001, we ran a robot design competition with the BBC children's magazine TV program *Blue Peter*.[2] That competition attracted 32000 paper designs from children aged 5–15 across the UK. Half of the designs in every age group came from girls. This is evidence that girls are prepared to engage in robot design activities as much as boys.

We believe that this topic merits more systematic research. We propose to do this by working with children in our local schools.

There are other access issues. Children living in deprived areas may have less access to robots and robot-based education than others.

7 Robotics in schools

Many schools in the UK already have robotics kits and use robotics in their teaching. These are early days, and these schools are pioneers.

In this article, an argument has been made that robotics is special, and that it can be used to motivate learning in many different areas.

Some children attend schools at which there may be no teacher qualified or confident enough to teach through robotics. At the Open University, we believe that there is a need to provide education and support for school teachers, and we are working on this.

If it is to be widely used in schools, robotics education *must* map on to the national curriculum. Many people are

working on this, and providing examples of new robotics-based teaching materials in the context of the particular subjects within the curriculum.

How much of the curriculum in science, technology, and mathematics can be mapped onto robotics is an open question. The whole curriculum? Half? We do not know, and there is clearly an important job to be done in answering that question.

Edutainment robotics is changing very rapidly. New hardware and software are appearing all the time. There is no single hardware or software platform that can be seen to be "the right answer"; all have advantages and disadvantages.

The way forward may be to map the generic features of robots onto the curriculum. For example, it is easy to see how wheeled robots with on-board timers can be used to teach various aspects of Newton's laws.

Another way forward may be to expect the suppliers of robot components to provide national curriculum-compliant teaching materials. Some suppliers realize that this may be the only way to sell their products, and they do produce teaching materials to go with them.

The question is whether robotics can be the most effective medium for teaching areas of the science, technology, and mathematics curriculum. There is no conclusive evidence either way, but I believe that it can, and that this will become increasingly obvious.

8 How can teachers be supported?

If robotics is to become a core activity in all our schools, who will teach it?

As RoboCup Junior has evolved, some excellent teachers have inspired their pupils to do wonderful things with robots. Of course, these are the self-selected best teachers in this area. We believe that many more teachers could achieve the same results if they were given sufficient support.

The needs of teachers have been identified as being very important by the RoboCupJunior division of the international RoboCup Foundation. It is realized that many teachers would like to form robot teams for sports or performance events, but lack the technical know-how or the knowledge of where to find suitable equipment and software within their budgets.

In UK schools, teachers are expected to deliver the national curriculum using lessons with planned objectives and outcomes. What kind of support would be most helpful to a teacher wanting to use robotics as a teaching medium, but unsure of how to do so?

First, teachers must know and be confident with the subject they are teaching. For many teachers this may mean filling in gaps in their knowledge, including getting them to build and program robots. At the Open University, we have identified this as an adult learning requirement that comes within our normal remit. We are already working on the production of educational materials for those who are going to teach school children using robotics.

Second, teachers require support in the classroom. The level of skill and knowledge required to design lessons based on robots to deliver particular parts of the national curriculum is much greater than the level of skill required to teach such a lesson. In the same way that we do not expect all school teachers to write their own textbooks, we should not expect teachers to prepare all their own robotics lessons.

9 Robotics and the national curriculum

If robotics is to fulfil its education potential in the UK, it is essential that it be explicitly integrated with the national curriculum.

At the Open University, we are beginning to assemble distance education teaching materials produced by various teachers, organizations, and suppliers. We hope that these materials will be useful to large numbers of school teachers. We also think that the mapping between robotics activities and the national curriculum should be made clearer, and we expect to make a contribution to this.

10 Conclusions

This article has addressed various issues and come to the following conclusions.

Do children learn anything from robotics? This answer to this question must be that robotics provides an effective way for children to learn many of the things on the national curriculum for science, technology, and mathematics. Arguably, robotics is the *most* effective way of motivating and supporting the study of many areas of the curriculum. The evidence is that robotics also has an impact on children's social skills, and helps them develop teamwork skills. Robotics certainly encourages children to use their imagination and be innovative in design. The area of robotic art from children remains to be investigated, but robotic art already stimulates interest in adults. Robotics may improve literacy and encourage creativity. It may motivate children to write more easily, as they document their designs and experiments. In robot competitions, it has been seen that children will integrate robotics into performances that include music, their own poetry, and themselves.

Is this different from other learning? Robotics *is* different from other modes of learning. It is multidisciplinary, and involves more subject areas than other motivating contexts.

Is this a fashion, or is it timeless? It has been argued that there is something special about robots which is akin to the relationship between humans and pets. On this basis, it is concluded that the current explosion in interest in robotics is more than just a fashion, and that it will endure. This is

essential if robotics is to make a long-term contribution to education.

Are there gender issues to be addressed? There *are* gender issues to be addressed in robotics. The evidence is that girls find robots as attractive as boys do, but in different ways. The solution lies in designing robot activities that are attractive to both.

How can we best exploit the potential? Robotics is currently an extracurricular activity for most children. No doubt the children learn much from it, but the potential of robotics to educate will best be realized through more formal education in our schools. To do this, our school teachers will require a lot of extra support. Some will be in the form of adult education for the teachers themselves. Once teachers are knowledgeable and confident enough to teach children, they will require support materials that link into the curriculum. These may take the form of complete lessons, or templates which teachers can complete in their local context, or just the mapping of curriculum goals to robot activities may be sufficient for some teachers.

References

1. Sklar E, Johnson J, Hautop-Lund H (2000) Children learning from team robotics. Report 2. Edutainment and Robotics Education Research Laboratory, Faculty of Technology, The Open University, UK, December
2. Johnson J, Hirst A (2001) The RoboFesta – Blue Peter Children's Robot Design Competition. Report 1. Edutainment and Robotics Education Research Laboratory, Faculty of Technology, The Open University, UK, March
3. Healy J (1998) Failure to connect: how computers affect our children's minds. Simon and Schuster, New York
4. Kitano H, et al. (1997) RoboCup: the robot world cup initiative. Proc Agents-97
5. Kröse B, Bogged R, Hietbrink N (2000) Programming robots is fun: RoboCup Jr. 2000. Proceedings of the Belgium–Netherlands AI Conference 2000
6. Lund HH, Pagliarini L (2000) RoboCup Jr. with LEGO Mindstorms. Proceedings of ICRA2000, New Jersey. IEEE Press, New York
7. Lund HH, Pagliarini L (2001) Educational aspects of RoboCup Junior. Mimeo. http://www.mip.sdu.dk~hhl