Children Learning From Team Robotics:

RoboCup Junior 2000

Educational Research Report

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5 December 2000

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RoboCup Junior is a division of the international RoboCup Community. The finding and views expressed in this document are those of the authors and do not necessarily represent those of the RoboCup Organisation.

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Keywords:
Robotics, Children, Education, Curriculum, Design, Technology, Science, Mathematics, RoboCup, RoboCup Jr, RoboCup Junior, RoboFesta

Abstract

RoboCup Junior (Jr) is a division of the international RoboCup initiative. It involves children participating in various competitive and cooperative robot challenges. Experience at three international venues shows that these challenges generate great excitement and interest from both children and adults. We question whether there is any educational value in these challenges, and this report presents results of a study we conducted in conjunction with the third international event – RoboCup Jr 2000. Our tentative conclusion is that there is enormous educational value for children involved in team robotics, both academically and in terms of their personal development.

1 Introduction

It seems self-evident that we must educate our children to understand the technological world in which we live. One technology that is becoming widely applied across many domains and in many subtle forms is *robotics*. Most of our machines and computer systems are getting "smarter", and as they do, the distinction between them and the robots of science fiction lessens, in the eyes of the observer. Indeed it may be difficult for an outside observer to distinguish the real mechanisms engaged for controlling robots, the materials used, etc. from fantastic images already implanted in his mind. This has been described as the frame-of-reference problem in autonomous agent design [Pfeifer and Scheier, 1999, pp. 112]. Today, many instances of automation (also in the form of robots) are rapidly spreading throughout our daily life, and it is growing increasingly important that the average citizen becomes comfortable with the notion of interacting with robots. Our view is that the more society and our children know about robots and technology, the better.

The RoboCup (www.robocup.org) initiative, founded at the International Joint Conference on Artificial Intelligence (IJCAI) in 1997 by Hiroaki Kitano, is an international effort whose purpose is to foster artificial intelligence and robotics research by providing a standard problem where a wide range of technologies can be integrated and examined [Kitano, 1997]. The ultimate goal of RoboCup is to produce, by the middle of the 21st century, a team of fully autonomous humanoid robot soccer players capable of winning a soccer game against the (human) world champions. A similar, but much less demanding, artificial intelligence landmark was passed in 1997 when IBM's Deep Blue computer defeated world champion Gary Kasparov at chess. RoboCup differs significantly from computer chess – agents act in a real-time, dynamic environment, where decisions must be made with incomplete information, control of various components may be distributed and communication between agents is an important factor.

While the RoboCup initiative serves the research community, at the same time it provides an understandable and approachable environment for bringing discussion of robotics technology to the level of the lay person. Such is the focus of the international RoboFesta movement, which started in Japan in 1998 (www.robofesta.net, www.robofesta-europe.org). RoboFesta puts forth the belief that it is necessary to be pro-active in making children – and society in general – comfortable with science and technology, by making technological subjects exciting and attractive through organised, approachable robot games.

In Paris, at RoboCup-1998, Henrik Hautop Lund introduced the notion of *RoboCup Jr* and demonstrated robot soccer players embodied in a simplified and familiar – LEGO – platform [Lund et al., 1999]. Since then, three official (and a number of unofficial) events have followed where children have participated in robot games. The first was in Stockholm in 1999 when Lund *et al*. tested their LEGO-based robot soccer game [Lund and Pagliarini, 2000]. They developed a special electronic soccer ball that emits infrared light and can be seen by LEGO robots more easily than the flourescent-colored balls typically used by the senior RoboCup leagues.

Figure 1. Autonomous football-playing robots

Subsequently, another RoboCup Junior event was held in Amsterdam in May 2000 [Kröse et al., 2000]. Nearly 60 children attended a one-day workshop where they formed teams and, using LEGO robotics equipment and computers for programming, designed and created soccer robots. Although the children knew nothing about the LEGO robotics system at the start of the day, they quickly learned how to program sequences of high-level commands, such as making their robot 'chase the ball'. By lunchtime, the children had working hardware and software. In the afternoon, a competition was held, and by the end of the day, prizes were distributed to the champions.

The atmosphere in Amsterdam was electric, but one could not help asking: "what are these children learning from this activity?" It would be too easy to say that, because they are interacting with technical things, they are learning something worthwhile.

Yet this has been the conventional wisdom as children use computers. Computers are an important part of our world: *true*. When children do anything with computers they are learning about them: *true of some things and not of others*. Therefore, every moment that children spend with computers has education value: *false*. In her recent book, Jane Healy [1998], a specialist in educational computing, suggests that no more than 10% of the available software for children has any educational value.

In this report, we question the same “obvious” relationship between robot games and the possibility of any genuinely useful educational outcomes. We present results of a study conducted at the first international RoboCup Jr tournament, which was held in Melbourne, Australia in September 2000, as part of RoboCup-2000. About 40 teams of children, 8 to 19 years old, participated in three robot challenges. Like Amsterdam, Melbourne too was electric, and some of the entrants were stunning, especially the newest challenge – a creative “dance” program.

Figure 2. Children with their dance robots

We interviewed twelve of the teachers who entered teams in the tournament in Melbourne, with the goal of investigating the educational value of RoboCup Jr. Based on their responses, we make observations and tentative conclusions. Our conclusions are tentative because first, twelve is a very small sample, and second, the sample is biased based on how the respondents were selected – the respondents were teachers who believed in the initiative because they chose to enter the tournament. In addition, this particular group of teachers was heavily biased towards high technical competence – most teach science and/or technology curriculum; several have degrees in engineering.

However with these caveats, we believe our results show that a robot competition can have very high educational and personal development outcomes, as well as fulfil requirements of local curricula. These results may extend to robot competitions other than RoboCup Jr, as discussed in section 5.

2 Background

In 1994, Tom Snyder wrote:

> No matter what we do, a huge infusion of technology is coming to education. It doesn’t matter if it works or not, whether we make mistakes or not. It’s coming because so much money is behind it. And because that infusion of technology is inevitable, it would be nice to start adding some new perspectives about technology in the schools. It’s just possible our decisions about technology in schools are not being guided by the instincts of our best teachers. Right now, we run the risk of being blinded by science. [Snyder, 1994]

More than twenty years ago, Seymour Papert linked technology with Jean Piaget’s *constructivist* theory of education to produce LOGO (or “turtle geometry”), a simple programming language that allows young students to learn geometry through computer-aided exploration. Papert published these ideas in his book Mindstorms: Children, Computers and Powerful Ideas [1980] and introduced the notion of *constructionism* – which states that children learn best when they are actively involved in building something that is meaningful to themselves[1].

Coincident with the introduction of LOGO, the birth of home computers spawned a burgeoning market for educational software. Subsequently, personal computers were purchased for use in most schools, and educational technology began to infiltrate the majority of classrooms. Today, schools are being networked at a rapid rate, giving teachers and students direct access to the World Wide Web.

Yet despite all the vast and varied hardware and software introduced during the last two decades, the order of magnitude improvement in student performance that many expected as a result of integrating technology in the classroom is still not evident. There are many reasons for this shortcoming. Some believe that the educational software has exploded too fast, without enough pedagogy behind the software or developmental psychology supporting schools' technology integration decisions [Healy,1998]. As well, "once [net] connections are established, many teachers find a shortage of quality software tools and curricula to make use of them." [Bruckman,1997] And there are also practical issues: "computer software and hardware become obsolete every 30 months, too swift a change for most schools to handle economically." [Gonzalez,2000]

Most learning systems have not been successfully deployed in practical environments, in spite of expensive resources and years of research. Kinshuk and Patel [1997] cite two primary reasons for this failure: (1) the underlying methodologies for developing most learning systems were not designed from an educational viewpoint, and (2) the development of most learning systems has left out the needs of teachers and students. Anderson, *et al.* [1995] agree, stating that their extensive efforts building intelligent tutoring systems were too focused on their own needs as researchers, and they made no attempt to address the curricular needs of teachers.

Yet no one is ready to admit defeat while the powerful allure of a successful marriage between technology and education looms. "Children assimilate information and acquire skills with astonishing speed when playing video games. Although much of this gain is of dubious value, the phenomenon suggests a potent medium for learning more practical things." [Brody,1993]

Or, as Eliot Soloway wrote, "Oh, if only kids were as motivated in school as they are in playing Nintendo." [1991] Many believe that the secret to education is motivating the student. Researchers in human learning have been trying to identify the elements of electronic environments that work to captivate young learners. Thomas Malone conducted comprehensive studies in the late 1970's and early 1980's and outlined several key factors that make electronic games intrinsically motivating. These are challenge, fantasy and curiosity. Challenge involves games having an obvious goal and an uncertain outcome. Fantasy, particularly intrinsic fantasy, involves building the educational task into the game so that the skills being learned are an inherent part of the game's fantasy. Curiosity involves "novel and surprising" elements, both sensory and cognitive. Additionally, Malone states that interaction with other humans contributes positively to students' motivation. [Malone,1981]

Meantime, Howard Gardner put forth his "theory of multiple intelligences", which describes each human mind as a unique combination of talents expressed across a wide range of cognitive spheres. His book Frames of Mind [1983] has been extremely influential in the field of education and has helped drive the trend in classrooms toward teamwork and projects that encourage and motivate different children with different needs.

It appears that RoboCup Jr may bring together many of these ideas. The involvement of classroom teachers helps integrate the initiative effectively into curriculum. The motivational aspects of challenge, fantasy and curiosity are neatly encompassed in the robot soccer game. The emphasis on teamwork allows children with a variety of interests and abilities an opportunity to pick their own challenges while contributing to the progress of the whole. The results presented in this report show that these goals – identified through research into the current and historical state of the integration of technology and education – may be successfully met through the RoboCup Jr initiative.

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[1] In the robotic context, the notion of guided constructionism was introduced in educational robot soccer projects [Lund, 1999].

3 Sampling, bias and generalisation

RoboCup Jr 2000 was advertised in newspapers and by word of mouth. It was also propelled by two very active and supportive local community members: Brian Thomas, a high school science teacher and local chair of RoboCup Jr 2000, and Heather Safstrom, a local supplier of Educational LEGO. The pool of teachers from which we selected the sample presented here is obviously very biased, and they may be more technically competent, energetic and adventuresome than most. The best teachers will be good teachers under any circumstances, and we must be careful of any claims we make from our responses. Thus, our sample was selected from what we believe to be a very biased subset of the population of all teachers.

The selection of the teachers to be interviewed was quite opportunistic. Before we began, we had a list of all the teams entered and their teachers. During the two days of the tournament, we approached teachers when they were not busy with their teams and asked them to be interviewed. The interviews took about forty minutes each, so if a teacher told us their team was competing in twenty minutes, we did not interview them at that time. Sometimes, this meant forfeiting an interview. So the guiding principles for selecting the teachers were that we could find them in the crowd and that they were available. In this respect, we have no information on how representative these teachers were of all the teachers at the competition. However, it is worth noting that of the 13 schools who had teams participating in the soccer challenge, we interviewed teachers from 9 of them.

The results of our study are thus too limited to generalise. We do not know if the events observed in Melbourne would apply to New York, London, Tokyo or anywhere else. However we can still obtain useful systematic knowledge from our study and can use the process and results as the basis for continued examination in future – as we intend to investigate related events in New York, London and Tokyo, and other places around the world.

Although the results do not necessarily generalise to all other teachers all over the world, they show that team robotics had certain characteristics for our special group of teachers and students. There is remarkable consensus among the teachers, and this suggests that there may be some underlying trends that may generalise over a larger, more comprehensive sample.

Finally, we note that certain systematic trends were observed from this biased sample in Melbourne. If these trends generalise to other places, this could be a very important result, and so suggests the need for further research.

Figure 3. Robot sumo: the robots compete to find and occupy the dark circular area.

4 Results

For the purpose of this paper, and given the nature of our data, we give a brief overview of the responses in Table 1.

subject number	1	2	3	4	5	6	7	8	9	10	11	12
number of years teaching	**2**	**n/a**	**15**	**n/a**	**15**	**32**	**26**	**12**	**3**	**20**	**32**	**10**
gender	**F**	**F**	**M**	**M**	**M**	**F**	**M**	**F**	**M**	**M**	**F**	**M**
1. RoboCup preparation:												
• in school	**N**	**N**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**N**	**Y**
• outside school	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**?**
• part of curriculum	**N**	**N**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**N**	**Y**	**Y**	**Y**
2. Educational value of RoboCup Jr	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**0**
3. Will you compete next year?												
• locally	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
• International	**?**	**?**	**Y**	**Y**	**Y**	**Y**	**0**	**0**	**Y**	**Y**	**0**	**Y**
4. Is robotics already in your curriculum?	**N**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
5. Influence on behaviour of children	**0**	**?**	**Y**	**Y**	**Y**	**?**	**Y**	**Y**	**?**	**Y**	**Y**	**?**
6. Influence on other schoolwork	**?**	**0**	**Y**	**Y**	**Y**	**Y**	**Y**	**?**	**Y**	**?**	**Y**	**Y**
7. Influence on teamwork	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
8. Motivation	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
9 Skills learned:												
• academic	**Y**	**0**	**0**	**0**	**Y**	**Y**	**Y**	**0**	**Y**	**Y**	**Y**	**0**
• personal development	**Y**	**Y**	**0**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**0**	**Y**

Key: **Y =** yes (positive), **N =** no (negative), **? =** not sure, **0 =** no explicit answer, **n/a** = not applicable

Table 1. Overview of the responses

The data in Table 1 is abstracted from the transcripts of the interviews contained in appendix B. From this fast and incomplete analysis, we make the following observations:

- **Most of the teams worked both inside and outside the classroom.**
- **In most cases, some form of robotics was already part of each school's curriculum.**
- **Less than ten percent of the participating children were girls, but most teachers surmised that expansion of the dance challenge may encourage girls in future.**
- **It is speculated that RoboCup Jr may help with numeracy and literacy.**
- **All of the teachers would like to compete locally next year and most would like to participate internationally (although budgets will naturally limit this).**

Additionally, we draw several tentative conclusions:

- **All of the teachers thought RoboCup Jr had educational value.**
- **About half of the teachers thought the children who participated behaved better during their preparation for the competition than they did during other classroom activities.**

- **Most teachers thought RoboCup Jr was helpful in other areas of their students' schooling, although some related concern expressed by a few parents and other teachers about time taken away from other lessons in order to prepare for RoboCup.**

- **All of the teachers commented on the beneficial lessons in regard to teamwork resulting from their students' participation in RoboCup Jr.**

- **All of the teachers reported that the RoboCup Jr competition itself was a motivating factor, particularly because: it is an international event, it imposes an absolute deadline and it gives children an entry-level role in the complex and stimulating field of robotics research.**

- **Most of the teachers thought participation in RoboCup Jr helped their students improve their technical skills.**

- **All of the teachers thought participation in RoboCup Jr contributed positively to the personal development of their students.**

Figure 4. Creativity and teamwork: major components of RoboCup Junior

5 Discussion

More than one of the respondents in our survey commented that the international context of RoboCup Jr, and the fact that the young entrants participated alongside the senior competitors – some of the top robotic scientists and engineers in world – was a tremendous motivating factor for them and their students.

Currently RoboCup Jr is LEGO-based and attempts are being made to develop other platforms that are also suitable for school children. Some teams used LEGO without modifying it in any way, others made considerable mechanical and electronic developments of their own, including spinning mechanisms for kicking and non-standard sensors.

In Melbourne, most of the participants were boys; indeed, less than ten percent of participants were girls. No girls attended the robot soccer or sumo tournament (though a few helped the team prepare at school but were unable to attend the tournament). Girls did participate in the dance challenge, which was restricted to primary age children (12 years and under). This increased participation could either be due to the creative nature of the dance challenge, the younger age group, or both.

Today it is generally accepted that girls and boys are different. However, we do not think that these differences should necessarily mean that boys do robotics and science, and girls don't. The dance challenge in Melbourne showed that (at least younger) girls will engage in robotics, and they appear to extend the field into creative areas which boys do not. We would like to develop and encourage this direction. Without doubt, some of the most creative and innovative aspects of RoboCup Jr 2000 were exhibited during the dance challenge.

Based on the experiences with RoboCup Jr and interviews with teachers, it is difficult to assess what components of the RoboCup Jr project are essential for educational success. Indeed, we may speculate that the results obtained with RoboCup Jr may transfer to other educational robotic projects, e.g., some of the robot games in the RoboFesta event. Here we mention the FIRST LEGO League (FLL) (www.legomindstorms.com/fll/), since this competition is already engaging 10,000-20,000 children especially in the USA, as well as Singapore, China, Denmark and Norway.

A comparison with FLL is compelling, since both RoboCup Jr and FLL have (thus far) used the same hardware platform, LEGO MINDSTORMS. While we cannot conclude as yet whether the use of specific hardware and software tool plays a major role in the results obtained, we can compare these two robot projects which use the same platform. The 1999 FIRST LEGO League Survey Feedback [Lund and Pagliarini,2000] provides numbers that seem similar to those obtained here, namely:

- 97% of coaches said FLL increased children's interest in science and math
- 95% said FLL provided information to children about careers in technology fields
- 77% of FLL teams were formed as an extra-curricular activity
- 12% used FLL to teach the following curricula: science, math, writing, reading, history, social studies
- 24% of those who used FLL to teach curricula also used it to teach other "soft skills" (e.g., time management, public speaking, group dynamics, computer science, engineering, technology)

Hence, we should be cautious when interpreting the results of the present study. The results may indicate that educational robotic projects with appropriate construction toys can be highly educational, rather than indicating that the RoboCup Jr task itself is the essential ingredient for achieving educational benefits. Some of the aspects shared with FLL are that both projects use a specific construction toy and involve easy-to-use programming environments. As well, both centre around friendly but competitive events that offer motivational factors such as deadlines and opportunities to share technology with others.

One element that RoboCup Jr provides over FLL is the fact that it sits at the entry-level to the senior division of the overall RoboCup initiative. Several teachers commented on the value of sharing the venue between junior and senior leagues. The experience of attending a high-quality, international research forum served to introduce the students to possible career paths and showed them directions that they might not otherwise see until (at least) partway through their undergraduate education.

Finally, we note that the enthusiasm and positive outcomes we present here may be a manifestation of the "Hawthorn Effect". In its simplest form, this means that intervening in a social system can in itself produce positive changes, because the people in that system may be encouraged by the extra and unusual amount of attention they are receiving. The term comes from a socio-economic study of the Hawthorn Plant of the Western Electric Company in the 1920's-30's when researchers observed an increase in productivity amongst workers, which might be explained by the fact that the workers liked being studied [Mayo,1945]. In the present case, the Hawthorn Effect may underlie the positive outcomes reported by the teachers: the unusual attention and extra resources experienced by the children might in themselves have been responsible for the positive outcomes.

6 Conclusions

Our study has shown that – for the teachers we interviewed in Melbourne – RoboCup Jr is very positive in many respects. Of these we highlight the following:

- RoboCup Jr fits in with existing robotics curriculum.
- RoboCup Jr is seen to be highly educational.
- RoboCup Jr is highly motivating for participants.
- RoboCup Jr advances both academic and personal development skills.
- RoboCup Jr may help with numeracy and literacy.
- RoboCup Jr teaches teamwork and tolerance of others.
- RoboCup Jr may attract girls into robotics, as well as boys.

If these attributes generalise to other teachers in other school systems, it could be seen that RoboCup Jr is a very positive educational initiative. We emphasise that our conclusions are tentative since they are based on such limited data.

The next international RoboCup Jr tournament will be held in Seattle (USA) in August 2001, at RoboCup-2001. A follow-up study will be conducted at that time.

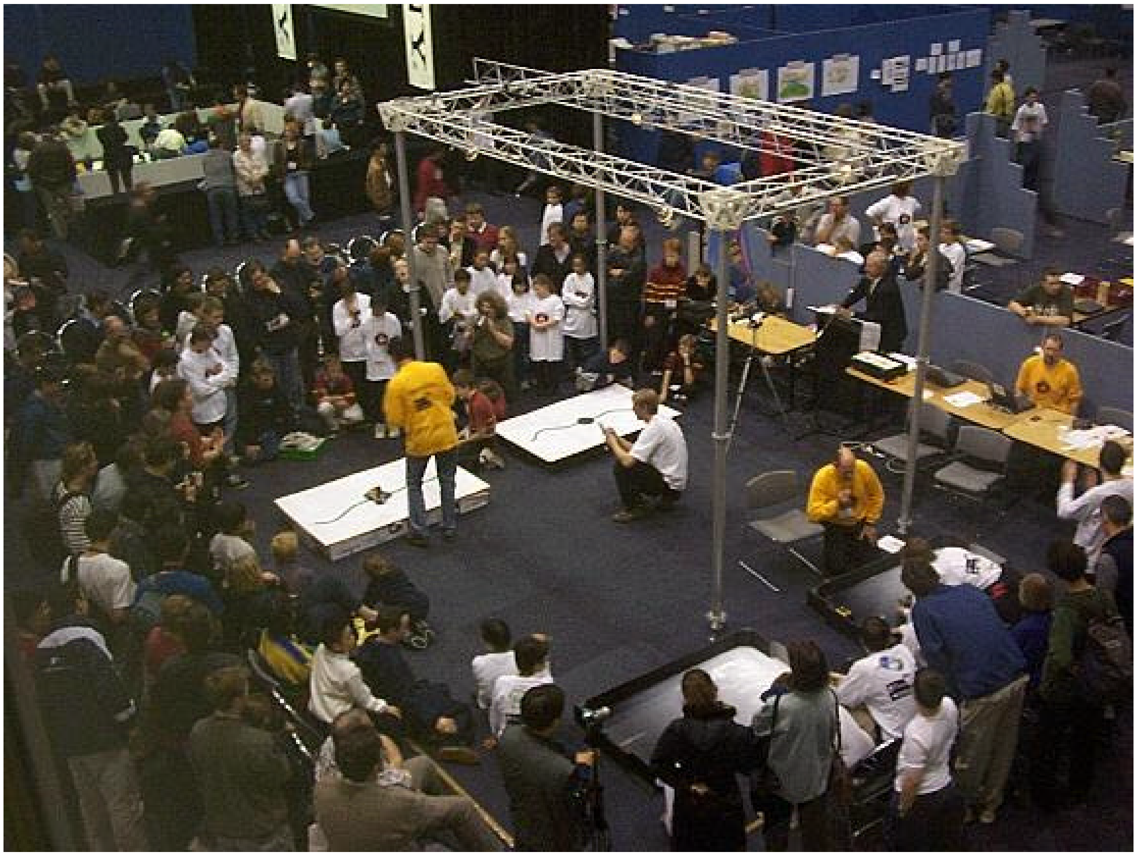

Figure 5. RoboCup Junior - Melbourne 2000

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