

*Scientific Challenge Award*

# RoboCupJunior

## Learning with Educational Robotics

*Elizabeth Sklar, Amy Eguchi, and Jeffrey Johnson*

■ The RoboCupJunior division of RoboCup is now entering its third year of international participation and is growing rapidly in size and popularity. This article first outlines the history of the junior league since it was first demonstrated in Paris at RoboCup-1998 and describes how it has evolved into the international sensation it is today. Although the popularity of the event is self-evident, we are working to identify and quantify the educational benefits of the initiative. The remainder of the article focuses on describing our efforts to encapsulate these qualities, highlighting results from a pilot study conducted at RoboCupJunior-2000 and presenting new data from a subsequent study of RoboCupJunior-2001.

The RoboCup-2002 Scientific Challenge Award went to work that examines the educational value of RoboCupJunior (Sklar, Eguchi, and Johnson 2002). In 1998, Lund and Pagliarini demonstrated the idea of a children's league for RoboCup, using robots constructed and programmed with the Lego Mindstorms kit that could play soccer (Land and Pagliarini 1998). Since then, RoboCupJunior has evolved into an international event (Kröse, Bogged, and Hietbrink 2000; Lund and Pagliarini 2000; Sklar, Johnson, and Lund 2000), where teams of young students build fully autonomous mobile robots to compete in one of three challenges involving a curriculum-based, student-driven approach, each requiring a different level of sophistication (figure 1).

The dance challenge is an entry-level event. Students build robots that move to music for as long as two minutes. Creativity is emphasized. It is possible to participate using simple robots that only employ motors and no sensors. The event is exciting and innovative. Some children even dress in costume them-

selves and perform alongside their robots.

The rescue challenge is an event where one robot competes at a time. The field is white, and the robot is required to follow a black line through a simulated disaster scenario, along possibly uneven terrain. There are no dynamic elements, but accurate control of the robot based on light sensor readings is essential and surprisingly difficult.

The soccer challenge is an advanced event. Two teams of two robots each play on a special field, 150 centimeters by 75 centimeters. The floor of the field uses a gray-scale mat, and the ball is an electronic device that emits infrared light (Lund and Pagliarini 2000). The rules of play were developed from the RoboCup small-size league.

The popularity of RoboCupJunior is self-evident, but one must ask, What are the students learning from these activities? It would be too easy to say that because the students are interacting with technology they are learning something worthwhile, but this appeared to be the conventional wisdom in the early days. Today's researchers are questioning this stance (Healy 1998; Reeves 1999; Snyder 1994). The goal of the work presented is to question the "obvious" relationship between robotics and educational outcomes, attempting to identify and quantify the educational benefits of RoboCupJunior. Rather than focus just on the technology itself, the work examines the overall learning environment that results when groups of students participate in team robotic activities. The results of studies conducted at RoboCupJunior in 2000 and 2001 are presented.

RoboCupJunior-2000 involved 40 teams of children, ages 8 to 19, from Australia (38

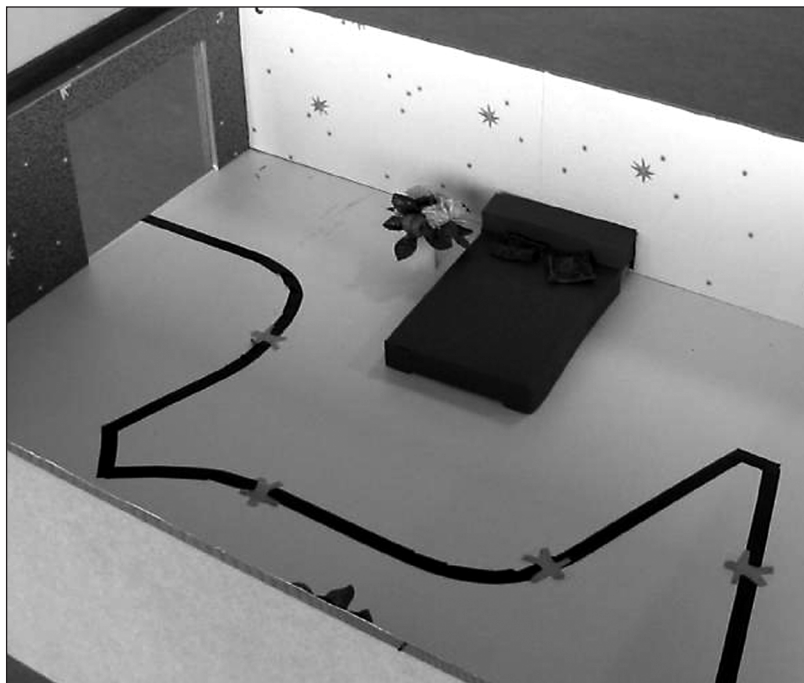
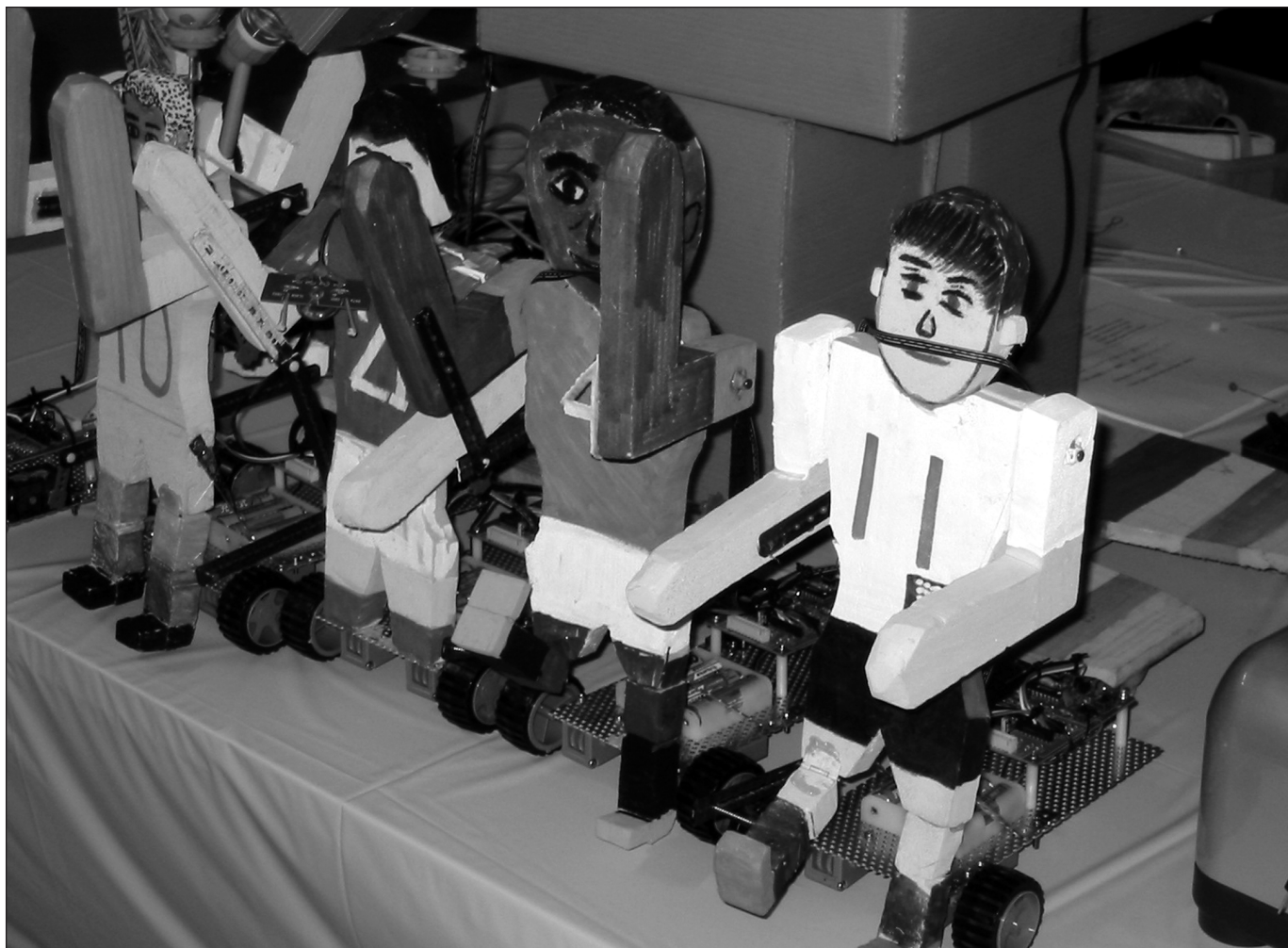


Figure 1. RoboCupJunior Challenges.

teams), Germany (1), and the United States (1). Twelve of the teachers who entered teams were interviewed, with the general stated goal of investigating the educational value of RoboCupJunior. This study revealed remarkable consensus of opinion among the teachers. RoboCupJunior fits in with existing robotics curriculum; is highly motivating for participants; advances both academic and personal development skills; teaches teamwork and tolerance of others; and appears to attract girls into robotics as well as boys. The RoboCupJunior competition itself is a motivating factor, particularly because it is an international event, it imposes an absolute deadline (that is, the date of the conference is fixed), and it gives young students an entry-level role in the complex and stimulating field of robotics research in an exciting context—alongside the senior RoboCup competitors, some of the top robotic scientists and engineers in the world.

At RoboCupJunior-2001, 25 teams participated from Australia (10 teams), Germany (5), the United Kingdom (2), and the United States (8). The students ranged in age from 7 to 23. Mentors, as well as students, were interviewed. They were asked to consider 13 specific skills and indicate whether they felt their involvement in RoboCupJunior had helped or hurt each of these skills, or if there was no effect (figure 2). The selection of the specific skills was based on the results of the study conducted in the previous year (Sklar, Johnson, and Lund 2000). The overall consensus is that all the skills named were helped more than they were hurt. Note that participants felt that reporting skills were helped less than other skills, which could be the result of the lack of activities such as keeping journals and writing lab reports. Further emphasis on reporting as part of the tournament itself (that is, posters and papers) will help promote development of this skill set.

The bars illustrate the number of participants who indicated whether each skill was helped, hurt, and so on. For example, 80 percent of the mentors indicated that they thought their students' math skills were helped through their preparation for RoboCupJunior, approximately 12 percent of the mentors indicated that they thought that the preparation had no effect on their students' math skills, and 8 percent did not respond to the question.

It is interesting to compare the mentors' and students' skill ratings. Overall, more mentors than students felt that RoboCupJunior had positive effects. It is likely more difficult for students to assess the effects objectively than it is for mentors. Also, it is harder for students to assess abstract skills, such as communication,

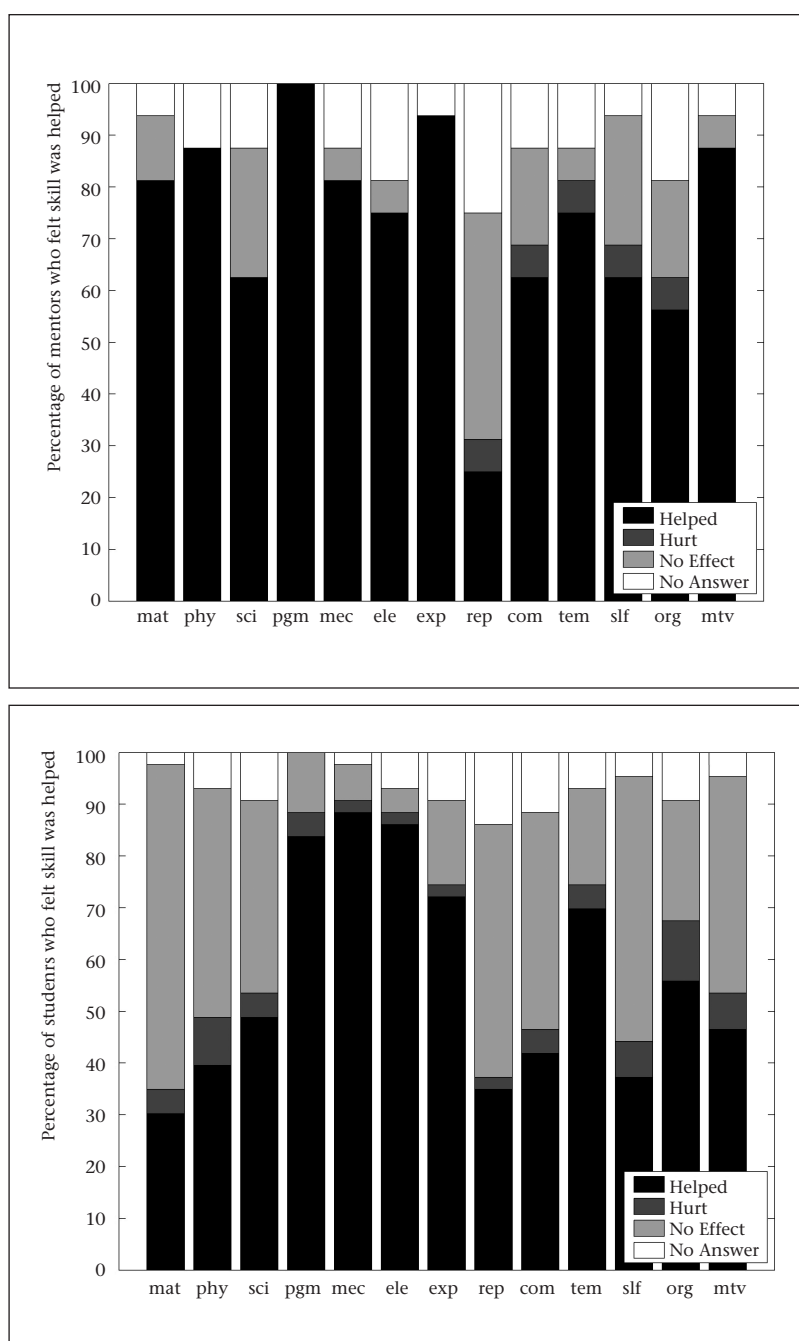


Figure 2. Effects on Various Skills (2001).

self-esteem, and organization, than it is for them to evaluate concrete skills, such as mathematics, physics, and programming. Future studies will investigate more effective ways of asking students about abstract skills.

The trends in motivational and developmental aspects were markedly similar between 2000 and 2001. Any differences found were mainly in terms of implementation. In 2000, all teams used the Lego Mindstorms platform. In 2001, other platforms were used: Fischer-



Technik mobile robot (16 percent of teams), Tetrix kit (4 percent), and Mindstorms (80 percent). Another difference was in the number of classroom teachers who acted as mentors. In 2000, almost all the mentors were teachers; in 2001, a small fraction of them were teachers.

The motivational aspects of educational technologies (Gardner 1983; Lepper and Henderlong 2000; Soloway 1991; Verner 1997) are also found in robotic soccer. Most teams spent more than two hours for each preparation meeting, which suggests that robotics activities are challenging and attractive enough to make students focus on their work for long periods of time. It also implies that to merge this activity into regular curricula, teachers need to make effective plans to adjust the length of an activity into the regular class period without distracting students' motivation or to extend the class period to give their students enough time to explore ideas.

The emphasis on teamwork in RoboCup-Junior allows students with a variety of interests and abilities an opportunity to pick their own challenges while they contribute to the progress of the whole, an experience that nurtures the varied and multiple intelligences of each participant (Gardner 1983). The work presented here fulfills a need in the community to examine the effects of these types of projects, find standard and effective ways of evaluating them, and define curricula that fosters and takes advantage of the positive elements identified.

### References

- Gardner, H. 1983. *Frames of Mind: The Theory of Multiple Intelligences*. New York: Basic.
- Healy, J. 1998. *Failure to Connect: How Computers Affect Our Children's Minds*. New York: Simon and Schuster.
- Kröse, B.; van den Bogaard, R.; and Hietbrink, N. 2000. Programming Robots Is Fun: RoboCup Jr. 2000. In *Proceedings of the Twelfth Belgium-Netherlands Conference on Artificial Intelligence*. Tilburg, The Netherlands: ILK.
- Lepper, M., and Henderlong, J. 2000. Turning "Play" into "Work" and "Work" into "Play": 25 Years of Research on Intrinsic versus Extrinsic Motivation. In *Intrinsic and Extrinsic Motivation: The Search for Optimal Motivation and Performance*, 257–307. San Diego, Calif.: Academic.
- Lund, H. H., and Pagliarini, L. 2000. RoboCup Jr. with Lego Mindstorms. Paper presented at the 2000 IEEE International Conference on Robotics and Automation, 24–27 April, St. Louis, Missouri.
- Lund, H. H., and Pagliarini, L. 1998. Robot Soccer with Lego Mindstorms. In *RoboCup-98: Robot Soccer World Cup II*. Lecture Notes in Artificial Intelligence, Volume 1604. New York: Springer Verlag.
- Reeves, T. A. 1999. Research Agenda for Interactive Learning in the New Millennium. Paper presented at

the World Conference on Educational Multimedia, Hypermedia, and Telecommunications (Ed-Media-99), 19–24 June, Seattle, Washington.

Sklar, E.; Eguchi, A.; and Johnson, J. 2002. RoboCupJunior: Learning with Educational Robotics. Paper presented at RoboCup-2002: Robot Soccer World Cup VI, 19–25 June, Fukuoka, Japan.

Sklar, E. I.; Johnson, J. H.; and Lund, H. H. 2000. Children Learning from Team Robotics: RoboCup-Junior-2000 Educational Research Report, Technical Report, The Open University, Milton Keynes.

Snyder, T. 1994. Blinded by Science. *CSS Journal* 4(1).

Soloway, E. 1991. How the Nintendo Generation Learns. *Communications of the ACM* 34(9): 23–26.

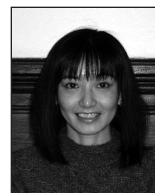
Verner, I. M. 1998. The Survey of RoboCup '98: Who, How and Why. In *RoboCup-98: Robot Soccer World Cup II*. Lecture Notes in Artificial Intelligence, Volume 1604. New York: Springer Verlag.

Verner, I. M. 1997. The Value of Project-Based Education in Robotics. In *RoboCup-97: Robot Soccer World Cup I*. Lecture Notes in Artificial Intelligence, Volume 1395. New York: Springer Verlag.



**Elizabeth Sklar** is an assistant professor in the Department of Computer Science at Columbia University in New York. She earned her Ph.D. in 2000 from Brandeis University. Her research interests center on learning in humans and agents, both virtual and embodied.

Her current projects involve using robots in classrooms for teaching topics other than strictly robotics and building agents that evolve by learning from humans in a variety of interactive environments. Her e-mail address is sklar@cs.columbia.edu.



**Amy Eguchi** is a doctoral candidate in the Faculty of Education at the University of Cambridge in England. Her dissertation is based on an ethnological study of the use of the internet among the Japanese school nonattendance population. Her research examines why and how

these people use the internet and how the internet enhances their communication and learning and helps develop their self-esteem. She joined the RoboCup community and has helped organize and research RoboCupJunior since 2001. She was a local vice-chair for RoboCupJunior-2002 in Fukuoka, Japan. Her e-mail address is eae24@hermes.cam.ac.uk.



**Jeffrey Johnson** is professor of complexity science and design at the Open University. His research is into the mathematical and computational foundations of complex systems, including multiagent robot and sociotechnical systems. For the last four years, he has led a growing team

working on robotics-enabled science, technology, engineering, and mathematics education for children and adults. He is a committee member of the international RoboCupJunior and RoboFesta movements.