Robotics-Centered Outreach Activities: An Integrated Approach

Javier Ruiz-del-Solar, *Senior Member, IEEE*

***Abstract*—Nowadays, universities are making extensive efforts to attract prospective students to the fields of electrical, electronic, and computer engineering. Thus, outreach is becoming increasingly important, and activities with schoolchildren are being extensively carried out as part of this effort. In this context, robotics is a very attractive and effective tool for fostering interest in science and technology among children and young people and for attracting them toward engineering. In this article, experience with different robotics-centered outreach activities in the Universidad de Chile (UCH), Santiago, Chile, will be shared. These activities include robotics courses for children, social robots as keynote speakers, mechatronics design courses, and participation in international robotics competitions, which contribute synergistically to the goal of attracting students to UCH's Electrical Engineering (EE) Department. Owing to its novelty, the use of social robots as keynote speakers for schoolchildren will be described in detail. Experimental results that demonstrate how sophisticated social robots can be used to foster the interest of young people in technology will be shown. Altogether, more than 3000 schoolchildren have participated directly in these outreach activities here in Chile, creating a sizeable impact in this country.**

***Index Terms*—LEGO Mindstorms, mechatronics, robotics outreach, robots, social robots.**

I. Introduction

THE world needs a growing supply of engineers to solve the complex problems facing society and to improve the quality of human life. In the case of electrical, electronic, and computer engineering, important challenges to be met include providing elder care, increasing the use of renewable energies, and developing technologies such as robotics, bioelectronics, nanotechnology, and more. Nevertheless, the number of students enrolling in engineering education programs appears to be declining, or is at least not growing at the required rate. There are many reasons for this, among them: 1) a lack of understanding on the part of many high school students and teachers regarding what engineering is and what engineers do; 2) a lack of adequate motivation and training of high school students in mathematics and science; 3) the association of engineering with difficult problems such as pollution, global warming, and unemployment; and 4) the availability of easier pathways to other high-paying professions. Therefore, extensive efforts are necessary if universities are to attract prospective students to the field. For this reason, outreach is becoming increasingly important, and activities with schoolchildren are being carried out extensively.

The aim of this article is to share experience derived from working with robotics as a tool for fostering interest in science and technology among children and young people and for attracting them toward engineering. Robotics is a highly motivating activity for children and young people. It allows them to approach technology both intuitively and in an amusing way while discovering the underlying scientific principles. Indeed, robotics has emerged as a useful tool in education since, unlike many other areas, it provides a nexus where the fields or ideas of science and technology intersect and overlap. From this starting point, a range of activities have been developed, largely through practical robotics courses, with the long-term goal of motivating children to pursue university careers in science and technology, to increase their technological literacy, and to become, at the very least, technology-friendly adults. In addition, robotics is inherently multidisciplinary, integrating disciplines such as electronics, mechanics, computer science, control theory, signal processing, computational intelligence, and so on. Therefore, it attracts students specifically to the fields of electrical, electronic, and computer engineering and motivates their participation in the development of challenging technological projects.

Robotics-centered outreach activities started at the Universidad de Chile (UCH), Santiago, Chile, in 1999, and currently include: 1) robotics courses for schoolchildren; 2) use of social robots to give motivational talks to schoolchildren; 3) mechatronics design courses for sophomore students; and 4) participation of senior and graduate students in international robotics competitions. All these activities are complementary, synergistic, and part of a global strategy that has three main goals: to motivate the interest of schoolchildren in science and technology, to attract prospective students to UCH, and to attract talented students to the Electrical Engineering (EE) Department when they are ready to specialize after their first two years of general courses.[1] The first two of these activities foster the interest of young people in technology and motivate them to pursue a career in engineering. The aim of the mechatronics design courses is to attract sophomore students in the engineering school to the EE Department and to dissuade them from leaving the school because of lack of motivation for learning mathematics and the basic sciences. Finally, participation in international robotics competitions—mainly RoboCup

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The author is with the Department of Electrical Engineering and the Advanced Mining Technology Center, Universidad de Chile, Santiago 837-0451, Chile (e-mail: jruizd@ing.uchile.cl).

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[1]In the UCH's School of Engineering, the first two years of study are common to all students.

soccer and service robotics competitions [1]—serves several objectives: to attract students to the field, to identify students who later will participate as monitors in the activities carried out with schoolchildren, and to establish the EE Department as a leader in the development of technology in Chile, which, again, attracts the best students to enter the engineering school. Naturally, this also requires having a team of professionals (journalists) who disseminate news of the school's projects and achievements to the public.

In this article, some robotics-centered outreach activities are presented, and the use of social robots as keynote speakers for schoolchildren is described in detail. The keynote speaker robot is the focus of this article because of its high potential as a motivational tool, owing to the recent development of sophisticated social robots.

This paper is organized as follows. Section II describes work related to the use of robotics in outreach activities. Section III presents integrated, robotics-centered outreach activities. In Section IV, the use of social robots as keynote speakers for schoolchildren is described. Finally, in Section V, some conclusions and directions for future work are given.

II. Related Work

Initiatives with the goal of fostering interest in science and technology among children using robotics as a tool have been carried out in different countries, including the USA, Canada, Mexico, England, Germany, France, Japan, Korea, India, Israel, and Australia. In South America, robotic activities for children can be found in Brazil [2], Argentina [3], and Peru [4]. Some global initiatives, such as For Inspiration and Recognition of Science and Technology (FIRST) [5] and RoboCup Junior [6], sponsor local, regional, and international robotics events (contests for young students).

Many articles have reported the use of robotics as a tool in education. While it is beyond the scope of this article to present an extensive review, some of these articles are cited. Reports that analyze the use of robotics in education and present the state of the art in the field can be found in references [7]–[11]. Some very recent work in this area is reported in [12], an empirical study about the use of LEGO Mindstorms as an instructional tool in secondary education, and in [13]–[15], in which practical robotics courses are proposed, with the aim of using robotics as a tool that helps students to learn topics such as mechanics, control, or programming.

III. Robotics-Centered Outreach Activities: An Integrated Approach

In this section, experience with robotics-centered outreach activities—namely, robotics courses for children, use of social robots as keynote speakers, mechatronic design courses, and participation in international robotics competitions—are described. As previously mentioned, these activities contribute synergistically to the goal of attracting students to the EE Department. These activities complement each other and are part of a global strategy that has three main goals: to motivate the interest of schoolchildren in science and technology, to attract prospective students to university, and attract talented students to the EE Department when they are ready to choose a speciality.

A. Robotics Courses for Schoolchildren

Between 2000 and 2002, different methods for implementing practical robotics courses for children were explored [16]: first, courses based on BEAM robotics [17], then courses based on the use of the Parallax Board of Education [18], and finally courses based on the LEGO MindStorms set [19]. BEAM- and Parallax-based courses focus mostly on hardware aspects of robotics, while LEGO-based courses focus on mechanics, sensors, and programming. The LEGO-based courses have several interesting features: 1) they are based on a kit that can be reused, and therefore the investment in equipment is shared among several courses; 2) there is a large community of educators in the world working with this technology, which facilitates sharing experiences and information; and 3) they enable very young children to participate in the courses. For all these reasons, this technology was chosen in 2002 for the courses. A working methodology, based on the work developed in the Robotics Academy at Carnegie Mellon University, Pittsburgh, PA [20], was developed for implementing the courses.

The four-day LEGO courses have the following structure. The first day consists of an introduction to the materials of the LEGO kit and the essentials of LEGO programming, using the Robolab visual programming language. Students work using the "Tankbot," a basic robot on which they can add sensors, modify and debug computer programs, and perform mechanical improvements. The children can also test platforms different from the original "Tankbot." Thus, they are encouraged to use their imagination. A teachers' working guide and the continuous presence of monitors support their efforts. The second day goes deeper into programming aspects. The third day focuses on mechanics, emphasizing design aspects and concepts. The development of a project is the goal of the fourth day. Children design and mount a project of their choosing that, later on, they show to family members and friends they have invited to an open house evening. From the beginning, the children work in groups of four, and each child takes a different role that changes every day. The four roles are project manager, programmer, information specialist, and materials manager.

It is important to mention that the courses do not have any prerequisite for attending them. The goal is to motivate children. Therefore, children cannot be selected using criteria such as school grades, previous experience, or degree of motivation. Even children who are registered by their parents instead of choosing to attend, and who have low motivation for the course, are accepted. The main challenge is to ensure that they enjoy the experience, to hold their interest during the whole week, and at the end, to change their negative perception, or reinforce their positive perception, of science and technology. Experience of several years of giving these courses shows that the important factors for success with children are the following:

1) The continuous presence of monitors, preferably engineering students, who work very closely with the children in the laboratory. In addition to assisting the youngsters, monitors share their experiences as engineering students and answer the students' questions about engineering. A good ratio seems to be one monitor for every 12–15 children.

2) The courses are given in a laboratory in the engineering department. This allows the children to become familiar with an engineering department and some of its activities.
3) The inclusion of robot competitions between the children's groups increases interest during the course. The competitions are organized every day, usually in the afternoons. Very often, one of the main driving forces for solving a problem or for learning some specific concept is to defeat the other teams. Every competition has a score, and the groups' scores in the different competitions are cumulated. At the end, the three highest-scoring groups get a special diploma.
4) Talks about science and technology (on topics such as artificial life, mobile robotics, or agents) are included to introduce children to various disciplines, which could be of interest for them in the future. The 30–40-min talks are given in the mornings, normally by an expert in the discipline (for example, a faculty member).
5) Lunch is provided to the children, and during lunchtime, games are organized, such as soccer. This causes the children to see the whole experience as very amusing; they have fun both in and outside of the laboratory.
6) An open house evening encourages family and friends to visit with the children and see the course's activities and projects. During this visit, children are very proud of their projects, and they show their creations to friends and younger brothers and sisters. This naturally has a multiplicative effect in those children; they also get motivated.

The structure of the courses and assessment data are reported in [16]. The courses have been very successful, and since 2002, more than 2000 children have participated in them. About 150 teachers have also been trained in how to use this tool in their schools. This has already resulted in many schools in Chile currently replicating these courses. In addition, a LEGO-based laboratory has been set up in a high school located in one of the poorest areas of Santiago by this group, with the support of the Chilean Ministry of Education. This laboratory complements other facilities of the school, and in addition to the school's own students, is also attended by schoolchildren from 12 middle schools located near the high school. A LEGO-based robotics laboratory has also been constructed in the Museo Interactivo Mirador (MIM) Museum [21], the main Chilean interactive science and technology museum. School classes that visit the museum can carry out basic robot-building experiments in the laboratory. This activity was started in 2003 when eight monitors from the museum were trained in the EE Department of the UCH, and it currently is very popular among schools visiting the museum.

It is important to stress that the last two initiatives (setting up of robotics laboratories in a deprived high school and in a technology museum) have an important social component because schools that do not have the necessary money and expertise to create their own laboratories use these facilities. The laboratories mentioned provide not only equipment, but also the required know-how and methodology. The general concept is to install community robotics laboratories that can be used by underprivileged schools. This aspect can be of interest for educators in many developing countries.

B. Social Robots as Keynote Speakers

Outreach is a very relevant activity for a university, but is, of course, not its main one. The primary drawback of implementing robotics courses for schoolchildren is the large amount of time that needs to be invested in this activity. Some universities have special units devoted to outreach (for instance, the Robotics Academy at Carnegie Mellon University [20]), but this is not the case here and not the case in many other universities. However, robotics courses can be complemented with other extensive outreach activities that can establish a first contact with the children. Talks about technology are frequently used for this purpose. Taking this idea one step further is exploring the use of robots as keynote speakers. The rationale behind this idea is that a robot giving a talk can have a much stronger impact on children than a human speaker can have. For some children, especially the ones that belong to deprived segments of society, listening to and interacting with a robot could be a very unique experience.

The development of a social robot was started in July 2006, and in October 2007, it was used for the first time as the keynote speaker during the XIII Chilean Week of Science. During that week, the robot gave talks to 228 schoolchildren coming from 10 different schools. In October 2008, the experience was repeated with 300 schoolchildren during the XIV Chilean Week of Science. The main features of the social robot used in this activity, the experience, assessment data, and projections are described in Section IV.

C. Mechatronics Design Course for Sophomore Students

Engineering is a six-year-long course in Chile, including summer internships in industry and a final engineering thesis. Students earn the title of "engineer" and the equivalent to a Master's degree in engineering. In this school of engineering, the first two years of study are common to all students, focused on mathematics, applied sciences, and basic engineering training. After the second year, students are free to select an engineering specialization (e.g., electrical engineering). They obtain the Bachelor's degree after finishing the fourth year of studies, and the engineer title after the sixth year.

In 1999, a hands-on mechatronics design course was started with the goals of attracting talented sophomore students to the EE Department and diminishing the number of students who leave the school because of a lack of motivation for learning mathematics and the basic sciences. In this course, students learn the basic concepts of electricity and electronics and project-design methodologies. They carry out a mechatronics project throughout the semester, working in groups of three. Students can either propose a project or choose one from a list. To accomplish the project, students have access to a mechanics workshop, an electronics laboratory, and different kinds of sensors, actuators, and computing devices.

The main challenge of the course is how to ensure that students with almost no previous knowledge and experience in electronics and mechanics can design and build a mechatronic device during the course. The methodology used includes:

1) Lecture and laboratory activities. Once a week students attend a lecture where they learn basic elements of electronics, mechanics, sensors, actuators, as well as project-

TABLE I
REASONS REPORTED BY STUDENTS FOR SELECTING THE EE DEPARTMENT (DEPARTMENT'S STUDY PLANS, PRESTIGE, INFRASTRUCTURE, RESEARCH QUALITY, PROFESSORS, MECHATRONICS COURSE, AND OTHER REASONS). THE *RANKING* COLUMN SHOWS THE IMPORTANCE GIVEN BY THE STUDENTS TO THE MECHATRONICS COURSE IN THEIR SELECTION

Year	Number of Students Entering the EE Department	Ranking of Mechatronics Course in the Students Election
2007	50	3rd
2006	83	5th
2005	57	6th

design methodologies. Twice a week, students carry out practical activities in the electronics laboratory and/or in the mechanics workshop, where they design, build, and integrate the components and subsystems of their mechatronics devices.

2) The duration of the course is 15 weeks, but it is divided into two parts; three weeks for basic laboratory training, and 12 weeks to develop the project. During the first three weeks, students get familiar with the laboratory and workshop elements (measurement instruments, mechanical and CNC machines, etc.) and carry out three basic laboratory experiments: mounting a basic electronic circuit (oscillator), interfacing the PC's USB ports with an external circuit (LEDs are turned on and off from a PC), and basic programming and use of a microcontroller board (based on the Microship's PIC). In this last experience, students learn how to use a C cross-compiler, how to load a program in the board, and how to use the microcontroller's I/O ports.
3) In their projects, students can use sensor, actuator, and controller boards that had previously been prepared for them. In this way, they can concentrate on the mechanical design, the programming of the boards, and the integration of the electronic and mechanical components. The boards that are made available to the students are a PIC-based microcontroller board, an H-bridge motor controller, a servo motor controller, and an infrared sensor board. All other circuits are built by the students.
4) Additional elements to be used in the projects, such as motors, additional sensors, electronic components, and covering material (e.g., aluminum) are bought by the students using a fixed budget provided by the department. The idea is to replicate aspects of real project development such as budget management and cost/performance tradeoff.
5) In their practical activities, students are advised and guided by an educational team composed of one mechanics technician and several laboratory assistants (one for every 15 students). The mechanics technician instructs the student in the use of the mechanical and CNC machines and about typical mechanical transmission mechanisms. He also acts as a consultant for any question related to mechanics. The laboratory assistants are electrical engineering students with at least two years of experience in laboratory activities. They share all the required know-how related to the design of electronic circuits. It became apparent that to have a motivated and well-trained educational team is a key factor for the success of this kind of course.

The course has been given twice a year since 1999, and more than 600 students have been trained, with more than 200 mechatronics projects being built. Some examples of projects are a snake robot, a quadruped robot, an Internet-controlled 3D robot arm, and a robot walker. Students have given good evaluations of the course, and the number of students in the department has increased by more than 50% since this course was started. Polls were carried out in the years 2005–2007, in which students entering the department were asked the reason for their choice. Using information obtained in a previous poll, students were asked to select one of the following seven reasons: the department's 1) study plans, 2) prestige, 3) infrastructure, 4) quality of research, 5) professors, 6) mechatronics course, and 7) other factors. Students' answers were tabulated, and the results ranked for determining their relative relevance. Table I shows the results. It can be seen that the mechatronics course is one of the most important factors considered by students for selecting the department (the third most important in 2007).

D. Participation in International Robotics Competitions

Promoting the participation of the students in robotics competitions has been going on since 2002, first in Latin American competitions[2], then in other scientific competitions such as RoboCup [1] soccer and @Home (service robotics). The original goals were: 1) to stimulate student involvement in the development of advanced technologies; and 2) to increase their interest in robotics. However, after a couple of years, it became obvious that this activity was synergistic with other initiatives, and that it serves the complementary goals of: 3) attracting talented students to electrical and electronic engineering; 4) identifying students who later on participated as monitors in the activities with children; and 5) placing the department in the position of leader in the development of technology in this country, which, again, helps to attract the best students to the engineering school. Naturally, the journalists who disseminate information about the projects and achievements have contributed to the success of the programs.

Participation in international robotics competitions requires the involvement of a large number of students and adequate organization of the activities. The methodology developed includes the following elements.

1) Students are organized in teams, and each team has participation in a specific competition (e.g., the RoboCup @Home Competition [22]) as its main goal. Each team is composed of at least one Ph.D. student and several Master's-level and engineering students. One of the Ph.D. students is in charge of the team, and s/he defines

[2]The author created the IEEE RAS Latin American Council, whose role is to promote and organize robotics competitions (see http://ewh.ieee.org/reg/9/robotica/).

the goals for the current year's competition in addition to guiding, together with the other Ph.D. students, the activities of the Master's-level and undergraduate students. The participation of the Ph.D. students on the team is a full-time job; his or her thesis is directly related to the team's main goal (for example, SLAM in home environments in the case of the RoboCup @Home competition).

2) Undergraduate and graduate students have different levels of involvement in the project. Some students are developing their theses and spend the whole day in the laboratory, while others work between 4 and 12 h a week as research assistants. One of the duties of the Ph.D. students is to set up different groups within the team—for instance, vision, self-localization, or manipulation groups. In each group, students with different levels of expertise work together and learn from each other. Skills and specific knowledge are shared directly among the students.
3) Undergraduate students participating in the project are no only electrical engineering students, but also students from the first two common years. The participation in the project motivates sophomore students to enter the EE Department, and EE students to enter the Master's or doctoral programs. Thus, a virtuous cycle is created.
4) The robots that have been built for the competitions (social robots, teams of robot soccer players) are very attractive to the general public, and the students who participate in the project like to show off their creations. Therefore, the laboratory encourages and facilitates the involvement of both students and robots in outreach activities such as interviews in newspapers and on TV programs, talks and demonstrations for visitors of the department, children, and the general public, as well as robotics courses for children.

One example of the synergistic relationship among the initiatives is the project involving Bender, a social robot (see description in Section IV-A). The main motivation behind this project was to participate in the RoboCup @Home competition [22]. The robot's structure and main mechanical components (head, arm, and body) were created in the mechatronics design course in 2006. The nine students involved in the project entered the department, and motivated by the RoboCup challenge, they started working with two Ph.D. students from the robotics laboratory in the integration of vision, world modeling, navigation, and decision-making algorithms in the robot. In July 2007, the team participated in the RoboCup 2007 World Competition (Atlanta, GA), where the robot won the RoboCup @Home Innovation Award. The students continued working on the improvement of the robot, and one year later, they participated in the RoboCup 2008 World Competition (Suzhou, China), where the robot again won the RoboCup @Home Innovation Award. In the meantime, the team observed that the robot could be used for educational purposes, and a project for transforming the robot into a keynote speaker was started. As described in the next section, the robot was used for this purpose in 2007 and 2008, and it has already given talks to more than 500 children. In addition, the robot's activities and achievements have been reported in several forms of Chilean media (newspapers, national journals, radio, and TV programs), which has served the dual purposes of disseminating scientific and technology information and positioning the department as the leader in innovation and technology development in Chile.

IV. Social Robots as a Motivation Tool for Schoolchildren and Students

Social robots are becoming of increasing interest in the robotics community. A social robot is a subclass of a mobile service robot designed to interact with humans and to behave as a partner, providing entertainment, companionship, and communication interfaces. It is expected that the morphology and dimensions of social robots fit them for operating adequately in human environments. Among other abilities, social robots should be able to: 1) move in human environments; 2) interact with humans using human-like communication mechanisms (speech, face, and hand gestures); 3) manipulate objects; 4) determine the identity of the human user and its mood to personalize its services; 5) store and reproduce digital multimedia material (images, videos, music, digitized books); and 6) connect humans with data or telephone networks. In addition: 7) they should be empathic (humans should like them); 8) their usage should be natural without requiring any technical or computational knowledge; and 9) they should be robust enough to operate in natural environments. Social robots with these abilities can assist humans in different environments such as public spaces, hospitals, home settings, and museums. Furthermore, social robots can be used for educational purposes.

When using a social robot to interact with children, it is of paramount importance for the robot to win the children's acceptance and for the interaction with the robot to be natural, intuitive, and based primarily on speech and visual cues. This can be achieved if the robot has a simple and anthropomorphic body design, has attention mechanisms that allow it to show interest in a given person or object, is able to express emotions, and has human-like interaction capabilities, such as speech and face and hand gesture interaction. The cost of social robots should also be low so that they can be introduced into natural human environments where persons or institutions with limited budgets will use them.

Taking all this into consideration, a general-purpose social robot that incorporates these characteristics was developed.

A. Bender, a Social Robot

The main idea behind the design of Bender, the social robot, was to have an open, flexible, and low-cost platform that provides human-like communication capabilities as well as empathy. Bender has an anthropomorphic upper body (head, arms, chest), and a differential-drive platform that provides mobility. The main components of the robot are[3]:

1) Chest: The robot's chest incorporates a Tablet PC as its main processing unit. The screen of the Tablet PC allows: 1) the visualization of relevant information for the user (a Web browser, images, videos, etc.); and 2) easy entering of data thanks to the touch-screen capability. The Tablet PC also provides 802.11bg connectivity. The chest also includes

[3]See robot pictures at http://bender.li2.uchile.cl/

TABLE II
BENDER'S MAIN FUNCTIONALITIES

Ability	Enabling Technology
Mobility	A differential-drive platform provides this ability.
Speech recognition and synthesis	CSLU toolkit (http://cslu.cse.ogi.edu/toolkit/).
Face detection and recognition	Face and hand analysis module.
Gender and age determination using facial information	Face and hand analysis module.
Skin and hand detection	Face and hand analysis module.
Tracking of faces and hands	Face and hand analysis module.
Hand gesture recognition	Face and hand analysis module.
General purpose object recognition	SIFT-based object recognition module
Emotions expression	Anthropomorphic 7 DOF mechatronics head.
Object manipulation	A 3 DOF arm with 3, 2 DOF fingers.
Information visualization	The robot's chest incorporates a 12 inch display
Standard computer inputs (keyboard and mouse)	The chest's display is *touch screen*. In addition, a virtual keyboard is employed in some applications.
Internet access	802.11b connectivity.

a microphone array that can determine the dominant speech source direction [23].

2) Head: The robot's head incorporates two CCD cameras, two loudspeakers, and one microphone. It has the ability to execute human-like pan-tilt movements (of the whole head). However, its most innovative feature is the capability to express emotions. This is achieved using five servomotors that control the movements of the mouth, eyebrows, and the antenna-like ears, and 14 RGB LEDs placed around each eye. In addition, it has RGB LEDs in the forehead to simulate the robot's breathing.

3) Arm: The arm of the robot is designed to allow for the manipulation of objects. It is strong enough to manipulate a large glass of water or a coffee cup. The arm has three degrees of freedom (DOF), two in the shoulder and one in the elbow, and is powered with a three-finger hand. Each finger has two DOF.

4) Mobile Platform: The platform provides mobility (differential drive), sensing skills (16 infrared, 16 ultrasound, and 16 bumpers), and support for the other components.

The robot height is adjustable, having an adaptable mechanical connection between the platform and the chest, but the typical setting is 1.2 m high. The robot weighs 15 kg and can work autonomously for about 3.5 h thanks to its internal batteries. A detailed explanation of the robot's hardware and mechanics is presented in [23].

Bender's most important functionalities are listed in Table II. All these functionalities have already been successfully tested as single modules. In [23] and [24], quantitative evaluations of the human–robot interaction functionalities of the robot, measured in standard databases, are reported. The evaluations indicate that the robot incorporates state-of-the-art face and hand gesture recognition systems [25], [26], which allow the analysis of video sequences coming from dynamic environments robustly and in real-time.

In [27], the ability of the robot to interact freely with humans using only speech and visual cues in a public space setting is evaluated. Experiments were carried out with 83 university students, and the main results were: 1) students could recognize the robot's facial expression in 70.6% of the cases; 2) 83.9% of them evaluated the robot's appearance as excellent or good; 3) 88.5% evaluated the robot's ability to express emotions as excellent or good; 4) 80.7% evaluated the robot's ability to interact with humans as excellent or good; 5) 90% thought that it was easy to interact with the robot; 6) 84% believed that the robot is suitable to be used as a receptionist, museum guide, or butler; and 7) 67% thought that the robot could be used for educational purposes with children.

It is worth mentioning that the robot has also received good evaluations from robotics experts. As mentioned previously, it won the RoboCup @Home Innovation Awards in 2007 and 2008 as the most innovative robot participating in the RoboCup @Home competition [22].

B. *Preliminary Results and Assessment Data*

The social robot was tested as a lecturer of schoolchildren in a classroom setting during the XIII Chilean Week of Science in October 2007. The robot gave talks to schoolchildren who were 10–13 years old, in grades 5 to 7. Altogether, 228 schoolchildren participated in this activity, and at each session, one complete class (∼20-25 children) attended the talk in a multimedia classroom. The robot gave more than 10 talks. The duration of each talk was 55 min, and it was divided into two parts. In the first part, the robot presented itself and talked about its experiences as a social robot. In the second part, the robot explained some basic concepts about renewable energies and about the responsible use of energy. After the talk, students could interact freely with the robot. The talk was given using the multimedia capabilities of the robot: speech and a multimedia presentation, which was projected by the robot (see pictures in Fig. 1).

After the robot's lecture, children, without having been given any previous notice, answered a poll regarding their personal appreciation of the robot and some specific questions on subjects mentioned by the robot. In the first part of the poll, children evaluated the robot, while in the second part, the children answered five technical content questions about renewable energies.

In the robot evaluation part, the children were asked to give an overall evaluation of the robot. On a linear scale of grades going from 1 to 7,[4] (7 being the best, 1 the worst), the robot was given an average score of 6.4, which is about 90%. In the

[4]This scale of grades is the one used by all schools in Chile.

Fig. 1. Bender giving talks to schoolchildren in groups of 20–25 children during the XIII Chilean Week of Science in October 2007.

TABLE III
PERCENTAGE OF CORRECT ANSWERS TO THE FIVE TECHNICAL CONTENT QUESTIONS

Technical Questions	% Correct
TQ1	75.9%
TQ2	33.7%
TQ3	31.6%
TQ4	75.0%
TQ5	60.6%
Overall	55.4%

second part, children evaluated the robot's presentation: 59.6% rated it as excellent, 28.1% as good, 11.4% as regular, 0.9% as bad, and 0% as very bad. The third question was, "Do you think that it is a good idea for robots to teach some specific topics to schoolchildren in the future?" 92% of the children answered "yes."

In the technical content evaluation part, the first three questions were related to energy sources (classification of different energy sources as renewable or non renewable, availability of renewable sources, and indirect pollution produced by renewable sources). The fourth question asked about the differences between rechargeable and nonrechargeable batteries, and the fifth question asked about the benefits of the efficient use of energy. The percentage of correct answers to each of the five technical content questions is shown in Table III. The overall percentage of correct answers was 55.4%.

In summary, it can be seen that the children who heard the robot's lectures gave it a very good evaluation (6.4 out of 7) and that 87.7% of them evaluated the presentation as excellent or good. They also had a very positive opinion about the use of robots as lecturers in a classroom environment (92%). Moreover, the children were able to learn some basic technical concepts, although they just heard them once from a robot. The main goal of this technical content part of the evaluation was just to see if the children could learn some basic content from the robot, not to measure how well they learned it. Therefore, control experiments with human instructors were not carried, although this will be part of future work. Finally, it is important

Fig. 2. Bender giving a talk to schoolchildren and interacting with them during the XIV Chilean Week of Science in October 2008.

to stress that the robot was able to give its talk and to interact with the children without any human assistance.

After this successful pilot experience, the robot has been used regularly to give monthly talks to children and high school students who visit the laboratory. Moreover, during the XIV Chilean Week of Science in October 2008, a major event with 300 children (13–16 years old) was held that included a 30-min talk by a human expert in robotics, a 30-min talk by the robot about renewable energy, an exhibition of humanoid robots, and interaction time between the social robot and the children. Fig. 2 shows some pictures of this event. The schoolchildren gave a very good evaluation of the whole activity, especially of the social robot. A quantitative evaluation was not obtained from the students because of their time constraints.

V. CONCLUSION AND FUTURE WORK

This article has presented experiences with robotics-centered outreach activities. The main initiatives—namely, robotics courses for children, social robots as keynote speakers, mechatronics design courses, and participation in international robotics competitions—were described and have been shown to complement each other in motivating students to further study electrical and electronic engineering. The main observed achievements of the described outreach initiatives are the following.

— The robotics courses for schoolchildren have allowed the direct training of more than 2000 schoolchildren, the instruction of more than 150 teachers who have replicated the courses in their schools, and the setting up of community robotics laboratories that are used by children from underprivileged segments of society.

— The hands-on mechatronics design course has fulfilled the goal of attracting students to the EE Department (the number of students has increased by more than 50% since 1999) and has fulfilled the students' aspirations; they gave positive evaluations of the course. In addition, three student projects started in this laboratory led to the construction of a sophisticated social robot.

— The participation in international robotics contests has led to stimulating student involvement in the development of advanced technologies, increasing their interest in the robotics field, attracting talented students to electrical and electronic engineering, identifying students who will later participate as monitors in the training activities with children, and situating the department as the leader in the development of technology in this country, which, in turn helps to attract the best students to enter the engineering school.

— A social robot as a keynote speaker has been built and fine-tuned. The robot has given talks to more than 500 students, and experiments show that the robot has gained a large acceptance from different groups of human users and is able to interact successfully with humans using human-like interaction mechanisms such as speech and visual cues. It is remarkable that children learned some concepts from the robot despite its limitations.

In general terms, new technological areas and opportunities for younger students and their mentors have been established. The outreach activities will be continued, hopefully with improved synergy. In addition, future work includes the improvement of the teaching abilities of the social robot and the measurement of how this integrated approach serves the goals of motivating the interest of schoolchildren in science and technology, attracting prospective students to the university, and attracting talented students to the EE Department. The teaching abilities of the social robot will be measured with the collaboration of science education experts. Control experiments with human instructors will be designed and carried out to quantify the possible added value of using a robot for teaching purposes.

The outreach activities have had an observable impact in Chile: Schools have already set up their own robotics laboratories following this experience, and some community robotics laboratories have been established. There is reason to believe that other engineering schools can reproduce these highly rewarding experiences and strengthen their communities in similar ways. The basic elements seem to be motivation, a solid background in engineering, and the will to learn through the process of working with children.

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Javier Ruiz-del-Solar (SM'06) received the diploma in electrical engineering and the M.S. degree in electronic engineering from the Technical University Federico Santa Maria, Valparaiso, Chile, in 1991 and 1992, respectively, and the Doctor-Engineer degree from the Technical University of Berlin, Berlin, Germany, in 1997.

In 1998, he joined the Electrical Engineering Department, Universidad de Chile, Santiago, Chile, as an Assistant Professor. He became Director of the Robotics Laboratory in 2001, and an Associate Professor in 2005. His research interests include mobile robotics, human–robot interaction, and face analysis.

Dr. Ruiz-del-Solar is recipient of the IEEE RAB Achievement Award 2003, the RoboCup Engineering Challenge Award 2004, the RoboCup @Home Innovation Award 2007, and the RoboCup @Home Innovation Award 2008. Since 2008, he has been a Distinguished Lecturer of the IEEE Robotics and Automation Society.