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A Learning Excellence Program in a Science Museum as a Pathway into Robotics*

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There is growing interest to the use of robots in science museums for demonstration of technological innovations and introducing the principles of human-robot interaction. This paper considers the educational robotics programs developed at MadaTech in collaboration with the Technion, aimed to promote public understanding of robots, motivate young people to study robotics, and foster excellence in technology and science education. The robot theatre performances and the OlympiYeda competition of the MadaTech 2010 Robotics Year are analyzed. The characteristic features of the programs such as learning in a rich environment, learning through interactive robot demonstration, and learning in a diverse community are evaluated.

Keywords: science museum; educational robotics; human-robot interaction, learning excellence program, multi-cultural education

1. Introduction

Education toward scientific and technological literacy has become an existential necessity for all [1]. Gaining access to scientific innovations, understanding them, and acquiring the ability to function in a rapidly developing high-tech dominated world, are matters of individual and communal sustainability [2]. There is a need for symbiotic combination of formal education, whose role is to impart systematic knowledge of basic disciplines, and informal education, particularly effective in broadening horizons, fostering curiosity, and promoting active learning [3]. Exhibitions and educational programs in science and technology museums play a central role in informal education [4].

In recent years, science museums have placed greater emphasis on exposing visitors to innovative technologies, using these technologies to spark enjoyable learning activities within technology-enhanced environments [5]. The introduction of technology into the museum poses technical, organizational and educational challenges. A growing number of science museums meet these challenges by introducing robotics [6]. The literature discusses diverse roles of robots in science museums, as exhibits, remote facilitators, and entertaining guides. Examples of such robots are given below.

Studies of robots, used as museum exhibits, are presented in [7, 8]. A 'mental commit robot' Paro [7] interacts with people, especially the elderly, affecting psychological, physiological, and social outcomes. Paro is designed and programmed to imitate the appearance and behavior of a Greenland seal. It is used at Stockholm's National Museum of Science and Technology, to demonstrate human interaction with an animate. The study indicated that Paro impressed the visitors positively, mainly because of its physical features and responses to sound, light, and tactile stimuli. Another example is the Personal Exploration Robot Rover [8], exhibited at five science museums in the US. The robotic exhibit served to demonstrate the role of rover missions in NASA's Mars Exploration Program, as well as robot autonomy. The study [8] indicated that the learning process was at its most effective, when using a robot to illustrate the subject matter and a human instructor to provide the explanation.

An example of a remote facilitator robot is the robotic micro-camera head used in the Zoology Department of the Carnegie Museum of Natural History (CMNH) in Pittsburg, to facilitate interactive tele-presence in the insect world [9]. The robot brings visitors face-to-face with exotic species of insects. The primary goal of the study [9] was to examine visitor interactions with insects mediated by a robot. Visitors navigated the camera head through the terrarium using a joystick, found cockroaches and followed up their behaviors. The study indicated increased time spent and more careful observation of the exhibit, leading to deeper learning about insects.

The most popular use of robots in science museums is for greeting and entertaining visitors, serving as way guides and exhibit instructors [10, 11]. The authors of [10, 11] discuss lessons learned from the use of such robots. They note difficulties in verbal communication with robots and point out that short multimodal responses, combined with questions, were most effective. Visitors were highly positive about robot presentations in museums, which stimulated an interest in science and technology. Their

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rating of robots' usefulness as guides is lower. The authors came to the conclusion that it is not mandatory for an entertaining guide robot to operate autonomously. Rather, it can effectively serve as 'a member of a human-robot tour-guiding team' [10].

Many science museums have recently offered hands-on learning activities using robot kits. A pioneer breakthrough program, The Computer Clubhouse, started at the Boston Computer Museum [12], was adopted by other museums [13], providing a strong impetus for rapid dissemination of similar programs. In their program, Resnick and Rusk [14] identified and applied principles of instructional guidance for such robotic activities: (1) support learning-by-design practices; (2) offer activities connected to learner interests; (3) foster a learning community; (4) create an atmosphere of mutual respect and trust. Other educators found these principles to be important and recommended their use in after-school mentoring programs.

This paper continues the discussion of museum robotics and presents robot exhibitions and educational programs developed at MadaTech—The Israel National Museum of Science, Technology and Space, in collaboration with the Technion. The aim was to promote public understanding of robots, motivate young people to study robotics, and foster excellence in technology and science education. The following sections of this paper are organized as follows: Section 2 describes the growth of robotics exhibitions and activities, culminating in MadaTech's 2010 Year of Robotics; Section 3 presents MadaTech's new robot theatre program; and Section 4 focuses on MadaTech's nationwide robotics competition for middle school students.

2. Robotics at MadaTech

Initial robotics education activities at MadaTech had begun in 2000–2001 in the form of brief hands-on lab sessions conducted in the computer class, using Lego Mindstorms kits. In the ensuing years, a robotics workshop on road safety was developed, implemented and upgraded. At this workshop, students conducted experiments and performed robot projects pertaining to automatic traffic lights at road intersections, automatic barriers, autonomous vehicles, Mars exploration with the Pathfinder robot, a smart crane, and a line follower.

In 2003–2006, the Museum developed first interactive demonstrations of robot behaviors for class visits and public lectures and embarked upon robotics programs. These included courses for technology teachers and international workshops for middle school students.

In 2007, the MadaTech Gelfand Center for Model Building, Robotics & Communication was established. The center comprises two robotics laboratories, a demonstration hall and auxiliary facilities. Each robotics laboratory is equipped with a network of twelve computer workstations, robotics software and audio visual equipment.

In 2007–2009, the center provided a wide spectrum of robotics activities, including robotics for school classes, semester- or year-long courses, training courses for kindergarten and elementary school teachers, international programs, and specially-tailored lessons for girls, new immigrants and families. A Robotics Mobile Laboratory was created, facilitating robotics workshops for students in peripheral schools in northern Israel. In 2009, tens of thousands of school students and teachers participated in these robotics activities.

The Museum heralded 2010 as the Year of Robotics. For the first time, the major thematic exhibition and educational programs centered on engineering through robotics, 'The Robot World: Scientific and Human Challenges.' The core of the thematic exhibition was the Robot Zoo, featuring a variety of computerized interactive mechanical models of animals, such as a chameleon, a rhino, a squid, a fly and more. Robot Zoo was complemented by a collection of state-of-the-art robots, presented in interactive demonstrations. They included humanoids, such as Nao (http://www.aldebaran-robotics.com/) and a RoboThespian (www.robothespian.com/), the robotic dog Aibo (http://support.sony-europe.com/aibo/index.asp) and other robots. The Exhibition also presented a variety of robots for military, industrial and domestic uses, loaned by governmental institutions and private companies. The Exhibition was extremely popular, enjoying about 350,000 visitors.

A number of innovative educational robotics programs were introduced in line with the Exhibition: (1) A robotics program for kindergarten to third graders, with activities based on *Lego We Do Education* kits—the eighteen hour course includes construction of a robotic model and an experiential inquiry into pre-programmed behaviors of the model, through interaction with it. About 1,000 students participated in the program. Top participants presented their project at the 2011 Junior First Lego League Festival 2011; (2) A 56-hour robotics program for excelling 8th and 9th graders from one of Haifa's junior high schools, based on Lego Mindstorms NXT kits, with optional participation in the FLL competition; (3) An intensive one-day workshop, for 100 excelling 9th grade girl students, in which they constructed a 'smart house' model using PicoCricket kits. The girls were also exposed to advanced robots, such as iRobot Create, Aibo and Nao.

3. Robot theatre performances for the public

MadaTech's Robot Theatre Program follows the long tradition of theatrical performances in science museums, as a way of effectively communicating science to the public. Such performances utilize drama to portray events from the history of science, discuss scientific concepts and introduce exhibits [15]. The Museum plays tend to be short, informal, tangible, dynamic and highly interactive, engaging audiences both cognitively and emotionally. Different techniques of theatrical interaction are used, including first-, second- and third-person interpretations, role demonstrations, storytelling and dance/music performances [16]. Various tools and technologies, such as puppetry and multimedia are applied, to get closer to the audience and render the shows more visual.

The initiative to introduce robot theatre to MadaTech is in line with pilot theatrical performances that have been very recently introduced into other museums [17, 18]. The decision to develop robot theatre performances at MadaTech was influenced by the following factors:

- From interactive presentations of the humanoid Nao robot, given by Aldebaran Robotics (France) at the Technion and at MadaTech we found that Nao's performances facilitate in introducing robotics concepts to the public in an exciting and attractive way. Consequently, the Museum ordered a number of Nao robots.
- During a 2009 visit to the new Korea Robot Land Theme Park in Incheon, we had the opportunity of learning from the interactive performances of another robot humanoid, Bioloid, presented by the ROBOTIS Co. to Robot Zoo exhibition visitors. These performances, in which a human actor demonstrated the robot through interaction with young students, attracted great interest and the emotional involvement of the students.
- MadaTech ordered a full-size humanoid robot, RoboThespian (www.robothespian.com), specially created to serve a robot theatre actor. The Museum also developed a short movie whose heroes are a human actress, Thespian and Nao robots and a virtual parrot. The film was shown to visitors as they entered the Robot World exhibition. This was our first experience in creating interactive demonstrations with humanoid robots.

The robot theater performance, developed at MadaTech with the participation of the authors, was a series of theatrical pieces, in which a human actor assisted by a technician demonstrated three different robots: a Roomba vacuum cleaner, an Aibo robot dog and a Nao humanoid. The performance demonstrated basic concepts of robotics, while illustrating robot functionality and behavior repertoire. When presenting Roomba, the actor talked about service robots. He playfully demonstrated the robot in action and explained principles of sensing and communication. The public was able to interact with Roomba and observe its reactions to spreading waste and clash with a virtual wall in the robot workspace.

Aibo's presentation emphasized its advanced intelligence compared to the robotic models of animals exposed at the Robot Zoo Exhibition. Aibo's different emotional reactions and capabilities of learning from interaction with the public were demonstrated. The culmination of the robot theater performance was the Nao show. The show consisted of three parts: greetings, a Tai Chi exercise, and a dance in memory of Michael Jackson. Each part demonstrated an aspect of a Nao function and was used by the human actor to introduce and illustrate scientific, technological and social concepts. In the greeting part, the robot presented autonomous behaviors: standing-up, walking, gesturing and human-like speech. During the presentation, the actor introduced concepts such as stability, locomotion, and text-to-speech capability. In the Tai Chi exercise, the explanation was based on the use of two physics concepts: center of mass and equilibrium. Spectators were encouraged to practice Tai Chi along with the robot. They experienced the difficulty of maintaining balance during the exercise and discovered that Nao performed better than some of them! The Nao's dance demonstrated the robot's capability to perform various movements and synchronize motion with music. The accompanying explanation focused on an analysis of the degrees of freedom of the robot used in the dance movements. Spectators were asked to compare Nao and humans in terms of degrees of freedom.

Demonstrations were delivered in a specially-arranged 100-seat amphitheater. The performance attracted wide public interest and was attended by most of the 350,000 Robot World visitors. Fig. 1 shows frames from the film and the performance.

4. The OlympiYeda competition in robotics

4.1 The OlympiYeda model

The OlimpiYeda ('Yeda' means 'knowledge' in Hebrew) is a nationwide annual competition in science and technology for 8th/9th graders, run by MadaTech since 1989. It aims to foster excellence in science & technology and to stimulate interest in scientific areas that go beyond the school curriculum. Competition topics vary from year to year and

(a) (b) (c)

Fig. 1 (a) From the film. (b) Interaction with Aibo (c) Spectators at the robot theatre.

have included: Sport Science (1992), Forensic Science (2002), Cardiology (2006) and more.

The competition has four stages:

1. *Entrance.* Two tests are run (in Hebrew and Arabic), with participation of thousands of students from junior high schools throughout Israel. One test is in general science; the other in mathematics and spatial reasoning. The tests help identify students capable of learning on their own and understanding scientific concepts beyond their school curriculum.
2. *Self-Study.* The selected students are given a list of subjects pertaining to the topic of the year, which they have to study on their own using the instructional materials in Hebrew and Arabic (many junior high school students in the Israeli Arab sector are not fluent enough in Hebrew). At the end of this stage, students take an exam on the studied material. The challenge of self-directed learning helps identify students highly motivated in the specific area. The highest achieving students move on to the next stage.
3. *Semi-Finals*. Students are invited to participate in the OlympiYeda overnight summer camp hosted by MadaTech. The program includes workshops at the Museum, topic-related lectures, excursions, student presentations and social events. The camp gives the students an opportunity to learn from leading experts in the area of interest. It exposes them to recent and ongoing research and to innovative technologies in the field. The camp creates a multicultural community of talented students who learn from each other and share their enthusiasm about the subject matter. When assessing learning achievements, we try to encourage cooperation and avoid competition among the students. Achievement assessments are based on student presentations, performance in individual and group assignments and a written test. The top eight students are chosen to participate in the final stage of the OlympiYeda.
4. *Finale.* Students participate in an oral quiz in front of a live audience, comprising classmates, family members, and educators. They respond to creative topic-related questions posed by experts in the field. This is a celebration of student knowledge in the field. The quiz is taped for TV. Four winners in the final stage receive Technion scholarships.

4.2 Organization and robotics activities

In this section, we will describe organizational and learning activities at each stage of the competition.

Stage 1. The general science test consisted of 40 questions and the mathematics and spatial reasoning test included 30 questions (all multiple-choice). Questions are selected from different science, mathematics, and technological literacy tests. The tests were developed in Hebrew and translated to Arabic. They were held in 108 junior high schools in the Jewish sector and 37 junior high schools in the Arab sector. In addition, some students took an internet version of the test. In total, 4,136 students participated, 2,937 of them Hebrew-speaking and 1,199 Arabic-speaking. Following the tests, each participant received the answers. Grading was based on statistical analysis of the test results. 1,152 students were selected for the next stage of the competition, 552 of which (298 Hebrew-speaking and 254 Arabic-speaking) enrolled for the next stage.

Stage 2. Each participant received a textbook, 'Think Mechatronics' and instructional materials, including links to robotics education websites. The self-study assignment included topics in mechanics, motors and gears, LEGO design and programming, system structure and control, and other topics. The textbook and other materials were translated into Arabic. At the end of this stage, 501 students (240 Hebrew-speakers and 261 Arabic-speakers) took an exam comprising 24 multiple-choice questions and one open question. One of the questions is presented below.

Question. Fig. 2 presents a robot carrying a

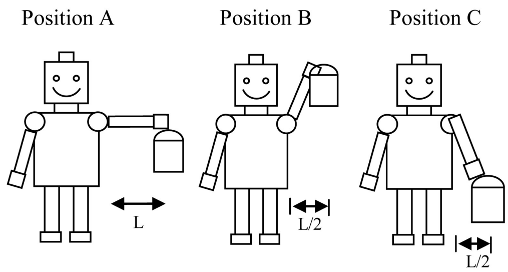

Fig. 2. A robot in three different positions.

bucket in three different positions. Which of the following statements is correct?

1. The torque created by the bucket is greater in position A than in positions B and C.
2. The torque created by the bucket is greater in position B than in positions A and C.
3. The torque created by the bucket is greater in position C than in positions A and B.
4. The torque created by the bucket is greater in positions B and C than in position A.

Based on exam results, the 31 highest achieving students were selected for the semi-final stage of the OlympiYeda. In preparation for this stage, each student prepared a lecture with a PowerPoint presentation on a robotics-related topic. They submitted the presentations to the OlympiYeda committee and got recommendations for their improvement. Our preparations for the semi-final stage included development of a curriculum and a cultural program, design of learning activities and solutions to organizational problems behind them, building and training a team of instructors and mentors.

Stage 3. The summer camp began with an introductory lecture, 'The Robot as a Magic Ball,' delivered by Prof. Verner. The definition of a robot, discussion of state-of-the-art robots, and examples of creative robot projects, undertaken by junior high school students aroused participant interest and generated a lively discussion.

The program's two main components were RoboWaiter and Robotic Model workshops. The RoboWaiter workshop was motivated by the new assistive robotics competition RoboWaiter [19] and conducted by Sarthak Khanal and Binay Poudel—two students (originally from Nepal) studying electrical engineering at Trinity College, Hartford, CT. The students received a prestigious Kathryn P. Davis Peace Foundation Grant for the project 'Robotics for Peace,' whose two objectives were:

- Endowing scientific and technological knowledge about building and programming a mobile robot RoboWaiter.
- Training a multi-cultural group of students and facilitating mutual work, leading to a peace dialogue and cooperation.

The RoboWaiter project challenged teams to create a robot that can retrieve a plate of food and carry it to a table, in a reliable and efficient manner. The arena simulates a home kitchen with the usual fixtures and dolls simulating people with disabilities served by the robot. Sarthak and Binay provided each group of school students with a *NXT Mindstorms Lego Kit* and all the other essentials required for work on a robot. Under their guidance, the groups built robots and programmed them to carry out the RoboWaiter task. This included significant work on testing and improving robot performance.

The Robotic Model session was conducted by Cuperman. It focused on the analogical links between biological and technological systems in general and between animals and robots in particular. Participants were familiarized with issues such as appearance, functionality, sensing and locomotion of nature-made creatures versus those of robots. During the workshop, participants were engaged in hands-on activities with PicoCricket construction kits. A PicoCricket (http://www.picocricket.com) is a tiny programmable computer that can react to input from a variety of sensors and operate a variety of actuators. The kit enabled participants to combine science, art and imagination, while practicing technology. Participants worked in pairs and coped with challenges of inquiry into biological phenomena and building robotic models that react to stimulus, exhibit diverse motion behaviors, and communicate and exchange data in the same way as their animal prototypes.

Semi-finalists also delivered lectures to their peers and to the OlympiYeda Committee. At the end of the workshops, they took a written exam based on the studied material. One of the exam problems was as follows:

Question. When running the PicoBlocks program presented in Fig. 3, how many chirps will the PicCricket play?

Based on the results of the exam and performance in the workshops, the eight highest achieving stu-

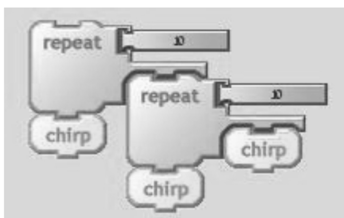

Fig. 3. A PicoBlocks program.

dents were selected for the final OlympiYeda stage. In preparation for the final stage, the students came to MadaTech for a four hour modeling session. At the beginning of the session, the students visited the Robot Zoo Exhibition. Then, each finalist got a personal assignment: using the PicoCricket kit, design and build a robot prototype which models a specific function of one of the animals presented in the exhibition. For example, one of the assignments was as follows:

> *Design and build a device which models the chameleon's ability to turn each eye independently of the other, in order to see a wider segment of the environment. The system should include two identical mechanisms that can turn the eyes left/right or up/down. Each mechanism should be controlled by a separate button.*

The robot model built by the student who performed the above assignment included two identical mechanisms, each driven by a separate motor through a transmission. Eye orientation was controlled by PicoCricket, on the basis of input from two variable resistance sensors. The model is presented in Fig. 4.

Stage 4. The final quiz was held in the MadaTech hall. The quiz consisted of three parts. In the first part, the students presented the prototypes, developed at the Robotic Model session, to the judges. The public was able to view the prototypes on large screens.

Each finalist had to answer a challenging question pertaining to his/her prototype. For example, Y., who developed the chameleon eyes model prototype (Fig. 4), answered the following question:

> *Does your prototype provide the same range of eye positions of a real chameleon? If so, how is this provided? If not, suggest an idea for upgrading your prototype.*

In the second part of the final quiz, each finalist presented his/her lecture and answered two questions pertaining to it. One question usually referred the technical aspect of the lecture content; the other, inquired about the student's vision of future developments on the subject. For example, student B. answered the following two questions:

Question 1. In your lecture, you described the advanced Da Vinci robotic surgical system. What special skills are required by a physician, to carry out surgery using a robotic system?

Question 2. Suppose we are interested in developing a robot for assisting elderly people who suffer memory deficiency problems. The robot's task is to locate a person who is away from home and safely guide him/her back. What functions must a robot possess, in order to carry out this mission? What are the technical subsystems and components needed to provide these functions?

The four best achieving competitors entered the third concluding part of the quiz. Our desire was to render this part the most appealing to the finalists and the audience. For this purpose, we availed ourselves of two robotics experts, noted international OlympiYeda guests, Prof. David Ahlgren from Trinity College (CT, US) and Natanel Dukan from the Aldebaran Robotics Company (France). Questions in this part were all related to the advanced humanoid Nao robot (an Aldebaran product). Mr. Dukan's role was to demonstrate Nao's performance, while Prof. Ahlgren, presented the questions and served as co-judge.

The three questions in this part of the quiz represent the three main educational themes: science, technology and society (STS). Three different Nao performances were selected: (A) kicking a ball; (B) a Tai Chi exercise; (C) blessing the audience in several languages. The first (technological) question was about the subsystems and components of the Nao robot system involved in performance A. The second (scientific) question asked to identify and define the scientific and engineering concepts behind performance B. The third (social) question referred to the human capabilities simulated in performance C.

All eight students in the final stage received MadaTech prizes. The four top finalists received scholarships for undergraduate studies at the Technion—Israel Institute of Technology.

5. Evaluation and discussion

The 2010 OlympiYeda in robotics included evaluation of educational outcomes. The first two stages of the OlympiYeda were delivered through distance education and their outcomes were evaluated quantitatively by means of scholastic knowledge tests. Our main interest in the evaluation study was on the summer camp as central part of the program in which the main robotics activities were concentrated. The camp was a suitable framework for

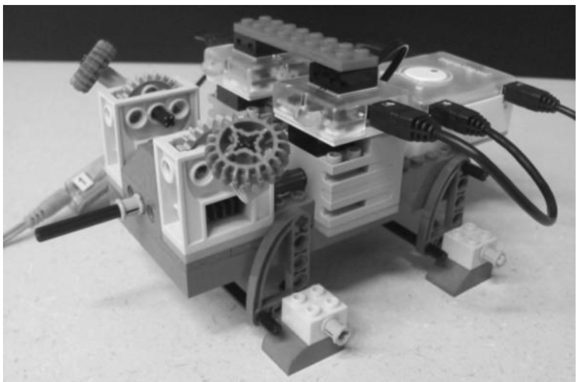

Fig. 4. The chameleon robotic model built using PicoCricket.

detailed evaluation of learning of its participants (N = 31). This evaluation was based on the analysis of student performances (presentations, workshop assignments, and the written exam) as well as data from observations, questionnaires and interviews. We focused the observation on three characteristics of the program: learning in a rich environment, learning through interactive robot demonstration, and learning in a diverse community.

5.1 Learning in a rich environment

From interviews with the students, we learned that most of them entered the program without background knowledge in robotics. The post-camp questionnaire asked them to evaluate the importance of different activities in which they participated. Its results are summarized in Table 1. The list of the camp activities is given in the first column, while the second column shows percentage of students who evaluated the activities as 'important' or 'very important'.

The Table indicates that the highest evaluation was given to the PicoCricket and RoboWaiter hands-on workshops. At the same time, the data show high positive evaluation of all the other activities (lectures, excursions, demonstrations, students' presentations) through which the students were exposed to theoretical principles and practical applications of robotics. Evaluation of the richness of the learning environment was indicated also by students' reflections:

'Lectures, the excursion to the robotic factory, students' presentations and especially preparing my own presentation contributed me.'

'From the factory visit I understood how robots are made and how they work; from the RoboWaiter workshop I learned to design and, most important, to program.'

'I learned about robots from the museum robot exhibition.'

5.2 Learning through interactive robot demonstration

At the end of the summer camp, the participants completed a questionnaire in which they were asked to express opinion about the robot theatre performance. Responses of the students are presented in Table 2. The first column includes a list of statements, the second column shows the percentage of students who agree or strongly agree with the statements, and the third column presents students' arguments.

From the survey results, almost all the students thought that presentation of modern robots and other innovative technological systems is important

Table 1. Evaluation of Camp activities

Activities	Percentage of high evaluations
PicoCricket workshop	96.7
RoboWaiter workshop	93.3
Excursion to the automated manufacturing factory	86.7
Lectures on basics of robotics	80.0
Demonstrations in the Technion control and robotics lab	80.0
Visit to the Technion medical robotics lab	73.3
Robot Zoo exhibition	73.3
Museum exhibitions (not robotic)	70.0
Meeting with the National FIRST competition champions	63.3

Table 2. Robot theatre survey results

Statements	Agree (%)	Arguments
Science museum is a right place to present robots.	96.5%	Robots as most innovative technological systems should be presented at the science museum.
Demonstration of advanced robots add to students knowledge of robotics.	58.6%	I learned from observation of robots in action. I learned about degrees of freedom and how to count them. It was especially interesting to see how Nao keeps balance when performing the Tai Chi exercise.
Nao's capabilities make it the 'premier actor' of the robot theatre.	86.2%	Nao's capabilities are above that of all other robots. Its human-like dance and behaviors were most exciting.
The actor's explanations help to understand Nao's functions.	86.1%	The explanations were convincing and helped to understand the technology behind balance keeping, visual perception, symbols recognition, and locomotion.
Aibo's demonstrations are instructive and impressive.	*Knowledge*: 62% *Impression*: 96.5%	Aibo is cool, impressive, cute, emotional, and behaves like a real dog. Its presentation was exciting and interesting.
Interaction with Roomba helps to understand how Nao and Aibo work.	38%	Excellent performance of the vacuum cleaning robot demonstrated how robots equipped by sensors function.

Table 3. Comparison of OlympiYeda and FLL

Category	**OlympiYeda**	**FLL regional contest**
Enrollment	Individuals, about 1000 students selected from 4,500 applicants participated in the entrance exam.	Teams of 4-9 students, about 500 participants in 2010.
Selectivity	A four-step selection of individuals demonstrated best results in different learning activities.	After completing projects, the teams participate in regional rounds. Best of them are selected for the national competition.
Guidance	Scaffolding by professional educators.	Tight instruction by team guides.
Focus of activities	Studying basic concepts of robotics, inquiries into topics of personal interest, building robotic models, seminar presentations, and thematic excursions.	Building a robot to perform given robot mission tasks and an inquiry assignment.
Participation framework	Open to every student with selection based on achievement.	Teams of selected students from schools which succeeded to mobilize required resources.
Assessment	Evaluation of individual achievements in all offered learning activities.	Evaluation of robot performances and team presentations.
Robotic environment	Lego NXT and PicoCricket kits, exhibitions of various robots.	Lego NXT robot kit especially designed for performing robot mission tasks.

and relevant for the science museum. Though presented after the hands-on workshops and other activities mentioned in Table 1, the robot theatre performances added knowledge to the majority of students. More than 86% of the students were excited by the variety of Nao's human-like capabilities; the important role of explanations given by the human actor during interactive demonstrations was noted. It is interesting, that while almost all the students were impressed by the Aibo's performance, the knowledge contribution of its presentation was evaluated lower. While some of the students mentioned the Roomba's demonstration of reactive behavior, the evaluation of its contribution to understanding the animated robot operation was relatively low. A possible reason is that Roomba is not an educational robot, but a service robot intended for home cleaning. It is not open for user programming and experimentation.

5.3 Learning in a diverse community

The OlympiYeda participants presented a culturally diverse group: Jews and Arabs, religious or secular, boys and girls, city and village dwellers. In order to create equal learning opportunities for all the students and to make the program joyful and friendly, the program was organized not as 'culture free', but followed the principles of culturally inclusive education [20]. As some of the students had difficulties in Hebrew comprehension and expression, learning materials were prepared also in Arabic, and assistance of interpreters was provided when needed throughout the program. Common living and social activities in the Camp helped to create the atmosphere of pluralistic learning community. Involvement of two Nepali American students as mentors contributed to this atmosphere.

Our study indicated that the multi-cultural climate of the program was highly evaluated by the students. More than 70% noted the value of social activities offered by the program; more than 85% mentioned that learning in the multi-cultural group was new and important for them. Typical responses from the students:

> *For me, the social contribution of the OlympiYeda was unique and most important. Meeting young people like me, but different, expanded my horizons more than any other curriculum. I gained good friends and hope we will stay friends for life.*
>
> *The big advantage of the Camp, to compare with other programs and competitions, is the connection and communication of different people interested in the same subject.*
>
> *The program combined collaboration and competition and this experience gave me a lot of self-confidence.*

5.4 Distinctive features of OlympiYeda in robotics

There are a number of international robot competitions for middle school students; one of the most renown among them is FIRST LEGO League (FLL) [21]. While mentioning the growing popularity of robot competitions, literature points to the need for deeper analysis of their educational impact [22]. One way to better understand specific features of different competitions is to compare them. Therefore, we find worth to compare the framework of the OlympiYeda robotics competition with that of the FLL. Our familiarity with FLL is based on participation in its regional competitions in Israel as judges and team guides.

The OlympiYeda and FLL robotics competitions are similar in that they both combine hands-on activities of design, building, programming and testing robots with topic inquiries based on applying science concepts. In both cases the themes of competition change each year. With this similarity, the competitions differ with regard to organizational and didactic categories, as specified in Table 3.

While FLL is designed for participation of teams enrolled by schools, OlympiYeda enrolls individuals who are interested in the subject and succeeded in the entrance exam. Members of FLL teams are selected by schools for the whole project; selection of best teams is based on judging their performance at the competitions. In the OlympiYeda achievements of participants are assessed at each stage of the competition and best achievers are selected for the next stage. The OlympiYeda scheme is similar to that used in mathematics and science Olympiads.

Schools have problems in recruiting mentors for FLL teams. Howell et al. [23] point out that often the recruited volunteers do not have teaching experience or technical background, or are uncomfortable with robotics. In contrast, the OlympiYeda program provides a carefully designed environment in which learning is scaffolded by professional educators of MadaTech. Activities of FLL teams are focused on building and programming a robot to perform missions of the robot game, as specified in detail in the contest rules. In addition, each team performs a project, which requires analyzing a given realistic problem and proposing its innovative solution. The OlympiYeda activities are different at each stage, performed individually or in small groups; their outcomes are carefully assessed.

Participation in FLL requires from schools significant investment in ordering construction kits and team guidance. Even with support of the Ministry of Education, most of the participating schools have only one FLL team. The OlympiYeda framework does not require these investments and opens equal opportunity of participation for all interested students. Hands-on activities in FLL are conducted using the LEGO NXT construction kit. Participants of OlympiYeda also use this kit, but get additional experience of developing bio-inspired robotic models using the PicoCricket kit.

With the mentioned advantages of the OlympiYeda competition, opportunities of using it as a specific pathway into robotics are limited. Limitations of the OlympiYeda include the following:

- This excellence program is oriented on students with developed learning skills and high learning motivation.
- As most of the students join the program without background in robotics, they have to overcome difficulties of studying its basic concepts through distance education.
- Rich learning opportunities are provided only to highest achieving students.
- It is essentially an outreach program not suitable for replication in formal education.

Because of its limitations, OlympiYeda cannot replace robot competitions and programs developed for other situations. The authors continue the study of the OlympiYeda towards extending opportunities of its adaptation to other situations. We already adapted the hands-on workshops described in section 4.2 as sessions and courses delivered at the Gelfand Center and in schools (by means of the Robotics Mobile Lab).

6. Conclusions

Growing use of robots in museum exhibitions and programs, as indicated by recent literature, raises questions about the place, role and value of robotics in museums of science and technology. Our paper addresses these questions by providing a broad view of robot exhibitions and different robotics programs developed and implemented at MadaTech—The Israel National Museum of Science, Technology and Space.

Robotic activities at MadaTech, started a decade ago, with brief hands-on lab sessions, catapulted to a new level, with the creation of a special educational division, the Gelfand Center for Model Building, Robotics and Communication. Over the past four years, the Center has become one of the Museum's central educational venues, providing lessons and courses at all levels of school education.

A strong impetus for further development was provided by the 2010 Year of Robotics at MadaTech. The challenge of presenting robotics before a large audience called for coping with new technical, pedagogical and organizational problems. This paper shows how these problems were dealt with, through collaboration with robotics experts both from industry and from the Technion.

One important lesson is that the way to introduce robotics in the science museum is through both exhibitions and educational programs. The existing frameworks for using robots at exhibitions as exhibits, remote facilitators, and entertaining guides can be enriched by 'museum theatre' performances, the shows in which the interaction of a human actor with public is mediated by the robot. From our experience and research, the performances at MadaTech were attractive and effective because they were interactive, scenic, tangible and real (non virtual). We found that animated and especially humanoid robots, such as Aibo and Nao, were of highest interest, and their performances were most knowable. We can recommend beginning the performance with explanation of basic robot concepts and their demonstration using more simple instructional robots.

The second lesson is that the science museum can offer an alternative to renowned school robot competitions such as First Lego League. The presented OlympiYeda in robotics puts emphasis on learning excellence. Being a competitive program, it facilitates collaboration and building a community of learners. The characteristic features of the program, highly evaluated by the students, were providing various opportunities for learning robotics and consistent implementation of principles of multicultural education.

The OlympiYeda 2010 robotics program engaged thousands of junior high school students in active learning of science and technology. The nationwide competition offered by the program challenged and motivated the students. The follow-up showed that through the combination of robotics and social activities offered by the OlympiYeda, the participants gained skills of self-regulated, experiential and inquiry-based learning, practical problem solving and collaborative teamwork, and enjoyed communication in a multi-cultural, intellectual community.

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