# A Cross-generational Robotics Project Day: Pre-school Children, Pupils and Grandparents Learn Together

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**Abstract:**
*Using robotics to interest kindergarten children in science and technology in a playful way is a rather new idea in educational robotics. Aiming to foster the integration of robotics already in pre-school education this paper presents an innovative robotics project for kindergartens. Initialized by the Graz University of Technology and the University of Teacher Education, the project involved different scientific and educational institutions. The focus was put on the cross-generational aspect, integrating kindergarten children, pupils up to the age of thirteen as well as senior citizens in order to initiate a vital social process between the different age groups. Within the project a robotics day in a kindergarten offering eleven different hands-on experiments, where children could actively participate, was organized. The goal of the project presented in this paper was to familiarize children in pre-school age as well as young school students with science and technology using different robotics platforms as pedagogical tools. Aiming at the investigation of the impact of the robotics project a first qualitative evaluation was conducted.*

**Keywords:** *RoboCupJunior, educational robotics, robotics in kindergarten, cross-generational aspects, qualitative evaluation*

## 1. Introduction

In the last decades educational robotics has gained increased attention. Several conferences and workshops deal with the use of robotics in education [24]. In addition initiatives like *RoboCupJunior (RCJ)* aim to interest young children and pupils up to the age of nineteen in science and technology [28]. On the contrary educational robotics with special focus on children aged between three and six years is less widespread. Science and technology are changing rapidly and young children have to be prepared for this development. The idea behind the concept of educational robotics in kindergarten is to use the robot as pedagogical tool to familiarize children in pre-school age with science and technology in a playful way.

By presenting an innovative cross-generational project for kindergartens this paper discusses how different robotics platforms could be integrated in the education of children between three and six years of age. Furthermore, it presents an interesting concept within the field of educational robotics: Different age groups (kindergarten children, pupils aged from eleven to thirteen, senior citizens) and different scientific and educational institutions (kindergartens, schools, universities) work together on a joint robotics project. Qualitative feedback was collected and analyzed within a first empirical evaluation. The aim of this evaluation was to investigate the learning effects and the medium-term impact (up to eight months) of the project on participating kindergarten children and pupils. Preliminary results and findings of the qualitative evaluation are presented in this paper.

The remainder of the paper is structured as follows: Chapter 2 deals with related research whereas chapter 3 gives a brief overview of the current situation of educational robotics in kindergartens in Austria. Chapter 4 provides a detailed description of the kindergarten project followed by the presentation of preliminary evaluation results in chapter 5. Chapter 6 draws conclusions and discusses future work.

## 2. Related research

As the level of awareness and importance of educational robotics rose over the last decades a great number of conferences, workshops, papers and books have been addressing this topic [3,22,24]. Alimisis and colleagues [1] for instance provide in their book an extensive overview of the theoretical background as well as practical aspects of robotics in education.

In [26] the authors describe how robotics can act as a tool to teach pupils the basics of engineering and programming. In addition they conducted empirical studies in order to investigate why robots seem to motivate children, even if they were not technically interested beforehand.

Whereas the use of robotics in pre-school education is not as wide-spread as in primary and secondary school various papers and articles exist which describe robotics platforms and projects for young children. For instance the authors of [5] present the experiences made introducing robotics in a kindergarten using *Lego WeDo*. Children had to build a small robot step by step. Afterwards they interacted with the robot, which was actually programmed by a teacher.

The article in [2] describes the integration of robotics in early childhood education following a constructionist strategy (learning by designing, using concrete objects to explore, identification of powerful ideas, self-reflection).

Janka [15] presents the use of the programmable robot-toy *Bee-Bot* in pre-school education. Different activities and games for kindergarten children and teachers were designed and qualitatively evaluated. The focus of this research was based on robot programming instead of construction and design. It turned out that although all children involved in the study basically enjoyed playing with the Bee-Bot and were not afraid of using this new technology the robot itself was not interesting to them for a longer period of time. The author also stated that some of the children showed a basic understanding of the robot's control principles whereas others seemed to be too cautious to increase their self confidence during the work with the Bee-Bot.

A short look in the history reveals that already in the early 19th century the German pedagogue Friedrich Froebel, who coined the term 'kindergarten', developed a series of educational toys and hands-on learning strategies. Many modern learning tools, for instance the *Lego Mindstorms* robotics kit, are based on his work [17, 29].

## 3. Background

Educational robotics for primary and secondary schools is well established in Austria. Among other initiatives a nationwide network of RoboCupJunior regional centers provides support for schools, teachers and pupils [12]. On the contrary only a few initiatives and projects can be found which use robotics in kindergarten and pre-school education.

One example would be the robotics course "Robots for Kids" which was set up in 2010 by the University of Applied Sciences Technikum Wien. The target group for this course are kindergarten children at the age of four to six years. Within the classes children can actively participate and in parallel they get a first impression of scientific working [29].

As another example the project "Technical and natural science in playschool" of Vienna University of Technology could be mentioned. Children aged between four and six years have the opportunity to visit different departments of the university and participate in experiments. Within this project one of the main topics was robotics.

Additionally, different scientific institutions and universities offer training courses and workshops for educators and children. For instance the Austrian Computer Society offers robotic workshops in order to teach kindergarten pedagogues how to integrate robotics into teaching.

The "Technisches Museum Wien" organizes workshops for children between the age of four and seven to teach them the basics of programming and robotics.

The initiative "Children visit Science" is an innovative approach within the context of kindergarten pedagogy in Austria. The intergenerational, cross-organizational project was originally initiated in 2010. The basic aim of this initiative is to provide pre-school children and pupils with access to different scientific fields and furthermore to give an insight into the research sector at different scientific institutions [11, 14].

In the first year the initiative comprised five educational modules, focusing on different topics (bioscience, experimental physics, criminalistics, chemistry, paper manufacturing). In spring 2012 a scientific project day on the subject of electrostatics and electricity was organized. Secondary school students in cooperation with their teachers prepared different hands-on experiments dealing with topics like how to establish a power circuit or how to test the conductivity of different materials. Pupils acted as guides explaining the experiments to kindergarten children. This concept formed the basis of the scientific robotics day described in section 4 [4, 10, 11, 14].

***Fig. 1. Two children working with the Bee-Bot***

Almost all above mentioned robotics projects and workshops use the *Bee-Bot*, manufactured by the British company *PrimaryICT*, as a learning tool (see Figure 1). The small programmable wheeled robot, designed for pre-school and early primary school children, is a widely adopted tool within the context of educational robotics in kindergarten. It can be controlled according to the principles of the *Logo* programming language [25]. Using the buttons on the back of the robot (forward, backward, rotate left, rotate right) children can enter a sequence of commands. Each forward/backward instruction moves the robot 15cm in the corresponding direction whereas each rotation instruction turns the robot by 90 degrees without changing its current position [15].

## 4. Project description

In November 2012 a cross-generational scientific kindergarten experiment day with special focus on robotics was organized as a joint project between a secondary school, a kindergarten, the University of Teacher Education and Graz University of Technology (TUG). The structure of the robotics day was based on the concept "Children visit Science" and the scientific project day on electrostatics and electricity described in section 3.

One main objective of the robotics project day was to prepare contents of the area of robotics respecting pedagogical and didactic aspects as well as principles of educational robotics ( [1, 7, 27, 31]). Therefore, members of the robotic lab at TUG together with kindergarten pedagogues and teachers developed eleven different hands-on experiments and educational games applying methods of research-based learning ( [21]) and the technique of storytelling ( [14, 20]). Respecting fundamental principles of educational robotics as stated by Frangou and colleagues in [7] children could actively participate, explore, test and interact with the robots.

During the project day at the kindergarten each experiment was carried out at a separate hands-on area, also referred to as 'experiment station'. According to the concept of an education partnership [30], secondary school students carried out and explained the experiments to kindergarten children and their grandparents. Pupils slip into the part of a teacher, accompanying the kindergarten children through their way of discovering and experiencing.

In preparation for their tasks pupils attended a half-day robotics workshop. Before this workshop they did not know any details about the experiments or the different tasks. The teacher only announced that she is looking for volunteers joining a robotics project. In the workshop pupils were first introduced to the basic concepts of robotics and the scientific background of each robotics experiment (e.g. explanation of sensor, motors, robot programming, and so forth). Students could choose their favourite robot to work with. Afterwards they got detailed instructions on how to carry out and guide different experiments.

To give the different age groups participating (preschool children, pupils, senior citizens) a basic understanding of robotics and artificial intelligence the experiment stations were structured around following major items using different robotics platforms:

- the programmable wheeled robot *Bee-Bot* [15]
- functionality of sensors using the *LEGO Mindstorms NXT 2.0* robotic kit [19]
- the humanoid robot on the example of the *Hitec RoboNova* [9]
- mapping and object tracking using the *Pioneer 3 DX* robot [8]

Figure 2 shows the different robotics platforms used as well as the excitement of children and pupils while carrying out hands-on experiments. In addition Figure 3 provides an overview of experiments focusing on different types of sensors. Following a brief description of each covered topic.

#### 4.1. Telling a story using the Bee-Bot

Based on the functionality of the Bee-Bot described in Chapter 3 two educational games were developed. The idea behind was to embed the tasks children have to accomplish into a story. In the first game children had to program the robot to follow a certain path on a special square grid mat. The path represented the different production stages in a glass factory (also see Figure 2a). The research question to the children was: "Can you teach the Bee-Bot how to make glass?".

The challenge of the second game was to program the robot moving from a starting point to an endpoint, stopping at certain intermediate positions on a square grid mat with fairy-tale motifs imprinted. The research question for this task was: "Can you tell the story of the *bad wolf and the three little piglets* whereby the Bee-Bot is acting the wolf?"

#### 4.2. Functionality of sensors

Seven hands-on experiments demonstrated the use and the functionality of the ultrasonic-, the light-, the sound- and the color-sensor. Children could interact with the different robots which were build using Lego Mindstorms. Research topics included: "Follow the light", "Don't drop from the table" (Figure 3b), "Avoid collisions", "Sweet-serving service robot" (Figure 2c), "Find and grab the can" (Figure 3d), "Sort the color bricks" (Figure 3a) and "Follow the noise" (Figure 3c).

#### 4.3. Humanoid robots

Using the example of the humanoid robot RoboNova the basics of humanoid robots were demonstrated. Pupils could control the robot by sending commands via the infrared remote controller. Children had to watch the robot carefully and afterwards imitate its movements (Figure 2b). The research question was: "Is a robot better at dancing than me?"

#### 4.4. Mapping and object tracking

This experiment station dealt with the topics of mapping and object detection using the Pioneer 3 DX robot with a SICK laser scanner and a Microsoft Kinect camera (Figure 2d). First the robot autonomously created a map of the kindergarten. Children followed the robot on it's way through the building. Afterwards the Pioneer performed an object tracking task using the Kinect camera. Children could actively interact with the robot by moving an orange ball. In parallel a member of TUG provided explanations on the functioning of the robot and the basic principles of mapping and object tracking. The tasks for the children were formulated as follows: "Supporting the rescue robot" and "Playing football with a real robot"

## 5. Results and preliminary evaluation

The first cross-generational robotics day was conducted respecting pedagogical and didactic aspects. Overall twenty-five kindergarten children participated. They had been divided into groups of three. Moreover ten pupils participated. Each group of children was accompanied by at least one grandparent. The described approach combined two major benefits: On the one hand pupils learned about scientific topics not only during the preparation process but also by guiding and explaining the experiments to kindergarten children. On the other hand kindergarten children had the opportunity to learn and gather practical experiences together with pupils and senior cit-

(a) Glass factory robot (Bee-Bot)

(b) Humanoid dancing robot (Hitec RoboNova)

(c) Service robot (Lego Minstorms NXT 2.0)

(d) Rescue robot (Pioneer 3 DX)

***Fig. 2. Kindergarten children, pupils, students and senior citizens together carrying out hands-on robotics experiments on different robotics platforms***

izens. In this context one important aspect was that pre-school children could actively participate in the experiments. Furthermore the integration of different age groups and different educational institutions fostered a vital social process between kindergarten children, young students, senior citizens as well as mentors, teachers and staff members of participating institutions. In general the concept of discovering and experimenting represents a valuable pedagogical approach within the area of pre-school education, fostering the learning process of children in a holistic way. In addition the robotics day formed the basis for a follow-up project at the kindergarten in order to deepen what children have seen and experienced [11, 14].

### 5.1. Qualitative evaluation

Within our plan to evaluate the cross-generational robotics project the first step was to investigate the impact on the age group of participating pupils. In the following step we will also investigate the impact on the group of kindergarten children.

We conducted semi-structured interviews [13] to collect qualitative data as well as to get positive and negative feedback with school students who guided the experiments during the robotics day. In order to obtain information about the medium-term impact and the learning effects it was decided to conduct the interviews around six months after the robotics day. The interviews took place at the school directly. Seven out of ten pupils voluntarily agreed on participating in this study.

**Methodology** The qualitative research technique of semi-structured interviewing is commonly used within the field of sociology, psychology, educational science and empirical software engineering [13, 18]. Preparing, conducting and analysing qualitative interviews are time consuming tasks. Nevertheless, we decided on applying this method since our aim was not only to obtain quantitative data but also to get personal feedback and collect additional information (i.e. interviewees' facial expressions, moods and feelings).

Based on the observations made during the robotics day and on discussions with teachers and pedagogues a set of questions, acting as a guideline during the interview, was designed. It was essential that those questions were formulated in an open-ended, non-directional way in order to avoid influencing interviewees' answers [6].

The first questions dealt with background information, information about the specific task performed as well as previous knowledge in the field of robotics. The main part dealt with pupils' experiences during the robotics day followed by questions asking for improvement suggestions and further experiences in the field of robotics made after the robotics day. The final question posed (only in case the interviewees did not already provide an answer) dealt with lessons learned from the pupils' point of view. Following a listing of the guiding questions[1]:

1) *Which grade do you attend?*
   a) *What is your favourite subject in school?*
2) *What was your task during the robotics day?*

a) *Why did you choose this task?*
3) *What did you know of robots before you participated in this robotics project?*
4) *Please describe your experiences during the robotics day.*
   a) *Did everything work out as it was supposed to (conducting and explaining experiments, acting as a guide)?*
5) *How was the cooperation with the kindergarten children?*
   a) *Where the children interested in the experiments? Did they actively participate?*
6) *How was the cooperation with the senior citizens?*
7) *Do you remember some situation or some activity especially? And why?*
8) *What would you change on the next robotics day?*
9) *Did you make any experiences in the field of robotics after the project?*
10) *What did you learn within the scope of this robotics project?*

For later analyses all interviews were audio-taped. Interviewees were asked for their permission to record the conversation. Furthermore, parents were asked to sign informed consents describing the main purpose and the procedure of the interview as well as stating legal and ethical aspects. All collected data was treated confidentially and personal information was made anonymous.

**Preliminary findings** For the analysis of qualitative data various different techniques could be applied (see [6]). Our approach was to transcribe all recorded interviews, to summarize inherent quantitative data and finally to perform a content analysis [23].

We interviewed seven students (four girls, three boys) aged from eleven to thirteen who currently attend grade two of secondary school. They all have basic knowledge of computers since this school provides one lesson of computer science every two weeks. Three pupils stated that they had previous experience with robot toys, one boy reported that he once watched a friend working with Lego Mindstorms and one girl already attended a Lego Mindstorms robotics workshop in primary school. The other two students never had anything to do with robotics.

As described in the previous section students participated in a half-day preparation workshop. Basically they could decide themselves which experiment to guide during the robotics day. Most pupils chose experiments which seem to fit their personal interests and talents. For instance one student interested in sports and physical education insisted on guiding the robot-dance station. Another student, who is a very talented speaker, decided for the Bee-Bot station where it was her task to retell a fairy tale while providing explanations on how to program the robot. Only one student reported that his robot was *"too complicated to handle"* and questions asked by visitors were *"too tricky"*. Asked for the topic and name of his station, the student had to think for a while until he could remember. It finally turned out that student's task was assigned by the teacher instead of chosen voluntarily.

Pupils also talked about their most memorable situations and experiences. One student for instance stressed out the special situation when he was controlling the humanoid dancing robot in front of a big audience. Similarly, two pupils talked about the joy of slipping into the part of a teacher, *"explaining things to little kids"*. Another student mentioned the great feeling of success when she illustrated the functioning of the robot to a girl from Romania which did not speak German at all[2]. Two pupils also remembered negative experiences (having trouble with a difficult kindergarten child; difficult technical questions by one grandparent; being afraid to provide explanations in English).

One aim of this qualitative evaluation was to find out what interviewees actually think about lessons learned and knowledge gained. Following a brief overview of students' statements:

- kindergarten children understood the functioning of the different robots very fast
- robotics is fascinating but it's much harder than expected that robots actually do what programmers want them to do
- many different robotics platforms and types of robots exist
- constructing and programming of robots mean a lot of work
- teamwork is important if you want to construct and program a robot
- the robotics project was an opportunity to improve English and presentation skills
- programs have to be written first and afterwards transferred to the robot

In sum all seven students were enthusiastic about their participation in the robotics project. Suggestions for improvement included the integration of one or two *"bigger robots with arms and legs or tracks"*. The overall feedback was mainly positive although interviewees also mentioned some problems and challenges during the robotics day (i.e. jamming robot gearwheels, unexpected robot behaviour, being nervous while speaking in front of an audience, providing explanations in English[3], tricky questions, troubles with difficult children). However, pupils pointed out the 'positive feeling' after handling these issues successfully (either on their own or by asking for assistance). During the interviews they still talked about 'their' robot and 'their' experiment station, even half a year later. Based on those statements and on the observations made during the interviews it could be concluded that pupils, despite problems and some negative experiences, were satisfied and felt proud of their achievements and that they identified with the chosen task and robots.

The interviews also revealed that the cross-generational concept worked out well. Although one of the interviewees complained about very complicated questions asked by senior-citizens all other pupils said that is was great fun to carry out robotics experiments together with pre-school children and their grandparents. Kindergarten children were fascinated by the robots, asked a lot and even tried to programme robots (especially the Bee-Bot) on their own. This shows that robotics was the perfect common topic for all involved age groups and that it has great potential to bring together kindergarten children, school students and senior citizens.

Student's statements and stories told indicate that both pupils and kindergarten children gained various technical and social skills during the robotics project. Furthermore, it's also worth mentioning that three months after the robotics day all ten students who guided the experiments, decided to attend an advanced robotics workshop at Graz University of Technology.

As previously mentioned the focus of this first evaluation was put on participating young students. The next evaluation phase will include the group of kindergarten children.

### 5.2. Further feedback and observations

Next to the evaluation described in the previous section we also obtained qualitative feedback from kindergarten pedagogues, grandparents, parents and pre-school children. In sum the feedback was mainly positive. For instance some parents reported that both children and their grandparents were motivated to build robots on their own after participating in the robotics day (i.e. using Lego Mindstorms). One teacher told about a child with special needs which also participated in the robotics day. The day after both the child's occupational therapist and it's psychologist noticed a significant improvement of it's behaviour. In addition kindergarten pedagogues reported that children were very enthusiastic about their first robotics-experience and still, half a year later, talking about the robots, asking *"when they will return"*.

In order to collect qualitative data directly at the robotics day, techniques of participant observation were applied [16]. We used both passive as well as active participation methods (field notes, informal interviews, discussions). In addition we also took pictures and videotaped the experiments. Considering ethical and legal aspects all collected data was treated confidentially. Beforehand parents were informed and asked for their permission to take pictures and to videotape experiments. Gathered data is still being analyzed, further findings will be published and discussed at a later date.

## 6. Conclusions and future work

Science and technology develop rapidly. In order to prepare children it is important to familiarize them already in kindergarten with science and technology. In this paper a novel concept for integrating robotics in kindergartens has been presented. The cross-generational, multi-institutional robotics project combined different robotics platforms in order to address kindergarten children, school students as well as senior citizens. Different scientific and educational institutions cooperated and organised the first robotics experiment day at a kindergarten. Children, pupils, senior citizens and visitors together explored eleven different hands-on robotics experiments.

The paper also discussed preliminary qualitative evaluation results. Within the plan to evaluate the cross-generational robotics project the first step was to investigate the impact on the age group of participating pupils. Pupils who guided the robotics experiments were interviewed in order to obtain positive and negative feedback as well as to perform a first investigation on the learning effects. Furthermore, qualitative feedback from kindergarten pedagogues, grandparents, parents and pre-school children was obtained. For latter analysis field notes and videos were made and pictures were taken during the robotics day. Preliminary results of a first data analysis indicate that using robots as pedagogical tools in kindergartens could be one way to achieve the goal of familiarizing kindergarten children with science and technology in a playful way.

All collected data of the first robotics day is still being analysed. In order to refine and improve the contents of the kindergarten robotics day presented in this paper further interviews with participating children as well as teachers and kindergarten pedagogues will be conducted. Further steps also include the investigation of the impact on the group of kindergarten children. Therefore both qualitative and quantitative evaluation methods will be applied. Based on the findings and on the lessons learned from the first robotics day further project days in different kindergartens in Austria will be organized. In addition a more detailed quantitative and qualitative evaluation on the medium- and long-term impact of such robotics days in kindergartens will be conducted.

## Notes

[1] All questions were translated to English since all interviews were originally conducted in German.

[2] In this context it is important to mention that the native language of all participants (pupils, children, teachers, senior citizens) was German since the robotics day took place in Austria.

[3] Pupils' native language was German.


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(a) Color sensor (sorting color bricks)

(b) Light sensor (detecting the edge of the table)

(c) Sound sensor (following the sound)

(d) Ultrasonic sensor (detecting and grabbing the can)

***Fig. 3. Experiments focusing on different types of sensors***

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