Innovative concepts in educational robotics: Robotics projects for kindergartens in Austria

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Abstract—Using robotics platforms for kindergarten children to interest them for computer science is a rather new idea in educational robotics. In this paper we present two different robotics projects in kindergartens. The Department of Computer Science at the University of Applied Sciences Technikum Wien established a course setting for children aged four to six years. Within the project they compared the performance of those kindergarten kids who received the robotics workshop with those who did not attend the training in order to analyze the effects of the course on the children's cognitive processes. The second project, initialized by the Graz University of Technology and the University of Teacher Education Styria, focuses the cross-generational aspect involving kindergarten kids, pupils as well as senior citizens. Within the project a robotics day in a kindergarten offering eleven different hands-on experiments for children was organized and a first qualitative feedback was obtained.

I. INTRODUCTION

Educational robotics has gained increased attention in the last decades. Several conferences and workshops deal with the use of robotics in education [21]. Initiatives like RoboCupJunior (RCJ) aim to interest young children and pupils up to the age of nineteen in science and technology [25]. 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 two innovative projects for kindergartens in Austria 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 first results of an empirical study evaluating the effects of using robotics in kindergarten.

The remainder of the paper is structured as follows: Chapter II deals with related research whereas chapter III gives a brief overview of the current situation of educational robotics in kindergartens in Austria. Chapter IV provides a detailed description of the kindergarten projects followed by the presentation of preliminary results aiming at this goal in chapter V. Chapter VI discusses conclusions and future work.

II. 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 address this topic [20], [3], [21]. 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. The paper in [23] describes 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 example the authors of [2] 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 [2]). 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 states 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 [15].

III. CURRENT STATUS

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 [13]. 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”. In 2010 the Department of Computer Science at the University of Applied Sciences Technikum Wien set up this course in cooperation with “Kinderfreunde Wien”. The target group for this course are kindergarten children at the age of four to six years.

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 have the opportunity to visit different departments of the university and participate in experiments. Within this project one of the main topics is 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.

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

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 [14], [12].

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. Pupils acted as guides explaining the experiments to kindergarten children. This concept formed the basis of the scientific robotics day described in section IV-B [5], [11], [14], [12].

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 lower 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 [22]. 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].

IV. PROJECT DESCRIPTION

The two robotics projects for kindergartens presented in this paper were carried out in Vienna and Graz. The following subsections provide a detailed description of each project.

A. Evaluation of the robotics course “Robots for Kids” for kindergarten children

The idea of evaluating this course arose while questioning whether the settings and the used contents are reasonable and helpful to teach first principles in programming using robots as a learning environment.

As a consequence it was decided to redesign the course in order to accomplish a setting, which can be evaluated by students of the Faculty of Psychology at the University of Vienna during the period from March to June 2012.

Therefore, the goal was to analyze the effects of the course on children’s cognitive processes in the context of executive functions. These are important parts when coping with the everyday school routine and are utilized for planning and initiating actions. The main issue was to evaluate whether the training with the robots has an influence on the performance of the executive functions [28].

Settings and content: There have been four kindergartens (private as well as public) involved in the project. Two of them with a group size of 12 to 16 children participated in the course, whereas the other two kindergartens with a group size of 27 children in total have not attended the course and have been used as a control group in order to compare the results. As a condition to participate in the project, the minimum age of the children was defined with 54 months (four-and-a-half-years). An absence of more than two lessons led to an exclusion of the target group.

The training was divided into six units, which were held in the morning at weekly intervals and lasted one hour. Four students of the University of Applied Sciences Technikum Wien executed the redesigned and standardized training schedule. Because of their simple user interfaces and the possibility to utilize them in team constellations, Bee-Bot robots have been chosen as training objects. The tasks which should be fulfilled each training have been defined.
in advance in order to guarantee that the two kindergartens have been subjected to the same terms. Additionally, the students recorded on a prepared sheet how many children were able to solve the specific tasks to get an overview of the performance of the kids.

Aims and hypotheses: The aim was to compare the performances of the pre-school children before and after the training. Therefore, four hypotheses were formulated [28]:

Hypothesis 1. The performances of the children who attended the robot course have improved in the post-test compared to those of the pre-test. If the result is significant it has to be worked out whether the increase can be explained by the robotics training. Therefore, the results have to be compared with those of the control group (children who were tested without having attended the training).

Hypothesis 2. After attending the training the performance of the executive functions is significantly better in the test group than in the control group.

Hypothesis 3. The statistical connection between the variables inhibition, shifting and planning is significant.

Hypothesis 4. Demographic factors have an influence on the performance at the pre-test.

B. A cross-generational robotics project day in kindergarten

In November 2012 a scientific kindergarten experiment day with special focus on robotics was organized as a joint project between the New Secondary School Voitsberg, the Kindergarten Rosental a.d.Kainach (both in Styria), the University of Teacher Education Styria 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 III.

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 [7], [27], [24], [1]. 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 ([19]) and the technique of storytelling ([14], [17]). 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 ([26]), 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. In this workshop the young students 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). Afterwards they got detailed instructions on how to carry out and guide the different experiments. In parallel kindergarten pedagogues plan and carry out extensional framework-projects in order to prepare the pre-school children.

To give the different age groups participating (pre-school 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 [16], the humanoid robot on the example of the Hitec RoboNova [10] and finally mapping and object tracking using the Pioneer 3 DX robot [9]. Figure 2 shows the excitement of children and pupils at the different stations. Following a short description of each topic.

1) Telling a story using the Bee-Bot: Based on the functionality of the Bee-Bot described in chapter III two educational games were developed. 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 1). The research question to the children was: "Can you teach the Bee-Bot how to make glass?". The task of the second game was to program the robot so that it moves 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?"

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!", "Avoid collisions", "Sweet-serving service robot" (Figure 2c), "Find and grab the can", "Sort the color bricks" (Figure 2a) and "Follow the noise".

3) Humanoid robots: Using the example of the 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) Mapping and object tracking: This experiment station dealt with the topics of mapping and object detection using the Pioneer 3 robot with a SICK laser scanner and a Microsoft Kinect camera (Figure 2d). The tasks for the children were formulated as follows: "Supporting the rescue robot" and "Playing football with a real robot"
V. PRELIMINARY EVALUATION AND RESULTS

This section describes the methodology used and results of the evaluation of the robotics course "Robots for Kids". Subsequently the outcome and preliminary qualitative evaluation results of the cross-generational kindergarten robotics project day will be presented.

A. "Robots for Kids": Evaluation methodology and results

Both the test group as well as the control group have been pre- and post-tested. The pre-tests took place in March and April 2012 with a time gap of one week minimum before the training started and the duration was announced with about 50 minutes (with a break after the first 20 minutes) for each participant.

To operationalize the second hypothesis a mixed design analysis with repeated measurements was chosen. Independent variables are the variables of the test- and control group as well as the two time measurements of the pre- and post-test. The dependent variables have been constituted by the performances of the children at the tests to determine the executive functions.

For the pre-test and post-test, following psychological instruments have been chosen:

- Kaufmann Assessment battery for Child [18]: displays the intelligence level and the language skills of the children. This instrument was just used for the pre-test.
- Dimension change card sorting test [29]: determines the shifting (cognitive flexibility), which means to display if the children are able to apply to newly learned rules.
- Day-Night-Stroop [8]: measures the inhibition respectively the endurance and the ability to concentrate over a certain period of time.
- Truck Load [4]: used to work out if the participants are able to plan their next steps (pushing the right button of the Bee-Bot).

After the six-week training the post-tests have been executed from May to June 2012. These have been conducted by other students of the Faculty of Psychology to avoid an influenced testing effect and the duration was 20 minutes.

The outcome of the evaluation of the robotics workshop for kindergarten children can be summarized as followed.

Regarding the performance of the test-group it could be figured out that there have been improvements in the area of planning and cognitive flexibility, but these have not been significant. However, the efforts concerning inhibition were significant. As a result it can be stated that the performance of the children who attended the robot course has been improved in the field of endurance and the ability to concentrate over a certain period of time.

On the contrary it could not be proved that performance after the training in the test group is significantly better than in the control group. The improvements have been nearly equally. Nevertheless this could be affiliated by a learning effect caused by the use of the same testing instruments at the pre- and post-test.

The third hypothesis can be proved right; there is a statistical connection between the three variables. This implicates that they can be matched with the construct of executive functions. An improvement in one of the areas (inhibition, planning, or cognitive flexibility) could therefore lead to an improvement in one of the others as well.

Concerning the demographic factors, simply the level of education of the participant’s parents had a significant effect on the different performances (of the test group in comparison to the control group) at the pre-test in the field of planning.

Summing up, the results do not show statistically significant improvements (despite the field of inhibition). Reasons for that could be affiliated by the used tests. It is possible that the tests have not been sensible enough to show the changes of the executive functions caused by the robotic training [28].

B. Kindergarten robotics day: Outcome and preliminary results

Respecting pedagogical and didactic aspects the first cross-generational robotics day was conducted. In sum twenty-five kindergarten children, divided into groups of three, and 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 afterwards by guiding and explaining the experiments to kindergarten children. On the other hand kindergarten children had the opportunity to

Fig. 2. Kindergarten children and pupils together carrying out hands-on robotics experiments
learn and gather practical experiences together with pupils and senior citizens. 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 [14], [12].

During the robotics day pictures were taken and experiments were videotaped to gather qualitative data. 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, findings will be published and discussed at a later date.

Right after the robotics day qualitative feedback from kindergarten pedagogues, grandparents, parents and children was obtained. This 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 psychologist noticed a significant improvement of it’s behaviour. Kindergarten pedagogues reported that children were very enthusiastic about their first robotics-experience and still, almost half a year later, asking when the robots will return.

Science and technology develop rapidly. In order to prepare children it is important to familiarize them already in kindergarten with science and technology in a playful way. As first comments and qualitative feedback from the robotics day indicate, using robots as pedagogical tools could be one way to achieve this goal.

VI. CONCLUSIONS AND FUTURE WORK

In this paper two concepts of integrating robotics in kindergartens in Austria have been presented. Furthermore, quantitative results of an evaluation of a robotics workshop for kindergarten children as well as preliminary qualitative evaluation results of a cross-generational kindergarten robotics day have been discussed.

A future evaluation project will use different psychological instruments for pre- and post-testing while evaluating a robotics course in order to avoid learning effects. Moreover, other tests, which measure the competencies used in robotics training in a more detailed way, could be applied [28]. In addition effects of robotics courses on emotional understandings can possibly be displayed. This is currently being analyzed.

In order to refine and improve the contents of the kindergarten robotics day presented in this paper qualitative interviews with participating children, pupils and teachers will be conducted. Based on the findings of those interviews and the lessons learned from the first robotics day further project days in different kindergartens in Styria will be organized. In addition a more detailed quantitative and qualitative evaluation on the impact of such robotics days in kindergartens is planned.

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REFERENCES


