Robotics Peer-to-Peer Teaching Summer School Project Involving University Students, Summer Interns and Middle School Students

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Abstract. This paper presents a robotics summer school concept involving teaching methods like peer tutoring and teaching in order to meet the demand of robotics summer courses at the University of Applied Sciences Technikum Wien and benefit from its didactical possibilities.

Keywords: Robotics in education · Curriculum · Summer school · STEM · Peer-To-Peer tutoring · Peer teaching

1 Introduction and Motivation

As part of the RoboCupJunior Austria [1] association, the department of Computer Sciences of the University of Applied Sciences (UAS) Technikum Wien is promoting educational robotics and supporting interested schools, teams and students with robotics kits, introductory courses and arenas to test their robots in a tournament environment since 2007 [2]. However, these supporting measures mostly involve schools and depend on the commitment of teachers. In order to also give students the chance to gather experiences and develop their skills in programming and building robots during summer break, the project "Robots for Kids" arose in 2010. This course was established in cooperation with the "Wiener Kinderfreunde" [3] a non-profit organization based out of Vienna that operates 160 kindergartens in Europe and provides afternoon care as well as holiday entertainment and education for children. In 2013 the course was split into a beginner and an advanced course to offer more experienced students the possibility to improve their skills using different programming languages and hardware.

Moreover, in 2012 the department for the first time offered twelve internships for students aged 15 to 19 years in the field of science and technology promoted by the "Austrian Research Agency (FFG)" [4] using robotics as a hands-on method, not only to increase confidence in using technology and to enlarge their knowledge in programming and science but also to help with tutoring the middle school kids of the "Robots for Kids" course.

Therefore, the project "summer school" was established, organizing and managing the different needs of the involved students as well as developing an adequate curriculum for them.

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2 Background and Related Research

Many initiatives offer robotics summer camps and courses for students of different age and educational background [5–7]. However, didactic teaching concepts therefore vary a lot.

One method of transferring the knowledge to younger students is peer teaching or tutoring. In that way students learn from other students who have dealt with the same challenges during their education. Inna Pivkina [8] distinguishes between peer learning assistants (PLAs), who help students learn in the courses that they recently took themselves and teaching assistants (TAs), who are students having graduated in the field they are teaching. Furthermore, it is stated that many students prefer PLAs to TAs or even achieved better results [9–11]. The introduction of "Big Brothers" and the resulting informal class environment can mutually benefit all peers [5].

Another perspective onto the topic delivers "Introductory biology course reform: a tale of two courses" [12], showing that the learning transfer is a two-way process. That means that the transfer of learning can be bidirectional – gained knowledge can be applied at work while new knowledge at the same time can be generated and vice versa. Figure 1 is showing that bidirectional learning transfer.

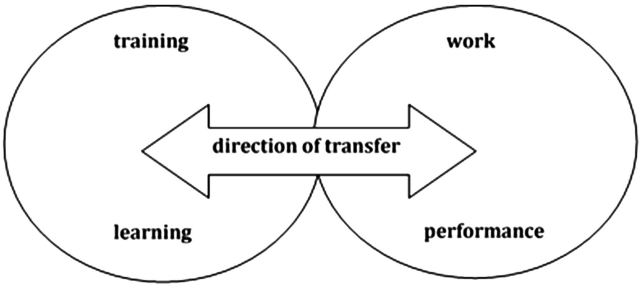

Fig. 1. Bidirectional learning transfer

3 Structure

Regarding this background the idea was to benefit from peer teaching by implementing the following structure, shown in Fig. 2.

Researchers and professors of the UAS transfer their knowledge to university students. Those students hired for the summer school then teach the interns (especially in the first two weeks of the internship, as further explained below) as well as the middle school students attending the "Robots for Kids" course. The interns support teaching the middle school students via peer teaching as mentioned above.

The summer school usually takes places during the long holiday break in the month of August. The interns (high school students) are hired for the whole month, whereas the two week-long courses for the middle school students (one for beginners, the other one for advanced students) are scheduled for the end of the month, generally the last two weeks of August. Experienced university students of the bachelor study program

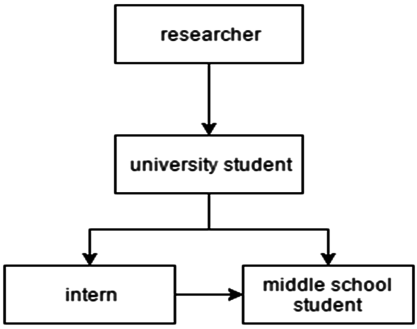

Fig. 2. Implemented teaching transfer

"Computer Science" are hired to train and mentor the interns as well as teach the summer courses.

Figure 2 shows an exemplary timetable containing the recruitment phase of the interns and university students as well as the individual duration time of the summer school courses (Fig. 3).

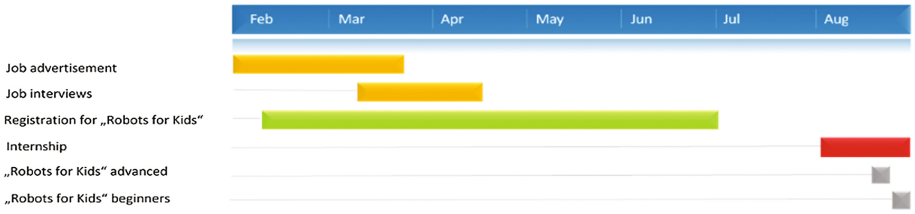

Fig. 3. Summer school timeline

3.1 Interns

The summer internship at the UAS Technikum Wien is a one month paid internship for students aged 15 and up. It consists of an average of two weeks of training for the interns followed by two one-week courses for middle school student. Generally, there are between 8–16 internships available.

Table 1 shows the distribution of internships regarding gender and current school type. Involving high school students attending schools without a technical focus or previous technical education was one of the main goals. This was the departments' choice as to give students interested in the topic who had no previous engagement with robotics or computer science the opportunity to develop their skills and interest in technical professions. Another focus was to hire predominantly female students and to motivate them to apply for technical studies later on.

The hiring process usually starts in February in cooperation with the Austrian Research Agency (FFG). Students can apply via their platform for one or more science related vacant positions. The CVs of the students are forwarded to the institution

Table 1. Demographics internships

Year	Project name	Amount of internships	Male	Female	School type with technical focus	School type without technical focus
2012	ROOT	12	6	6	0	12
2013	RADAR	8	5	3	1	7
2014	SPIRIT	16	9	7	5	11
2015	MAZE	12	4	8	4	8
2016	EXPLORE	15	5	10	4	11

offering the vacancies. Moreover, the job advertisement is also sent to partners of the university in order to reach more interested students. The applications are checked for basic requirements and most students are invited to an interview to give all of them the chance to proclaim their suitability as well as the chance to grow their experience with job interviews.

In order to decide whose motivation for the internship is the highest, following questions, amongst others, are part of the interview:

- Why did you apply for the internship?
- Have you ever heard of RoboCupJunior or any other robotic initiative?
- What do you like to do in your free time?
- Can you name a situation you are specifically proud of?
- Which profession do you want to achieve?
- When you are working in a team, which role do you generally engage?
- What is annoying or despairing you?

The motivation behind the detailed interview for the internship is not to test the students but to highlight their strengths to form a team of interns whose teamwork compatibility is rather high.

3.2 Middle School Students – "Robots for Kids"

Since 2013 there are two courses available – one beginner course at the end of the month and an advanced one, taking place one week before. 25–60 students are attending each course, varying slightly per year. The registration is operated by the "Wiener Kinderfreunde" who are also promoting the course on their website and other platforms.

The students start on Monday morning with an introduction of the organizer, followed by the decision which group they want to join (categorized into the three RoboCupJunior disciplines [13]). The students are guided through the learning process by three university students (one for each discipline) as well as by the interns and supervised by pedagogues provided by the "Wiener Kinderfreunde" during break time.

Table 2 shows the number of students participating at the beginners and advanced course and the gender distribution. The percentage of girls participating at the course is slightly growing over the years due to marketing activities from both the UAS Technikum Wien and the "Wiener Kinderfreunde". Nonetheless, the goal is to increase the number of female students up to at least 30% within the next five years. 2016 only 13

Table 2. Demographics "Robots for Kids"

Year	Beginners course	Advanced course	Male	Female
2012	62	–	58 (94%)	4 (6%)
2013	45	30	69 (92%)	6 (8%)
2014	42	29	60 (85%)	11 (15%)
2015	42	30	63 (87%)	9 (13%)
2016	45	13	48 (83%)	10 (17%)

students took the advanced course due to the distribution of public holidays and the resulting need to reschedule the course more ahead of time.

4 Development of the Curriculum

The main goal of developing the curriculum for the summer school was to create a solid basis of knowledge, followed by practical applications to foster the understanding and at the same time adjust the content in a way that all target groups profit the most.

4.1 Curriculum for Summer Interns

The curriculum of the internship has been iteratively developed over the last 5 years. The "Robots for Kids" summer course existed previously, but in 2012 the decision was made to include interns to support it. This addition made it possible to split up the previous single course into an advanced and a beginner course and significantly refine the course contents while also developing this curriculum to introduce the interns to research and development as well as teaching as practiced at the UAS Technikum Wien.

This curriculum for the summer internship is meant to fulfil two main goals: Firstly, it should prepare the interns adequately for the task they need to perform during the internship. Mainly that includes supporting the teachers by solving minor problems of the students during classes as well as continuous support in finding creative ways to improve their programs and robots. As such the interns need to be both technically capable as well as able to effectively deal with frustrated kids and interpersonal problems.

The second goal of the internship is focused on the interns themselves, providing them with the opportunity to experience research and development in an authentic environment. This includes small and practically focused research projects often dealing with integrating different systems with each other or solving specific problems by using unknown sensors or programming techniques.

In summary, the curriculum aims to prepare the interns for their tasks so that the quality of the courses and therefore the continued existence of this internship is ensured but it is also meant to give interns a suitably thorough insight into both teaching and researching in a professional environment.

The current iteration of the curriculum is structured as follows:

- 2–3 days of basic introduction to programming using a variation of C, heavily interspersed with practical exercises

- 1–2 days each of solving the tasks of the RoboCupJunior Rescue Line and Soccer Leagues, respectively
- 5–6 days of focused research by the interns on their own projects
- 1 day of preparation for the courses including an introduction to tutoring/teaching for the interns
- 2 × 5 days of summer courses given by university students and supported by interns

The specific order and length of those points slightly varies each year based on the abilities and interests of the interns as well as the distribution of holidays.
Specific breakdown:

- Basic introduction to C (2–3 days)

The interns for this internship generally consist of students from schools without a technical focus and little to no experience in programming and robotics. This is a deliberate choice by the organizers further explained in chapter 3.1. As such, this introduction starts from the very beginning and aims to teach the interns both how and why programming works and is very much inspired by the introductory courses given to university students at the UAS Technikum Wien. The goal is to not just teach the basics of a programming language but to also give the interns a deeper understanding of programming as a whole so that they are able to further expand their knowledge on their own.

- RoboCupJunior Rescue Line & Soccer (2 × 1–2 days)

In order to cement the knowledge of the interns, 1–2 days each are spent solving the Rescue Line and Soccer tasks of the RoboCupJunior. The interns work in groups of two mostly independently on the tasks. This provides the opportunity to utilize their knowledge on an unfamiliar task that requires them to both apply their knowledge in a new way on a much more complex problem than their previous exercises as well as introduce the added element of mechanics and robotics to them. For this, the LEGO MINDSTORMS NXT and EV3 sets are used to simplify the construction process so that the interns can focus on solving their problem with generally familiar LEGO Technic hardware rather than having to learn yet another new skill.

Furthermore, this part of the internship functions as a valuable evaluation opportunity for the interns. While they are working in their own groups, cooperating and competing with other teams and experiencing their first major successes, frustrations and failures, the teachers can gain insight into their abilities both pertaining to technical problem solving as well as interpersonal mediation. These observations are later used to find ideal research projects for the interns as well as utilize them optimally during the courses.

- Research Projects (5–6 days)

The research projects are a main focus of the internship and as such there is significant effort put into their viability to provide an enjoyable and enlightening experience for the interns as well as potential benefit for the UAS Technikum Wien. In the current version of the curriculum the interns get a full introduction to scientific work comparable to that of a university student and spend generally 1–2 days

evaluating various topics assisted by the teachers. Typical projects include evaluating the viability of sensors or programming techniques for specific applications, developing integrations for technology into other systems or creating and evaluation solutions for common robotics problems.

The project is chosen in such a way as to provide the interns with both a reasonable challenge as well as a satisfying result. Generally, every intern will have their own project, however, sometimes more complex projects will be worked on by two intern each focusing on different aspects in their work. The research process itself is mostly based on experimentation. Seeking out literature and establishing comparisons is encouraged but due to the limited time available and the relative inexperience of the interns this is usually only a minor part of their work.

Organizationally, the main parts of the research project are completed in the week preceding the two week-long summer courses, however, because there are frequent and lengthy pauses for the younger students, the interns also have the opportunity to do work on their paper during those pauses and after the students leave. The research projects are concluded by a presentation at the end of the internship, based on a bachelor thesis presentation. There, the interns must present their work within 5 min following standard university guidelines after which the course teachers as well as members of the university staff ask them questions about the specifics of their work as well as closely related projects.

- Preparations for "Robots for Kids"

The last part before the summer courses includes both physical preparations of rooms, robots and workplaces as well as an introduction to tutoring/teaching and several other important aspects and previous experiences useful for working with kids. Since each group in the summer course is led by only on university student, the interns capability to support him/her is of paramount importance. (See Sect. 5.1 "Educational Aspects" for more details).

4.2 Curriculum for Middle School Students ("Robots for Kids")

The summer courses consist of two one-week courses organized in cooperation with the "Wiener Kinderfreunde".

Of the two courses, one is meant for beginners using the graphical programming interface from LEGO for their LEGO MINDSTORM NXT and EV3 robots while the other is an advanced course dealing with the same topics and using the same robotics but programming with the same C-like language used by the interns. The advanced course is taking place before the beginner course to avoid kids coming to both courses. While kids that visited beginner courses in previous years could use their experience to improve their programs and robots, taking part in both of them in succession could be negatively impacting the enjoyment of their peers and themselves because both courses deal with very similar topics.

Both courses are based on disciplines of the RoboCupJunior. Specifically, those disciplines are OnStage, Rescue Line and Soccer Light Weight League. At the start of each course and after a short introduction show of those three disciplines the children will be asked which one they prefer and divided into up to three groups each dealing

with one discipline. When interest in one league is disproportionally high, the group for the respective discipline will be split in half the kids interested in the least popular discipline in that course will be asked to move to other groups. Offering those disciplines in the courses provides natural advantages because the RoboCupJunior is already a focus of the UAS Technikum Wien which means that capable experts are available to teach those courses and the participants are introduced to the RoboCupJunior which might be a way for them to continue their engagement with robotics and programming. It also adds an incentive to return to the advanced course and apply their knowledge to another discipline.

The courses are structured similar to the internship itself beginning with a slightly simplified introduction to programming on the first day followed by more advanced exercises introducing the goals and requirements of the respective discipline. On the third and fourth day, the kids work mostly on their own, usually starting with the construction of their own robots and then beginning to rewrite the programs of their previous exercises. Depending on the progress and motivation of the students the fourth day can also include a short preliminary competition to show the children the remaining flaws in their programs and robots. Finally, the fifth day is concluded by a competition amongst the members of a group. Parents and friends of the students are encouraged to attend to give the students an opportunity to present their achievements as well as provide an additional level of motivation for them to build and program the best robots.

During the course the children work in groups of 2–3 on their robots. The courses are taught by one teacher each supported by the interns. Interns are each assigned 2–3 groups of students and are responsible for solving minor problems so the teacher can concentrate on the group as a whole. In addition, they provide an always present personal contact for their groups and can both help them with problems in construction and programming as well as continually encourage and morally support them.

5 Experiences

Since the internship was organized and lead largely by the same personnel, a significant amount of improvements in various aspects could be made, based on the experiences of the previous years.

5.1 Educational Aspects

In the current iteration, the internship includes several different educational aspects. The introductions, both to the interns and the students are conducted conventionally but include a large amount of practical exercises to give the opportunity to immediately make use of every new information. Every theoretical unit is also very much focused on explaining why something works the way it does in order to foster a larger understanding of programming and robotics instead of just teaching how to solve specific tasks. Throughout the courses there are also regular comparisons between the tasks at hand and real world applications of sensors and techniques so that the interns and students can develop an understanding of the relevance of their tasks in a professional setting.

In order to strengthen the interns' knowledge and motivate them to expand it on their own, the internship also includes several opportunities for them to teach others. Firstly, after the immediate introduction the interns will be assigned more advanced tasks to research on their own and prepare a short teaching session for the other interns. Those are typically based on what they have previously learned but include new functions or sensors whose specifics they have to research on their own as well as prepare suitable exercises for their fellow interns. They are also encouraged to make their session as interactive as possible and not just deliver a standard presentation.

Secondly, the interns are heavily involved in teaching the "Robots for Kids" courses. While the theoretical part is done by a university student, each of the practical exercises is heavily guided by the interns. Since they have already dealt with similar exercises they can now use those experiences to help the course participants. Knowledge they gain while teaching the kids can be transferred again into their research work.

5.2 Other Aspects

In addition to the mentioned educational aspects and the interns'introduction to research and teaching the internship also includes other elements meant to develop skills and awareness helpful for their future careers.

One part of that is the personal job interview every intern has to complete. During the internship itself, the main interviewer as well as the university students that were present during the interviews will conduct an extensive debriefing about best practices and common mistakes made in job interviews. They also more specifically discuss mistakes made by interns and how to improve their curriculum vitae, application and general demeanor during a job interview.

To foster deeper understanding of teaching, regular public feedback discussions will also be held with the interns during the course of the internship. Those not only serve to inform the teachers on the opinions of the interns but are also meant to give them an opportunity to think about how they would improve the proceedings of the internship.

Consolidating the last two points, a personal, private exit interview will be held with each intern discussing their specific shortcomings and successes both during the job interview and the internship itself.

Lastly, to provide the interns with a tangible proof of their performance, each of them receives a personal employment reference letter, outlining all the strengths they presented during the internship both to help them in obtaining further jobs as well as to be an official statement of all their successes and outstanding achievements for themselves.

Despite the corporate social responsibility of the UAS regarding the offer of extra-curricular activities, one goal is to motivate middle and high school students to start a bachelor study program at the UAS later on. First experiences show that the motivation is high and that students do not fear the contact with technology after participating at a course or completing an internship. Moreover, statistic material delivers that already three participants of the "Robots for Kids" course later on applied for an internship.

Additionally, following data was gained from a survey conducted on interns from 2016, three months after the internship. Nine out of fifteen interns answered the survey.

- 50% now consider a technical job, 10% are sure that they want a technical job and 30% already wanted a technical job before the internship.
- 90% of interns found teaching kids to be helpful for their own retention and 10% very helpful.
- 40% of interns found working with kids improved their social skills a little and 20% found them to be improved very much.
- All interns reported, that the found the job interviews and the subsequent discussions of best practices and problems specific to them to be very helpful for their future.

5.3 Financial Aspects

The salary of the interns is heavily supported by the Austrian Research Promotion Agency (FFG) while the "Robots for Kids" courses are organized in cooperation with the "Wiener Kinderfreunde". Profits from the kids courses go towards paying the two university students responsible for training the interns and teaching the separate groups of the kids courses. In order to support up to three groups of children (divided into the three disciplines of the RoboCupJunior initiative), a third university student or an older, more experienced intern will also be hired for the duration of the courses (last weeks of August). Regarding available financial resources of the UAS the summer school itself is quite cost saving.

6 Conclusion and Future Work

In its current form the internship and the summer courses harmonize very well with each other, providing both support and benefit to each other as well as being important in their own right. The internship has the major advantage of being fully financed by itself which ensures it continued existence and has growing retention rates both in terms of returning kids as well as interns that return to the UAS Technikum Wien for other jobs, further engagement with robotics in their spare time or to study robotics or computer science.

In order to continue development in this sector the work of the authors, current plans include founding a robotics club in cooperation with the UAS Technikum Wien to further support both the course participants and the interns' interest and engagement with robotics throughout the year. This includes workshops for specific topics and supervised access to materials such as robots, computer equipment, 3D printers, personal programming and electronics support. This robotics club will be a program to support the already existing activities such as the RoboCupJunior Austrian Open competition and the UAS Technikum Wien's engagement in various schools in Vienna with introduction courses and classroom support for new robotics and computer science classes.

Lastly, to further improve the effectiveness and knowledge gained, an expansion of long terms studies regarding the impact of these activities on student numbers, gender distribution and general interest in robotics and STEM subjects will be made starting this year. A constant evaluation and improvement cycle is the main reason this program has progressed to such a successful state will be a main staple in all future developments.

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