PROGRAMMING IN PRIMARY SCHOOLS -CHALLENGES AND OPPORTUNITIES

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PROGRAMMING IN PRIMARY SCHOOLS – CHALLENGES AND OPPORTUNITIES

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Abstract

The purpose of this paper is to describe and analyze a course with programmable robots in order to evaluate challenges and opportunities of robotics in primary education and to identify factors for an introduction of playful programming and a successful implementation to computer science education at primary schools.

Created with the aim of fostering problem-solving thinking skills and integrating digital education at primary level, a technical equipment, including a set of Beebots, Lego Wedo 2.0 and iPads, was given to 13 primary schools, last school year. Target group of the course were students of the third and fourth level. The methodological structure of this course leads from the haptic level of the practical and integrated use of robotics to the level of digital abstraction. The course was conducted in Lower Austria, following a nationwide pilot project.

At the end of the project, a survey was conducted among representatives of the participating schools in order to obtain feedback on the skills achieved and to gain insights into opportunities and obstacles in the implementation of coding and robotics to promote problem-solving oriented thinking.

Keywords: primary school, computational thinking, computer science education, robotics.

1 INTRODUCTION

Meanwhile educational robots are increasingly seen as a useful tool for developing cognitive skills, including computational thinking (CT), for students of all ages. It is important to note that in the 21st century, computational thinking will be a basic skill needed by all individuals and should therefore be encouraged in the early years of school, primarily to foster problem solving thinking skills and 21st century skills like creativity and critical thinking [13]. Using educational robots can be an effective way to introduce computational thinking because students are able to systematically complete tasks and develop the sequenced step-by-step coding commands required to program a robot [7]. Due to their haptic access, programmable robots are very suitable to introduce programming in a playful way in primary schools.

With regard to contemporary teaching and learning, it is important to mention the 4C model, which defines learning and innovation skills. The four Cs, critical thinking, creativity, communication and collaboration, are by far the most popular skills of the 21st century. They represent one of four dimensions in the concept of educational goals and educational content [14]. Creativity is perhaps the most important skill that students need to learn for the 21st century. It is necessary to develop innovative solutions to the many challenges of the 21st century [10]. Anwar et al. [2] concluded in their systematic review of studies on educational robotics, comparing numerous studies, that the use of educational robots among other benefits can contribute to promote 21st century skills such as creativity and increase students' motivation.

In Austrian's education system, programming as a part of computer science is comparatively poorly spread. A comprehensive, mandatory teaching content is not yet available in the mandatory school system, in some schools it is implemented as a school-autonomous focus [5]. However, it is planned that digital skills and in particular the concept of informatics education will be anchored in the future primary school curriculum, with a focus on media education and reflective use of the Internet as well as playful access to technology and problem-solving [6].

This research aims to describe the results of an intervention through educational robotics to promote computational thinking and 21st century skills of students and to consider why computational thinking should be anchored in the future curriculum of primary schools and which factors will be important in its implementation.

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2 COMPUTATIONAL THINKING AND ROBOTICS

2.1 Computational thinking

Jeannette M. Wing [19] described computational thinking as “involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science”. From her point of view “computational thinking is a fundamental skill for everyone, not just for computer scientists” and it “is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” [20]. Algorithmic thinking is the basis for understanding and solving complex problems from school and everyday life and paves the way for the development of one's own creative power (Making). Combined with playful methods (Game Based Learning), high motivation and lasting learning success can be achieved for girls and boys alike and basic digital education can be strengthened in the transition to secondary school [12]. Overall, “technology curriculum in primary schools can play a significant part in supporting students to develop technology literacy, but also literacy capabilities more broadly configured” [8].

2.2 Educational robotics

“One of the emerging resources to develop problem-solving thinking skills, as well as students' own digital competence is educational robotics. A robot is a tangible object, with which you can interact with the environment through programmed instructions, as a tool for the development of cognitive skills, through play, creativity or the resolution of challenges” [9]. Furthermore Benitti [3] summarizes that “educational robotics have an enormous potential as a learning tool, including supporting the teaching of subjects that are not closely related to the Robotics field.” In terms of primary school education, it is relevant that learning by doing and inquiry-based learning is transferable to computer science content [15]. Educational robotics can be an effective way to introduce computational thinking as students are able to systematically complete tasks and develop the sequenced step-by-step coding commands required to program a robot [7]. There are several approaches to the legitimation of learning with digital media and via digital media, which have already been dealt with in detail. Diversity of methods, interaction, working world, living world and reflection on action are five approaches to legitimizing the use of digital media and implementation of educational robotics in education [5]. Modern, competence-oriented teaching, especially at primary level, should aim to promote motivation, problem-solving skills and especially creativity. Futschek [11] argues that is also essential to emphasize that Computational Thinking can be learned and taught at all ages, from kindergarten to matriculation and of course beyond. Weigend [17] also states that children from the third grade onwards have no problems understanding and using the basic elements of a programming language for controlling activity flows and naming entities. Bers et al. [4] describe that easy-to-use visual programming tools and the use of robots are already suitable for small children to support their development of coding and computational thinking skills. As a result of digital change, lifelong learning will become a natural part of this. People have to learn to filter out useful information from a lot of collected information. To do this, they must be able to identify problems and then solve them [18]. It is important that programming in the classroom is designed in such a way that it actually promotes children's creativity, that algorithmic thinking is encouraged and that one does not stick to reconstruction and deconstruction of existing content [5]. Furthermore, for the primary level in particular, it is advantageous if informatics skills are also used in non-informatics contexts where computational thinking is the focus. Examples are the structured decomposition of problems or the creative modeling of problem solutions.

2.3 Beebots and Lego Wedo 2.0

Two examples to introduce coding and robotics in primary school are Beebots and Lego Wedo 2.0, because they are especially suitable for 6-10-year old children by promoting haptics and introducing them to informatics thinking.

A Beebot is a very simple floor robot that represents a bee without wings (Fig. 1). It is programmed by seven buttons on the back. The programming is done with the key forwards, backwards, left turn, right turn, pause and delete. The program sequence is not started until the GO key is pressed. This means that the steps to the destination must be planned in advance. Nevertheless, its easy handling and the fact that it makes programming literally tangible for children makes the Beebot particularly suitable for encouraging problem-solving thinking [16].

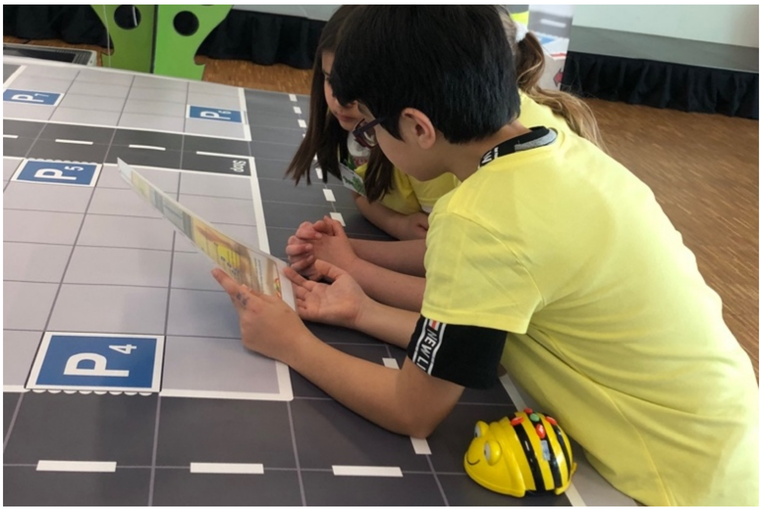

Figure 1 Beebot.

The Lego Education WeDo 2.0 Set (Fig. 2) is a Lego construction kit that was developed for use with students in the overall teaching of primary school with a focus on computational thinking. It is controlled via smartphone or tablet. There are numerous variation possibilities to assemble robot models and program them with a visual programming language. Due to the different focuses in the corresponding app, many topics, which are mainly found in science subjects in the classroom, can be explored.

Figure 2 Lego Wedo 2.0.

2.4 Project description

The Coding project which is called “Denken lernen – Probleme lösen” (Learn to think and solve problems) was carried out as a pilot project in 2017/18 and subsequently continued in various states. The project is intended as a first measure of the digitization strategy of School 4.0 in primary school.

Created with the aim of fostering problem-solving thinking skills and integrating digital education at primary level, a technical equipment, including a set of Beebots, Lego Wedo 2.0 and iPads, was given to 13 primary schools in Lower Austria, in the last two school years. The methodological structure of this course leads from the haptic level of the practical and integrated use of robotics to the level of digital abstraction. The main objective of the project was to promote computational thinking at primary school and to provide an interdisciplinary approach to coding and robotics.

Target group of the course were students of the third and fourth level. Each class had the equipment to work with for six to seven weeks depending on the schedule.

3 METHODOLOGY

3.1 The Study

The study is based on a comprehensive research of thematically relevant empirical studies and empirically founded theories which leads to the following research question:

To what extent can challenges and opportunities be identified in the introduction of playful programming with programmable robots and which factors should be taken into account during implementation of coding and robotics to promote problem-solving oriented thinking?

The study was conducted in June 2020. 13 schools participated in this coding and robotics- project in Lower Austria in the school year 2019/20. One representative from each school was asked to participate in the survey. Due to school closures and the special conditions because of the Covid-19 restrictions, it was decided to conduct a written survey.

9 teachers from these 13 schools answered the questionnaire. 7 female and 1 male primary school teacher and one person did not give any information about the gender took part in the survey. In order to keep the scope and thus the processing time of the online survey as low as possible, some constructs were recorded with only one item. In many cases, the five-level Likert scale ("strongly agree", "strongly disagree") was chosen as the answer format.

The questionnaire consisted of 8 closed and 8 open questions. Due to Covid-19 not all schools had the possibility to carry out the project this school year again, so they reported about the experiences of the previous school year in which they had already participated.

3.2 Limitation of the study

Since participation in the study was optional and the questionnaire was answered by teachers who voluntarily participated in the coding project, it can be assumed that the survey was probably filled out by people who have a positive attitude towards digital media and educational robotics. In addition, it is only a small sample of teachers who participated in the survey and therefore the answers cannot be generalized.

4 RESULTS

4.1 Educational Robotics as an interdisciplinary-educational tool

At this item, the question of how the robots were used in an interdisciplinary approach (Fig. 3) during the treatment was examined.

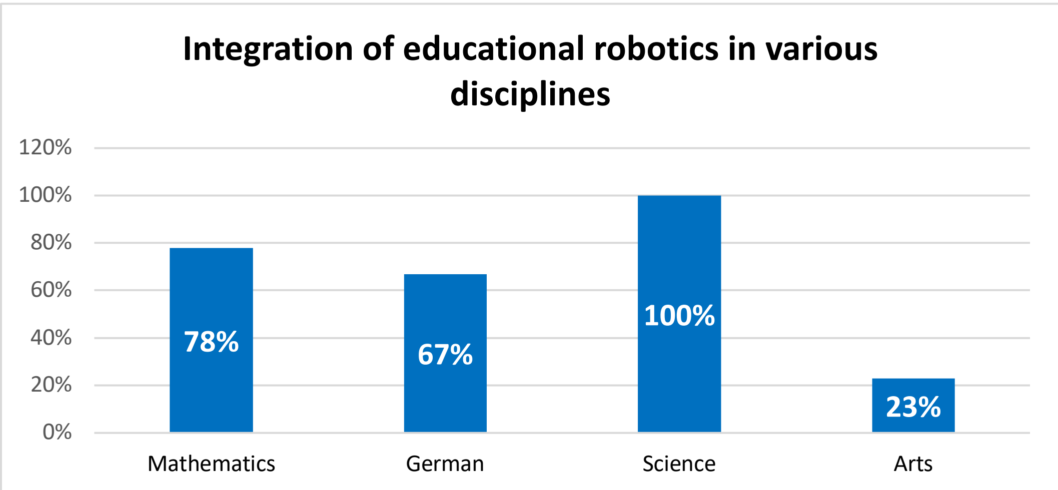

Figure 3 Robots integration.

All respondents mentioned that they used the robots in Science. 78 % of the respondents used them in mathematics lessons and the integration of robotics in the subject German was also mentioned quite often (67 %). But robots were also used in Arts (23 %).

4.2 Students' competences

The participants of the project were asked to what extent they perceived that competences such as communication, critical thinking, collaboration, creativity and problem-solving skills could be promoted by working with tangible robots (Fig. 4). The respondents agreed with the research that these 21st century skills can be fostered in primary school with robotics. 88,78 % of the respondents strongly agree that *collaboration* and *problem-solving thinking skills* are most promoted. 77,78 % participants of the project strongly agree that *creativity* and *communication* are also fostered by using educational robotics.

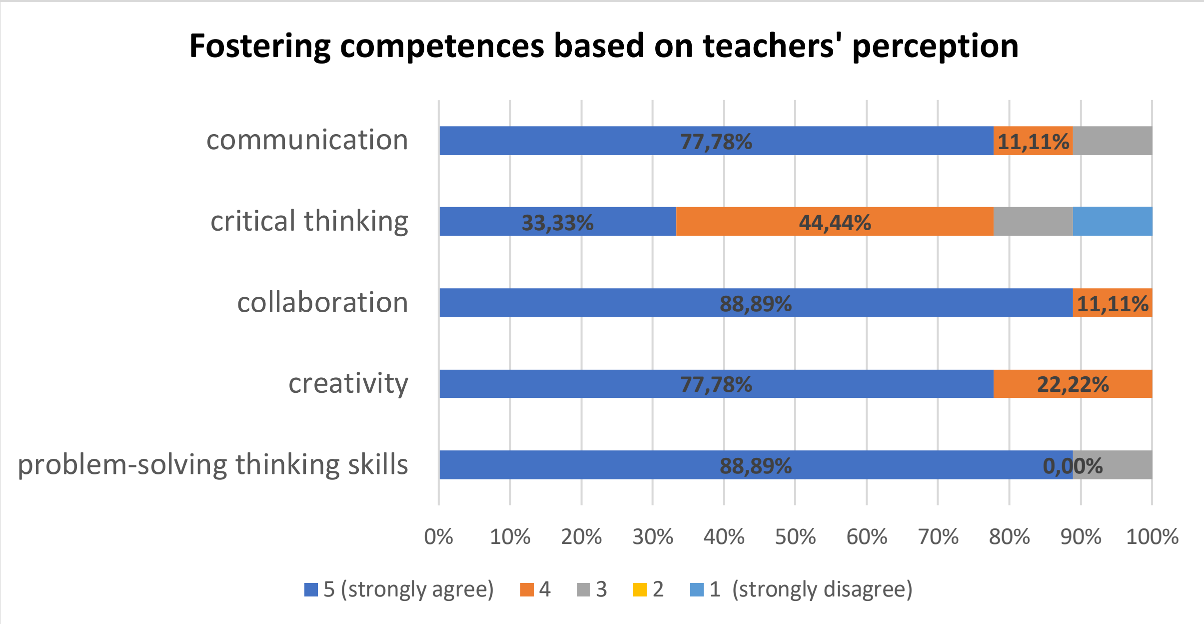

Figure 4 Students' competences.

In addition, the participants were asked in an open-ended question, which further competencies are promoted by the use of educational robots. The respondents named the following competencies that they believe are promoted by using educational robots:

- abstract thinking
- anticipatory thinking
- endurance
- networked thinking
- planning
- precise formulation
- spatial thinking
- strategic thinking

4.3 Implementation of coding and robotics

The item "*Implementation of coding and robotics"* asked whether respondents thought that coding and robotics and computational thinking should be anchored in the future primary school curriculum (Fig. 5).

Most of the respondents (89 %) agreed that computational thinking including coding and robotics should be a part of the future primary school curriculum.

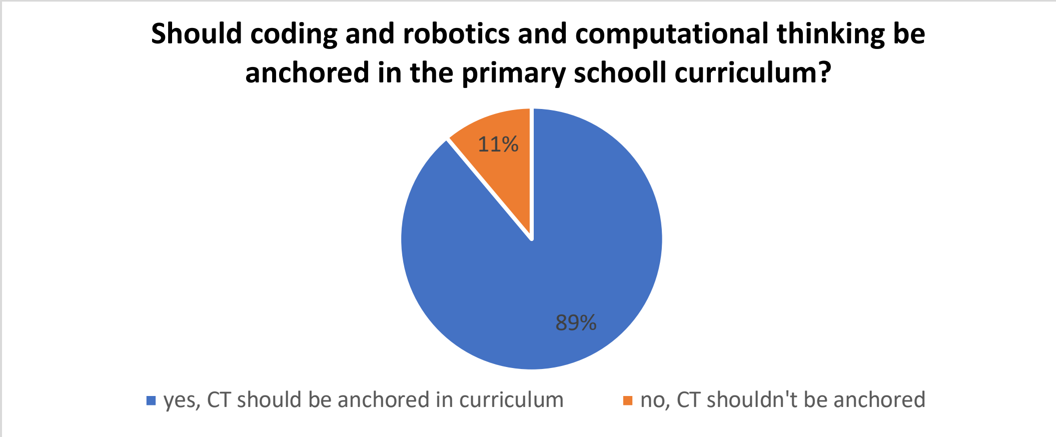

Figure 5 CT implementation in curriculum.

The participants of the project were also asked whether they could imagine that they would be interested in deepening the topic of coding and robotics in class. All respondents welcomed a deepening of the topic. The reasons given were that the topic is motivating and exciting for the students. It also promotes many skills and because this area is important for the future and the children's interest in technology. It was also mentioned that the basic knowledge acquired should definitely be deepened so that problem-solving thinking is encouraged even more.

4.4 Important factors for the implementation of coding and robotics

In Fig. 6 the important factors of implementing coding are rated by the participants of the project.

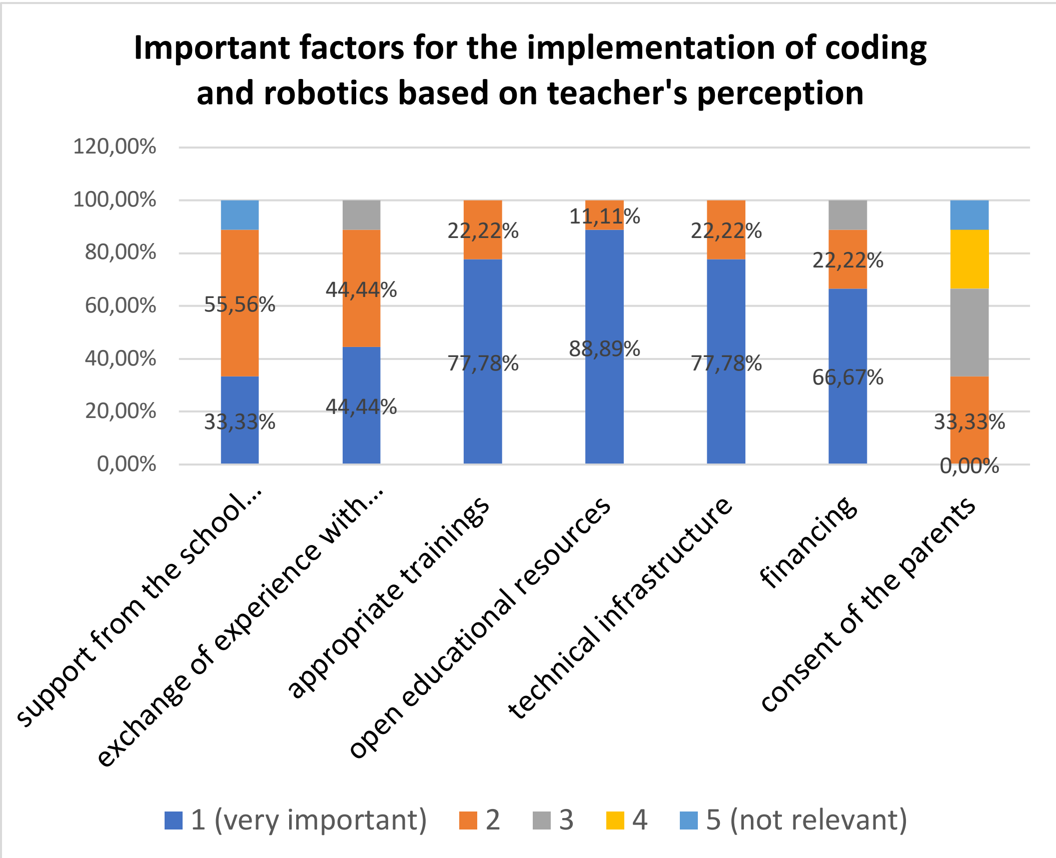

Figure 6 Important factors for the implementation.

Respondents identified the providing of materials (88.89%) for classroom support, appropriate training (77.78%) and the provision of technical infrastructure (77.78%) as very important factors (Fig. 6). It does not seem very important to the respondents that parents also agree with their efforts.

The answers in the open question were similar. Teachers considered these factors to be conducive to successful implementation:

- interest of the teacher
- additional time resources
- well equipped with IT
- interest/approval of the school supervisor
- corresponding material available
- anchoring in the curriculum
- digital literacy of teachers

These factors were perceived as obstacles to a successful implementation:

- lack of equipment/deficient infrastructure
- lack of time resources
- disinterest of many teachers
- lack of financial resources
- too many children in the class/too little space
- no appropriate education/training of teachers

5 CONCLUSION

The findings of the project are that teachers agree that the introduction of coding and robotics with the help of tangible robots contributes to the development of skills such as creativity, communication and problem-solving ability. There is a clear tendency that coding and robotics and thus the introduction of CT in primary schools is desired and can only be achieved if it is anchored in the curriculum. Due to the mentioned interdisciplinary use of robots in the individual subjects, it can be clearly seen that tangible robots are very suitable to be integrated into primary school lessons due to their haptic access.

However, a successful introduction cannot take place without clarifying the most important factors. The most important factors would be an appropriate training program, suitable technical infrastructure and clarification of financing. The fact that coding and robotics are not yet widely used in primary school depends on various factors, such as a lack of financial resources, too many children in a class and, at present, the disinterest of some teachers.

In order to enable teachers to tackle the challenges of computer science education in a meaningful way, it is therefore necessary to offer high-quality continuing education for teachers and to provide technical infrastructure and free materials.

However, since a future implementation of CT in the primary school curriculum is planned, it can be assumed and desired that educational robots will be more common in the classrooms in the future.

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