First steps into STEM for young pupils through informal workshops

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Abstract— **In this work in progress paper we present an example of innovative practice in organizing informal STEM education workshops with young children. The workshops were divided into two learning scenarios, unplugged programming and hands-on robot play. Unplugged programming encourages understanding of the core concepts of programming such as algorithms and computational thinking rather than focusing on the programming language. In the second learning scenario, pupils were introduced to two educational robots used as a learning tool - Thymio and Codey Rocky. The aim of the second activity was linking the programming concept to a real-world scenario. Qualitative and quantitative data were collected using pre- and post- questionnaires. The pre-questionnaires contained questions about the pupils' background knowledge, i.e. basic concepts of programming and robotics. The post-questionnaires were designed to evaluate the workshops impact on the pupils' perception of these observed concepts and their overall satisfaction with the workshops. Combining unplugged activities with robots helps bridging the gap between imagination and reality, therefore improving learning.**

Keywords— unplugged programming, algorithms, educational robots, Thymio, Codey Rocky, human-robot interaction, STEM skills, kindergarten, K-12

I. Introduction

As part of the regular science outreach activities at the University of Zagreb Faculty of Electrical Engineering and Computing, different STEM (Science, Technology, Engineering and Mathematics) educational workshops and guided visits to the faculty laboratories are organized [1]. Each visit typically consists of lab presentations and two 45-minute workshops in which children are introduced to different areas of computer science (CS) and electrical engineering, at a level suitable to their age and prior knowledge. In our previous work we discussed the importance and reasoning for using game-like and unplugged coding activities at some of the events we organized [2], and since they were well accepted, a decision was made to adapt these activities into small educational workshops. Two of these activities, described here, promote computational thinking (CT) [3] through simple unplugged game-like coding activities and puzzles, and then apply acquired knowledge to the controlling of educational robots.

CT is one of the fundamental skills in the CS education, and arguably one of the most important skills of the 21st century [3]. Therefore, one of the key tasks for teachers is to prepare students for such a world and teach them CT from a young age. It is suggested that creating and playing computer games and building robots can enhance CT and problem solving [4][5] as well as improve children's engagement and interest into different learning topics [6]. Also, unplugged CS activities, besides being easy to implement in different settings and with different time constraints, could have significant impact on the students learning motivation and engagement after a relatively short one-time session [7].

Mathematics has a reputation of being hard and for a lot of pupils that has an effect on shaping their opinion and attitude about it [8]. Sometimes we see a transfer of this attitude to CS, as it is often connected to mathematics. Even though CS is still not an obligatory subject in all primary schools in Croatia, most pupils use tablets and computers at home on a daily basis [9]. However, they use them for gaming and rarely for learning programming or for development of CT [10]. In this paper, we examine if one short workshop at the University can change the perceptions of the youngest students about CS, programming and robotics, even if they have not heard those terms before [11]. Once they become familiar with those terms, they can explore them by themselves and think of them as a potential future occupation.

II. Methodology

A. Participants

Target group of the workshop concept presented in this paper are preschool and elementary school pupils. Due to children's playfulness and curiosity at early age, programing concepts can be transparently introduced using educational robots as a tool [12]. Introducing technology novelties early on means confidence with the subject later on and greater adaptability to similar problems [13].

Workshops were held at the University twice, once for 43 kindergarten children (aged six) and secondly for 87 second grade pupils. All of them coming from the same city. Gender distribution can only be observed for the second workshop because qualitative data were not collected for the kindergarten children. In the second workshop, there were 42 boys and 45 girls.

B. Activities

The duration of the workshop was 1 hour and 30 minutes. Half of the time was dedicated to the unplugged programming activity and the other half to the hands-on robotic play.

1. Unplugged programming

Materials needed for the unplugged programming activity were writing tools and graph paper programming worksheets as seen in Fig. 1. The activity is based on similar CS unplugged activities for the youngest pupils [14][15]. To highlight the pupils' creativity through artistic expression and to make the workshop casual, pupils were handed out colorful felt tip pens.

Worksheets were designed to gradually introduce pupils to the concept of programming by changing the complexity of the exercises and the answer delivery method. The goal of each exercise was for the Pacman to eat the fruits. The complexity is determined by the graph paper dimensions and the starting position of Pacman in regard to the fruits and the obstacles. The answer delivery method varies in circling the right pattern of arrows after recognition ("debugging"), writing down the right pattern ("programming") or designing the Pacman environment.

The first two exercises were provided as an introduction to unplugged programming. 3x3 graph papers were used. The pupils were expected to circle one of the four proposed answers to depict Pacmans movement on the grid to reach the fruit. The answers were composed of arrow symbols making it easy for young children, unfamiliar to letters, to understand. The next three exercises (exercises 3, 4 and 5) were designed to examine the pupils' understanding of the concept, by writing down the answer by themselves. In this type of exercise, pupils were stepping from the recognition concept to reproducing the right pattern. Two of the exercises were made more complex by introducing brick walls as obstacles between Pacman and his goal. The last 3x3 graph paper (exercise 6) was left empty for pupils to draw their idea of the Pacman polygon, to exchange graph papers with their friends and solve their polygons.

Further on, the graph paper was enlarged to 6x6. The first exercise at this stage (exercise 7) was to evaluate the answer attached to the Pacman polygon, with true or false. For the following two graph papers (exercises 8 and 9) they were expected to write down the answer by using the minimization method introduced in exercise 7. Multiple arrows in the same direction were represented with a multiplier and a direction arrow.

The tenth exercise was done on the 8x8 empty graph paper where pupils were encouraged to creatively design their own Pacman polygon using obstacles and multiple goal objects. With this exercise pupils were practicing constructing knowledge and could artistically express their idea by drawing and coloring. To provoke more effort in designing a demanding polygon, pupils were asked to challenge the teacher with their polygon. The teacher solved it on the whiteboard, with help of the whole class.

Exercises were solved in pairs to strengthen teamwork concepts such as sharing, respect, expressing opinion etc. (Fig. 1). Working in pairs was also chosen due to the beneficial influence on the overall understanding and task performance [16]. Pupils working in pairs were helping each other to solve the task faster, debate different opinions and evaluate the answers efficiently in real-time.

2. Hands-on robot play

For the second activity of the workshop, hands-on robot play, Thymio [17] and Codey Rocky [18] robots were used. Both robots are intended for children aged 6+ years. The combination was chosen due to the different user interfaces. Codey Rocky was controlled using the Makeblock application on a tablet and Thymio by using the on-robot buttons. Both robots are vehicle shaped. Codey Rocky comes with a display in the form of a cat's head and Thymio has no display but can change its color to show different preprogramed behaviors. The hands-on robot activities were designed to introduce students to a fun practical application of programming, while avoiding the time consuming and higher-level introduction to programming the robots on a computer.

Pupils tested robots' functionalities and how the same functionality, e.g. movement, can be realized by different actions depending on the platform. With this platform combination, we wanted to provoke thinking about programming code, where arrows for Pacman movements could be implemented in various ways in terms of robots control.

In the beginning of the hands-on robot play activity pupils were given only short instructions for Thymio and for Codey Rocky. The instructions for Codey Rocky included how to connect the robot to the tablet and how to drive. Pupils had to discover all other functionalities by themselves. Additionally, they could change the robot display in a creative way using the interface on the tablet (Fig. 2). The instructions for Thymio included how to turn on the robot and how to choose and start the preprogramed behaviors.

Thymio has six preprogramed behaviors described by different colors and moods [17]. To be more challenging and motivating for the pupils, they had to find out which color of the robot denotes which behavior. As a help, they got printed worksheets with descriptions of the behaviors (Fig. 3). The worksheet consisted of six Thymio robots in different colors (pink, blue, green, yellow, dark blue, red) and short description of the preprogrammed behaviors under each listed mood. The pupils needed to connect the behavior with the color. Pupils used arrow buttons to navigate between the programs and the central round button to start or stop the program. Although each pupil had its own robot, most of them worked together and showed each other which behavior they discovered.

To motivate kindergarten children to engage with Codey Rocky more actively, a robot race was performed. In this game, pupils were lined up against one wall which was also the starting point for the robots. The goal was to deliver a package to the opposite wall as soon as possible. Aside from showing competitive spirit, in order to be successful in this race, pupils should show calmness, patience, fine motoric skills and intelligence. There were two approaches for driving Codey Rocky straight ahead. First option was using the turbo button that has a short timeout between button uses. Second option was continuously having the up arrow on the wheel pressed with the risk of losing a package if a wheel position was shortly misaligned from the straight direction causing the robot to turn aside. In this case, speed was controlled by dragging the wheel circle towards the outer circle. Another choice pupils had was placement of the package in front of the robot, with a longer or shorter side propped on the robot.

C. Data acquisition

Data acquisition was performed by using pre- and post-questionnaires (Fig. 4, Table 1.) and the unplugged programing worksheets (Fig. 1). By combining these two source types, it is possible to make a declarative knowledge assessment (with questions such as „what is programing?“) and procedural knowledge assessment (with unplugged programming worksheets). The questions in the questionnaires were adjusted to the age of the pupils and were created to measure possible changes in the perception of the pupils about programming and robotics before and after the workshop.

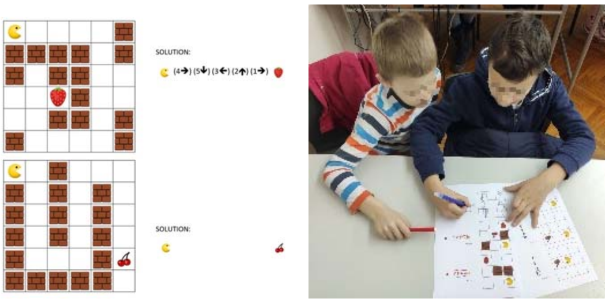

Fig. 1. Left: unplugged programing worksheets, right: pupils work in pairs.

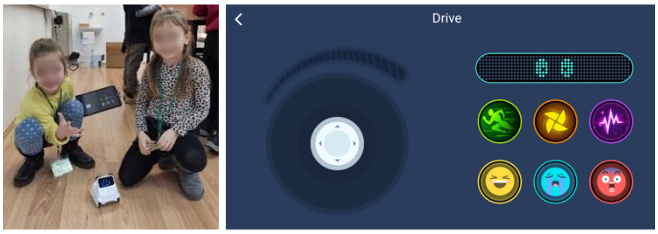

Fig. 2. Left: pupils control the Codey Rocky, right: Codey Rocky Makeblock application screenshot.

Fig. 3. Left: pupils control the Thymio, right: part of the worksheet with described preprogramed behaviors of the Thymio.

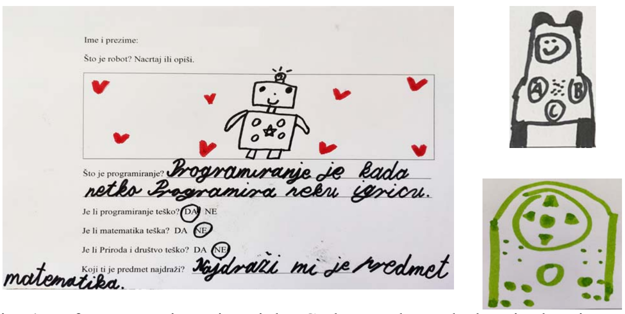

Fig. 4. Left: prequestionnaire, right: Codey Rocky and Thymio drawings of the pupils from postquestionnaire.

TABLE 1. PRE- AND POST- QUESTIONNAIRE.

	PRE-QUESTIONNAIRE	POST-QUESTIONNAIRE
1.	What is a robot? Draw or describe.	
2.	What is programming?	
3.	Is programming hard? YES/NO	
4.	Is Math hard? YES/NO	Grade unplugged programing workshop: 1 2 3 4 5
5.	Is Social studies hard? YES/NO	Grade Thymio: 1 2 3 4 5
6.	What is your favorite subject?	Grade Codey Rocky: 1 2 3 4 5
7.	/	Who is better (circle): Thymio Codey Rocky

III. RESULTS AND DISCUSSION

A. Unplugged programming worksheets

The unplugged programming exercises are described in Section II and percentages of correct answers are given in Table 2. The answers for each exercise were graded and analyzed. Analysis of the results for the sixth, seventh and tenth question is omitted, because they cannot be answered with a single correct answer or because they were solved with help from the teacher. The first two introductory exercises were solved correctly by all pupils. Of the 3x3 graph paper exercises, 63% of the pupils that gave a wrong answer in the fourth exercise gave the correct one in the fifth exercise. Fourth and fifth exercise together, are correct in 73% of worksheets. Using the same analogy for the 6x6 graph paper, 35% of the worksheets with a wrong answer to the eight exercise, show a correct ninth exercise. Eight and ninth exercise are correct in 31% of worksheets at the same time. We can see a rise in the wrong answer trend with the rising of exercise complexity and graph paper size. Although the workshop lasted for 45 minutes, most of the pupils successfully solved several exercises and showed understanding of the presented CS concepts.

TABLE 2. CORRECT ANSWERS IN THE UNPLUGGED PROGRAMMING. SIXTH, SEVENTH AND TENTH QUESTION ARE OMMITED

Exercise	1	2	3	4	5	8	9
Graph size	3x3					6x6	
Correct answers, %	100	100	93	86	82	56	47

B. Pre- and post- questionnaire analysis

Second grade pupils filled out questionnaires (Table 1). The answers from the pre- and post- questionnaires were analyzed and compared. The first three questions were the same in both questionnaires. The second group of questions in the pre-questionnaire was regarding the pupils opinion of formal curricula, and the second group of questions in the post-questionnaire was about their opinion of the workshop.

The first question was an open-ended inquiry about the pupil’s perception of robots. The pupils were given freedom in the answer delivery method, they could draw or write the answer. The distributions of the answer delivery methods are shown in Fig. 5. A slight difference can be seen in the pre- and post- questionnaires which could show that after the workshop, the pupils could more easily express their perception of robots by drawing. Drawings analysis from the prequestionnaire showed that 88% of pupils envisioned a robot as a humanoid, only 5% as a vehicle and 4% as an animal. In the postquestionnaire, humanoid robot drawings occurrence dropped to 60%. Total occurrence of vehicle type robots was 35%, showing 30% increase compared to the prequestionnaire perception. Drawing robots as humanoid robots in the prequestionnaire might imply that pupils had no prior encounter with an educational robot as most educational robots are vehicles. Drawing vehicles in the postquestionnaire on the other hand shows change in robot perception.

Our goal with the second question was to see the students understanding of programming before and after the workshop. The answers offered a variety of pupils' thoughts on the meaning of the term programming, e.g. having to do something with computers, robots, games, technology, programs, mathematics, electricity etc. 18% of pupils in the prequestionnaire and 20% in the postquestionnaire stated simply that they do not know the answer or did not answer the question. The data gathered from these pupils were also taken into consideration throughout the analysis.

Pre- and post- questionnaire results regarding the third question were compared to examine the possible change of opinion about the pupils impression of programing difficulty during the workshop. In the prequestionnaire, 59% of the pupils claimed programing is hard while in the postquestionnaire 46%. 83% of the pupils did not change its answer after the workshop. 15% changed the answer from YES to NO, meaning they consider programing no longer hard after the workshop, and 2% changed the answer in the opposite manner. Subject difficulty results might imply that claiming something is hard comes from lack of familiarity with the subject. The drop of the programming subject perception as hard after just one workshop gives a promising result that a view of a subject can be affected by innovative learning scenarios.

The last three questions in the prequestionnaire were about the difficulty of subjects from the students formal education such as Math and Social studies. Answers to the fourth and fifth question showed that 89 % of pupils consider that math is not hard and the same percentage that Social studies is not hard. Only 5% of all pupils consider both subjects hard. The last prequestionnaire question, examined pupils' preference of school subjects. The distribution of answers is given in Fig. 6. Taking into consideration that the pupils mostly liked physical education (Fig. 6.), using innovative practices that include challenges and moving freely, such as using robots as a learning tool for teaching CS, reconciles curricula and playing.

The next three postquestionnaire questions collected quantitative feedback of the workshop activities on a scale of 1 to 5 where 5 is the best grade. The average grade for the unplugged programming activity was 4.95, for the Codey Rocky robot play it was 4.89 and 4.12 for Thymio. The last question asked the pupils' robot preference, and 18% of votes were assigned to Thymio and 82% to Codey Rocky. Observing the grades of the workshop activities implies that pupils like the unplugged activity more than the robot play. The reason might lie in the fact that the design of the learning scenarios is different. First one was guided, and the exercises were short, with finite time to solve each worksheet making it dynamic and engaging. The second activity on the other hand was designed to let pupils explore robots at their own pace and optionally do motivation challenges. Regarding human-robot interaction, Codey Rocky was more accepted by the pupils, what might be due to the controller being a tablet [9].

We made an interesting observation about the first and the last question of the postquestionnaire. The pupils' answers showed a slight discrepancy in drawing the robot and choosing the best robot. 5% of pupils drew Thymio and chose Codey Rocky as a better robot, while 2% drew Codey Rocky and chose Thymio as better.

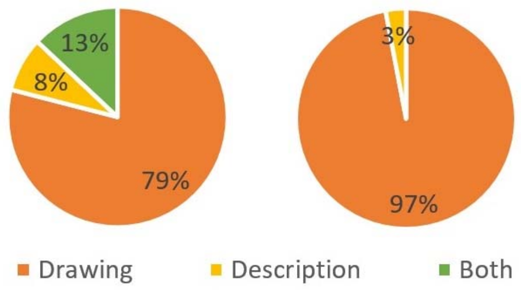

Fig. 5. Answer delivery method distribution: left: pre-questionnaire, right: post- questionnaire.

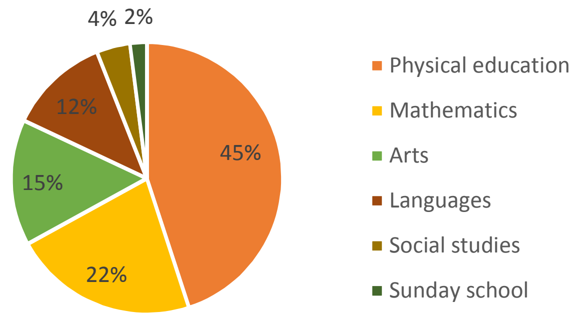

Fig. 6. Favorite subject distribution.

IV. Conclusion and Future Work

In this paper, we have proposed an example of innovative practice in organizing informal STEM workshops with lower grade students. The design of presented workshops can be easily adapted to any environment, formal or informal.

This workshop promotes different skills, like writing and reading skills, mathematics, digital skills (handling a robot) etc. Designing a custom Pacman game board and drawing on the Codey Rocky display include the art aspect in STE(A)M and improves pupils' graphomotor skills by encouraging precision while handling a pencil. Learning by listening is used only to instruct students about the activities and learning by doing concept is mainly used through the whole workshop due to the age of participants.

Our future research in this field will include development of new lessons that will cover more STEM topics and new case studies with more students and different age groups. Future studies should also further explore both theoretical and practical components of these workshops, widening the knowledge base and practical experience of conducting different STEM workshops with young children.

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