Training Primary School Teachers for Coding Robots and Implementing Unplugged Coding Activities

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Abstract

Computational thinking is a problem-solving process, and one of the core skills students develop integratively during their primary education. One of the approaches for developing students' computational thinking is practicing coding activities in class while using educational robots, or unplugged coding activities, if the school lacks in digital equipment. This paper presents the dual training model for in-service teachers on how to use robot coding and unplugged coding activities for developing students' computational thinking in primary education. A total of 327 teachers have actively participated throughout 13 accredited trainings which have been conducted live and online over the past four years. Results show that the participants have effectively developed their own computational thinking skills, as one of the core teachers' digital competences, recognized the importance and possibilities of implementing coding activities in primary school teaching, and are more prepared to integrate topics related to computational thinking in their class.

Keywords

Teacher training, Coding activities, Educational robots, Unplugged coding activities, Primary school teachers

1. Introduction

Computational thinking is a problem-solving process, and one of the core skills children need to develop integratively during the first cycle of their primary education. In her paper, Jeannette M. Wing defined Computational thinking as a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability… Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science. Computational thinking includes a range of mental tools that reflect the breadth of the field of computer science [1]. In order to develop computational thinking with young children, in-service primary school teachers and educators need to be digitally literate at an advanced level, and further improve their own digital competencies through professional development and authorized trainings.

In 2018, for a three-year cycle, the Institute for Improvement of Education in Belgrade as the authorized institution has accredited 58 teacher trainings [2] with the aim of developing and improving digital competences of in-service primary and secondary school teachers and educators. The topics included Internet safety and security, advanced use of professional software, Web tools and digital design, Mobile learning (m-learning), and other similar.

A team of young and enthusiastic in-service primary school teachers with an extensive background in STEAM and robotics in education have gathered in order to create and provide a comprehensive teacher training for in-service teachers on how to use educational robots and unplugged coding activities for developing and improving pupils' computational thinking in the first cycle of primary education.

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They gave it a poetic title: Coding is easy now, everyone can learn how (in Serbian: Programiranje je lako, naučiti ga može svako) [3]. Since Digital literacy and Critical thinking have been listed as skills for the 21st century [4], the team agreed that their training should not be related exclusively on using current digital devices, software or internet tools, but on developing computational thinking, problem-solving, decomposition, pattern recognition, abstraction, algorithm and coding, throughout the entire educational system, integrated within all school subject. Therefore, their training was listed in the domain General teaching topics, and was focused on primary school in-service teachers, teaching in the first educational cycle (children cage 7-10) [3].

2. Educational robots and unplugged teaching activities: The dual training model

The dual training model was developed as an eight-hour course focused on developing and improving digital and teaching competences of in-service primary school teachers through various activities focused on 21st century skills, algorithms, coding, developing computational thinking through interdisciplinary approaches, unplugged coding activities, educational coding games and educational robots [3]. The general objectives of the dual training module for in-service primary school teachers was to increase the teaching efficiency by improving their competence for applying and developing computational thinking in primary school teaching and learning by using educational robots and unplugged teaching activities with an interdisciplinary approach.

Educational robots are created with the aim of solving problem situations in education and teaching. They can be adapted depending on the age, previous knowledge and child interests. Depending on the nature of the primary school teaching subjects and their teaching methodology, educational robots can be customized in appearance, work function, program and other enhancements. There are physical robots and emulators (virtual or software robots), whereas physical robots are more suitable for early robot literacy and the development of computational thinking [5].

The most important characteristics of educational robots are: flexibility (change of form, function); digitization (storage, sharing and analysis of data as well as communication with other devices); repeatability (in robots for training such as foreign language learning); humanization (the robot becomes a motivating partner in learning, encourages curiosity and imagination) and interaction with people (using speech or face recognition) [6]. There are two approaches for developing pupils' computational thinking: practicing coding activities in class while using educational robots, or unplugged coding activities, if the school lacks in digital equipment. Henceforth, the training model needed to be in dual form, covering both aspects.

When implementing coding, there are two types of coding practices: unplugged and plugged-in. Unplugged practices do not feature device involvement, while plugged-in practices make use of digital devices. When introducing coding to young children, it is important to start with concrete representations involving unplugged, hands-on practices that allow children to physically move things around without requiring abstract coding, and to experience play-based digital learning [7].

During the dual training model, in-service primary school teachers and educators were presented with numerous opportunities of implementing computational thinking, coding and robotics in everyday teaching, correlating with many school subject from the first cycle of primary education (such as language, foreign language, mathematics, science, music, art, even physical education). They were introduced to the possibilities of teaching coding for younger primary school children with and without the use of digital technology (unplugged coding activities), and encouraged to (individually, and in groups) interdisciplinary develop computational thinking, as one of the basic skills for life and work in the modern society. Furthermore, by applying computational thinking and coding skills while solving problems, children develop creativity, critical thinking, decision-making, perseverance, communication, teamwork and responsibility in everyday situations.

3. The methodological approach of developing computational thinking

The initial training authorization by the Institute for Improvement of Education in Belgrade was given in the school year 2018/2019. During the three year authorization period, 13 accredited trainings have been conducted in different cities such as Belgrade, Smedrevo, Arilje, and Obrenovac [3], and a total of 327 primary school in-service teachers and educators around Serbia have actively participated in the training, developing and improving their digital skills through computational thinking. Due to the outbreak of the pandemic and the declaration of a state of emergency and the Decision of the Government of Republic of Serbia on the suspension of classes in higher education institutions, secondary and primary schools [8], the training had to be unexpectedly transformed in its hybrid version, and the final five trainings were carried out online, via Microsoft Teams platform. Since the pandemic outbreak forced the majority of institutions to temporarily shut down, the Institute's new authorization cycle was postponed for a year, extending the previous authorization cycle for a total of four years and making all previously authorized trainings for in-service teachers automatically prolonged.

The methodological approach of developing computational thinking for in-service primary school teachers and educators during the dual-training model consisted of 8 methodological stages: (1) 21st century skills, (2) algorithm, (3) developing computational thinking through interdisciplinary approaches, (4) coding, (5) unplugged coding activities, (6) educational coding games (7) educational robots and (8) self-reflection and evaluation.

The average number of participants per training was between 20 and 30 in-service primary school teachers and educators, giving the participants the opportunity to actively participate in discussions, interact within different smaller work groups, as well as to individually explore the prepared training materials and equipment such as educational robots and unplugged teaching activities.

In the first stage, the participants discussed about which skills were considered as necessary for upcoming generations, such as creativity, critical thinking, problem solving, decision-making, perseverance, communication, teamwork, responsibility… and whether today's teachers are adequately preparing children for life in the future. Through an active discussion, the participants shared their views and opinions, and agreed that education we are offering today usually cannot precisely predict the professions, activities, habits or jobs of the future, and therefore the education and improvement must not end when exiting the school.

Then, in the next stage, we established the main terms and terminology such as code, coding and algorithm, giving the in-service primary school teachers and educators practical exercises which can entirely be transferable in children activities, and applicable in primary school classrooms, in accordance with the children's age, complexity of the activity and the specific needs of the teaching subject itself (educational games such as pixel art, follow the code...). The participants searched for examples of coding in everyday lives of primary school children, and concluded that algorithms are all around us, we use them every day, whether when making breakfast, crossing the street, washing our teeth or taking a test. Numerous different educational situations have been designed, everyday situations which can be transformed into an algorithm have been observed, with the conclusion that children often encounter algorithms and can notice them on an intuitive level [5]. Furthermore, by analyzing primary school textbooks, within small workgroups, primary school in-service teachers and educators have gather examples of algorithms in various school subjects.

In stage three, each workgroup was given a lesson from different subjects (e.g. Language: storytelling; Art: pointillism (pixel art), Music: traditional dance; Mathematics: left/right, above/below; Science: reading maps…). Their task was to develop a lesson plan for the given lesson by implementing unplugged coding activities at an intuitive level, meaning children are not aware they are coding, however they are developing their computational thinking through interdisciplinary approaches. The produced plans were shared among groups which formed a creative environment for sharing ideas among participants.

The fourth, plenary, stage focuses attention on the terms related to computer coding such as graphic coding, block coding, loop, bug, debugging, if/then…, where the trainers explained the terms and gave examples, comparing coding types, while in the fifth stage participants were given examples of unplugged coding activities. Though exploring and collaborating within the working groups, in-service

primary school teachers and educators developed and improved their own ideas, examples and task which were presented to other participants and eventually collected in an idea compilation for them to use in their classrooms. The compilation was gathered by the trainers and distributed in a digital form via e-mail to all the participants after the training.

Individually, or in pairs, in stage six participants explored educational coding platforms (code.org and runmarco.allcancode.com) for young learners. Their task was to try and pass as many levels in various educational coding games as they can in a given period of time. Moreover, as they solved their digital tasks, they needed to notice which equipment (computers, tablets, mobile devices, internet access, personal accounts…) they need in their own classrooms in order to implement a similar coding activity, which platform is more suitable for their pupils (depending on children's age, their interests and previous experience, as well as the characteristics of the teaching subject in hand) and to assess whether the children would be more or less successful in similar activities then their teachers. While working on coding platforms, the participants concluded that when coding children develop logical thinking, problem solving, perseverance, cooperation, and communication, which are listed as 21st century skills, and essential for their life.

In the seventh stage, participants were given physical devices, educational robots (Bee-bot and Mouse robot Colby), with a minimal plenary introduction, in order for them to individually research the robot's possibilities and holistically approach the robot's properties and possibilities, based on their personal interest, and teaching styles [5]. After a short individual research of the robot, the participants are given their first task: to program the educational robot to go around a given obstacle and return to the starting position. Although it seemed as a simple task, it turned out to be challenging for the participant. However, the task was successfully solved within an interactive group work.

The designed sequence of steps for the robot movement was then transferred in graphic code. During the code writing process, errors in the code have been observed and corrected (simulating the debugging process). Moreover, the repetition of certain steps within the code (Loops) and the possibility of their compression were observed, in order for the participants to advance their coding competencies, as well as the basic terminology of graphic coding [5].

The primary school in-service teachers and educators then observed the educational potential of working with robots in the classroom: their task was to design educational situations for primary school children at various levels of complexity, depending on the children's age, individual opportunities and interests. An additional inspiration for designing educational situations was the introduction of various specialized mats for the movement of educational robots (such as city plan, school premises, geographical map...).

After introducing several different types of educational robots, a comparative analysis of the technical characteristics and the quality of the device, as well as the complexity of the requirements that different educational robots enable, was made, setting assumptions for the appropriate age and coding experience when working with each of the offered types of educational robots. Additionally, alternative software solutions, emulators of educational robots on computer and mobile platforms, which provide the possibility of developing computational thinking without using educational robots and a good solution in case of lack of financial resources, or individual work at home [5].

During the training, the participants actively researched the given materials and debated within the group, independently found various solutions to given situations, discussed and designed new tasks on multiple levels of complexity depending on the age of children, while the role of the trainers was to ask specific questions and focus on the activity flow within the dual training model. Throughout the self-reflection and evaluation process in the final stage of the training, primary school in-service teachers and educators emphasized that their competencies for the implementation of educational robots were significantly developed and improved while working directly with physical digital devices and adaptation with software alternatives (emulators).

It was pointed out that the individual and work in groups provided permanent and practical knowledge, as well as inspiration for further independent research in their teaching. At the beginning of the training, the participants stated that they were not familiar with educational robots and their possibilities, and by the end of the training they assessed their knowledge and competences at a significantly higher level, as well as the need for the implementation of educational robots in their daily educational practice.

4. The hybrid transformation

Due to the outbreak of the pandemic and the declaration of a state of emergency and the Decision of the Government of Republic of Serbia on the suspension of classes in higher education institutions, secondary and primary schools [8], the training had to be unexpectedly transformed in its hybrid version, and the final five trainings were carried out online, via Microsoft Teams platform. For some teacher trainings the migration to cyberspace was a natural process, especially to narrative type lectures, where the participants were mostly passive listeners. However, a teacher training for coding robots and implementing unplugged coding activities was developed as an active workshop, where the participants were given tasks which included hands-on activities, with its peak through working on physical devices, educational robots.

The trainers had to make difficult decisions when adapting the training activities into their online versions. For example, some group activities, such as analyzing textbooks were transformed into individual, and the result was the lack of interaction and idea exchange among participants. Some group activities, such as creating examples of lesson plans were conducted in breakout rooms during the Teams session. Dividing participants into breakout rooms proved to be a challenging task, since the majority of the participants was not fully aware of the process, however by the end of the training most of them emphasized the breakout room experience as innovative, and certainly a huge development for their digital competences.

The biggest challenge was transforming the activity related to programing physical devices into the hybrid format. The presentation of the robots was conducted frontally, by the trainer, and by watching online video materials. However, the hands-on activity had to come down to working individually using the online emulator (beebot.terrapinlogo.com). The trainers believed this transformation was not sufficient enough, since the object of the activity was to hold physical devices directly. Nevertheless the implementation proved some segments were transferable using the online emulator, and the participants did obtain new experience and developed their digital competences related to computational thinking.

5. Training evaluation

As prescribed, all authorized trainings for the three-year cycle had to be evaluated by every participant at the end of each implemented training, using a standardized evaluation form developed by the Institute for Improvement of Education in Belgrade. The evaluation form was anonymous and it contained 14 questions in the standard 5 point Likert scale. The questions (among those related to age, gender, and education of the training participant) regarded the working conditions during the training, the relation between the expected and executed training time frame, the interaction between the trainers and the participants throughout the training, the overall organization and implementation of the training, whether the expected training outcomes have been achieved, if the participants feel they have improved their competences…

After each implemented training, the evaluation forms have been distributed to the participants, collected after the completion. The overall evaluations of each implemented training have been uploaded to the Institute's database which is available online. The evaluation score for each individual implemented training is given on a scale from one to four, where score one represents the lowest score, and four is the highest score. The Institute's database of the overall evaluations is updated in real time and is available online [3], and the overall evaluations for the dual training model for developing computational thinking with educational robots and unplugged teaching activities are presented in table form. Since the training cycle was unexpectedly transformed into its online version, table 1 illustrates the overall evaluations, after each of the eight live sessions, and table 2 presents the overall evaluations, all five online sessions. At the end of each table, a total number of all the participants is given, as well as the Overall Average Evaluation. Comparing the Overall Average Evaluations between the Live Sessions (3.92 out of 4) and Online Sessions (3.84 out of 4), there is a visible decrease, which might imply that the participants feel that online training sessions cannot fully replace live interactions and discussions within groups, especially when implementing a training which promotes unplugged and hands-on activities using physical devices such as various types of educational robots.

Table 1
The overall evaluations, per Live Session (LS), total of 8

	LS 1	LS 2	LS 3	LS 4	LS 5	LS 6	LS 7	LS 8	Total
Participants	22	26	29	30	22	26	30	29	192
Overall evaluation	3.9	3.97	3.78	3.88	3.89	3.97	3.97	3.97	3.92

Table 2
The overall evaluations, per Online Session (OS), total of 5

	LS 1	LS 2	LS 3	LS 4	LS 5	Total
Participants	20	21	25	24	23	192
Overall evaluation	3.95	3.53	3.81	3.98	3.95	3.84

Although the training was mainly focused on primary school teachers, other educators applied to participate, such as primary school principals, school counselors, librarians, teaching assistants, science teachers, computer science teachers, religion teachers, even physical education teachers. Results show that the participants have effectively developed and improved their own computational thinking skills, as one of the core teachers' digital competences, recognized the importance and possibilities of implementing educational robots and unplugged coding activities in primary school teaching, and are more prepared to integrate various topics related to computational thinking in their classes.

6. Subsequent activities and systematic transformations

During the COVID-19 pandemic, in the 2020/2021 school year, a new teaching subject named the Digital World, has been introduced in the first grade of primary education [9]. With the successive introduction of each subsequent year in the next grade, the Digital World will be a compulsory teaching subject to all children from the first to the fourth grade in Serbia by the school year 2023/2024. Next to Digital society and Digital safety, Algorithmic or Computational thinking is one of the three teaching topics within this subject, and a foundation for pupil primary education [10]. Some outcomes of this teaching topic at the end of first grade include analyzing simple known procedures and suggesting steps for their implementation, interpreting agreed meaning of known symbols and implementing the described procedure, noticing and correcting the error in expressed by symbols (algorithm), checking for validity, repairing (independently or collaborative), and understanding the link between algorithms and behavior of digital devices [11].

The introduction of the new compulsory teaching subject in the first cycle of primary education indicates the national need to develop digital competences at a young age and to prepare primary school children to safely and properly use digital devices for learning, communication, collaboration and development [11]. This need was recognized by a team of young and enthusiastic primary school teachers with an extensive background in STEAM and robotics in education, who have created and provided a comprehensive teacher training for in-service primary school teachers and educators on how to use educational robots and unplugged coding activities for developing pupils' computational thinking in primary education, years before the new teaching subject has been introduced in Serbia. Their dual training model pioneer ventures vitally resemble the activities primary school teachers implement in their classrooms when teaching the subject Digital World today.

7. Conclusions

One of the core skills students need to develop during their primary education is computational thinking: a problem-solving process where children practice decomposition, pattern recognition, abstraction, algorithm and coding, while improving their creativity, critical thinking, problem solving, decision-making, perseverance, communication, teamwork, and responsibility. In order to develop computational thinking with young children, digitally literacy of in-service teachers and educators in the first cycle of primary education needs to be at an advanced level in order for them to be able to lead and organize integrative activities in class which stimulate children and create a safe digital environment.

Computational thinking can be developed using various approaches, such as practicing coding activities in class while using educational robots, or unplugged coding activities, if the school lacks in digital equipment. While pre-service teachers are intensively developing their digital skills and during their formal university training through a series of compulsory subject which include The Methodology of Teaching Computer Science, in-service teachers develop and improve their digital competencies through professional development and accredited trainings, such as the dual training model on how to use robot coding and unplugged coding activities for developing students' computational thinking in primary education.

The dual training model implies training participants (mainly in-service teachers and educators in the first cycle of primary education) are enabled to develop computational thinking of their pupils with the use of digital devices such as educational robots and unplugged practices which do not feature device involvement (important when starting with concrete representations involving hands-on practices that allow children to physically move things around without requiring abstract coding, and to experience play-based digital learning).

The comprehensive teacher training was created using the methodological approach of developing computational thinking and it consisted of 8 methodological stages: 21st century skills, algorithm, developing computational thinking through interdisciplinary approaches, coding, unplugged coding activities, educational coding games, educational robots and self-reflection and evaluation.

After each of the thirteen trainings conducted live and online, all of the 192 participants have went through a thorough self-reflection and evaluation process, and the results show that the participants have effectively developed their own computational thinking skills, as one of the core teachers' digital competences, recognized the importance and possibilities of implementing coding activities in primary school teaching, and are more prepared to integrate topics related to computational thinking in their class.

Furthermore, after a longer timeframe, it has become evident there is a need for developing a completely new compulsory teaching subject at a national level where children will actively improve their digital competences. However, computational thinking, as a core skill in primary education, needs to be developed integratively, using interdisciplinary approaches, and throughout all teaching subjects, not exclusively during the classes of the new compulsory subject the Digital World.

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