Teacher training on Educational Robotics: a systematic review

Lorella Giannandrea
Department of Education, Cultural Heritage and Tourism, University of Macerata, Via Luigi Bertelli, 1, 62100 Macerata MC, Italy. Tel: +39 3383932695. Email: lorella.giannandrea@unimc.it

Francesca Gratani
Department of Education, Cultural Heritage and Tourism, University of Macerata, Via Luigi Bertelli, 1, 62100 Macerata MC, Italy. Tel: +39 3389396606. Email: f.gratani@unimc.it

Alessandra Renieri
Department of Education, Cultural Heritage and Tourism, University of Macerata, Via Luigi Bertelli, 1, 62100 Macerata MC, Italy. Tel: +39 3296168610. Email: alessandra.renieri@unimc.it.

Correspondence to: Francesca Gratani, Department of Education, Cultural Heritage and Tourism, University of Macerata, Via Luigi Bertelli, 1, Macerata 62100 MC, Italy. Tel: +39 3389396606. Email: f.gratani@unimc.it

ABSTRACT

This study systematically reviews the literature concerning structured training experiences with Educational Robotics (ER) by in-service teachers (ISTs) and pre-service teachers (PSTs). The sixteen papers selected highlight the relevance of these courses in order to update professional identity and to support professional development (PD) beginning with undergraduate education. Through these training sessions, both ISTs and PSTs adapted and integrated their knowledge about robotics and the pedagogy behind it, coming to understand the benefits that new technologies can offer. Therefore, they built a positive attitude towards ER and enhanced their self-efficacy. This enables teachers to properly integrate ER in the classroom, using a more conscious and less obsolete methodology. Consequently, they become, together with their students, active co-designers of the educational process. Finally, improvements in teaching methods and contents will significantly impact on the learning process, especially in terms of motivation and inclusion.

Keywords:

Professional Development, Educational Robotics, Teacher Training, Adult Learning

1. INTRODUCTION

Over the past decades, we have witnessed the emergence of a gap between the rapid advancement of technology and the slow change in the educational system and teaching methods (Camilleri, 2017). As a result, teachers often present a lower level of digital skills than their students and they are largely not aware of all the benefits that technology, and especially robotics, can offer. The use of robotics can indeed facilitate learning: it allows children to develop both computational and critical thinking, STEM skills, as well as transversal competences and it also encourages them to interact with their environment and deal with realistic challenges (Alimisis, 2013; Negrini, 2019; Somyurek, 2015).

In recent years, robotics activities have been rapidly expanding in school contexts all over the world (Kucuk & Sisman, 2018) and many educational institutions are making large investments in infrastructure and equipment (Majherová & Králík, 2017). But are they simultaneously investing in their teaching staff?

Past studies showed that most teachers are unable to properly integrate robotics into their teaching practice (Camilleri, 2017; Mataric, Koen, & Feil-Seifer, 2007; Sisman & Kucuk, 2019). Hence, the growing need to invest in specific training to upgrade the teachers' skills and educate them on new methods to teach robotics and prepare students for today's challenges. However, the training of teachers, and particularly future teachers, on robotics is still scarcely considered by research. Therefore, given the current relevance of these issues, we decided to lead a systematic review of teacher training experiences on robotics worldwide.

The next paragraph explores the need for teacher training in digital skills and, specifically, in robotics. Then, the paragraph called "Method" illustrates the research method and the selected reviewed papers. Finally, the findings are reported in the paragraph "Results", which is divided into three sections. After describing the various training experiences, we analysed the participants' feedback both on the experience and the course structure, and we discussed the impacts on the teaching and learning process.

2. BACKGROUND: THE DIGITAL SKILLS GAP AND THE NEED FOR TEACHER TRAINING

The new educational scenario, influenced by technology and digitalization, has led to several challenges for nowadays teachers. They are called to transform their teaching practice, in order to introduce technologies and 21st century skills (Scaradozzi, Screpanti, Cesaretti, Storti, & Mazzieri, 2019). However, there is a gap between school practices and the expected attitudes in the social reality (Giacomassi Luciano, Altoé Fusinato, Carvalhais Gomes, Luciano, & Takai, 2019).
Many teachers are familiar with technology, but they still need to learn about its integration (Mueller, Wood, Willoughby, Ross, & Specht, 2008) and how to train students to develop the required skills (Scaradozzi et al., 2019). An imperative requirement of our society is to prepare teachers to provide effective skills and content. This is possible by updating their curriculum knowledge (Moore, Tank, Glancy, & Kersten, 2015) and making them able to use this knowledge in practice. In this sense, it is important to invest primarily in the PSTs' training (Giacomassi Luciano et al., 2019; Gabriele et al., 2020).

The sooner the teachers become acquainted with technology, the better they can cope with it and use it in their daily activities (Aldunate and Nussbaum, 2013). As a result, students will be able to face the challenging tasks that take place in real contexts (Kaya et al., 2017), it increases students' interest in STEM (Chalmers, 2017; Park & Han, 2016) and fosters technical and scientific skills (Chioccariello, 2009). But it also enables the development of transversal skills that are fundamental in modern society (Alimisis, 2013; Chioccariello, Manca, & Sarti, 2002).

Nevertheless, robots are still being underused in schools (Negrini, 2020). In part this is due to the teachers' lack of ICT expertise and to the misconception that such activities are too complex for their competences (Tondeur et al., 2012). Teachers' beliefs about new technologies can indeed represent an important limiting factor for their successful implementation in schools (Hew & Brush, 2006; Lawson & Comber, 1999).

Finally, ER has proved to be one of the most promising tools for achieving an inclusive education (Eguchi, 2014; Karna-Lin, Pihlainen-Bednarik, Sutinen, & Virnes, 2006). Therefore, there are strong reasons and needs to train support teachers as well (Agatolio, Pivetti, Di Battista, Menegatti, & Moro, 2017), in order to exploit all the meaningful benefits of technology.

3. METHOD

The development method of this review mainly referred to the six steps outlined by Machi and McEvoy (2016) in their book *The literature review: Six steps to success*.

The present study, carried out between March and April 2020, aims to investigate the various training experiences on robotics for ISTs and PSTs worldwide. The survey was then focused on the importance that such experiences can have on the participants' PD, as well as on the possible impacts on the teaching/learning process.

We then outlined the following research questions:

1. *Which training experiences on robotics have been led for PSTs and ISTs?*
2. *What feedback did the trainees give about the training? How was it detected?*
3. *Why can these experiences be important for the PD of PSTs and ISTs?*
4. *How can ER, improved by this kind of courses, actively modify the learning process?*

As far as the literature search was concerned, we chose three databases, accessible from the net called *Ianus* of the University of XXX: EBSCO (Education Research Complete), Scopus, and Web of Science (WOS). We included the following Boolean research operators: *Robotics* AND *Teacher Training*, and we limited the research to articles or conference proceedings, published in the last five years (2016-2020). We thus obtained 175 results: 18 in EBSCO, 86 in Scopus, and 71 in WOS. Some of them were mentioned in more than one database. Excel tables were used to collect and organize these results and a list of inclusion and exclusion criteria was defined.

We chose to include every article focused on:

- training experiences on robotics for PSTs and/or ISTs;
- training experiences on robotics for teachers of all school levels.

We decided instead to exclude any article based on:

- training on robotics related to the industrial, medical or machine learning field;
- training or projects on robotics involving only students;
- reviews or theoretical issues;

- guidelines or frameworks for training implementation;
- detection of teachers' knowledge or perception of robotics.

From the first selection, mainly made through the reading of the abstracts, we identified 54 articles. Afterwards, we led a more in-depth reading of these articles and we finally definitively selected 16 papers, listed in *Table 1*. Finally, we analysed them through another table, aimed at highlighting the following features of interest (*Table 2*): nation, duration, robot used, participants number (actual nr. of PSTs and /or ISTs studied), target (PSTs / ISTs) and school level, characterized by the approximate age range of pupils.

The next paragraphs will show the results of the literature survey and critique, in order to answer the research questions outlined.

4. RESULTS

The selected contributions are geographically spread around the world: 4 from the US [7, 9, 14, 15], 3 from Italy [4, 8, 12], 2 from Turkey [5, 10], 1 from Greece, Spain, Slovakia, Switzerland, Brazil, and the United Arabs Emirates. There is also one study in cooperation between different nations: Greece-Italy-Latvia [3]. They report ISTs experiences [1, 3, 4, 6, 8, 9, 11, 14, 16], PSTs [2, 5, 7, 10, 13, 15] or ISTs / PSTs [12] that mainly lasted a few weeks/months. The projects beneficiaries worked (or will work) at all the school stages: Kindergarten [6, 11], Primary [5, 6, 7, 10, 14], Junior and/or Senior High school [3, 9, 14, 16]. In some cases, the school stage was not mentioned [1,2, 13, 15], in other cases the research was led for all the school stages [4, 8, 12]. The training courses involved generally 20/30 trainees, except for studies [4] (184 participants), [8] (254 participants), [12] (196 participants), [16] (59 participants). In [4, 12] it is specified that some of the trainees were support teachers (15% in [4] and 44.2% in [12]). During the courses, the most used robots mentioned were: Lego Mindstorms EV3 kit [3, 4, 8, 14, 15, 16], the Arduino kit/board [1, 2, 4, 9] and Blue/Bee Bot [4, 6, 8, 11]. In [7] the used robots were not mentioned, whereas in [1, 2, 4, 8, 9, 12] the researchers used different kinds of Educational Robots.

4.1 Which training experiences on robotics have been led for PSTs and ISTs?

4.1.1 PSTs

Majherová and Králík (2017) describe an experiment involving 13 bachelor degree students who specialize in computer science teaching. The participants were divided into two groups: a full-time student group (8 students) and a group of external students (5 students). The authors tried to compare two approaches to teaching robot programming, following a sequence of key tasks ranging from simple to complex. They used a robot called BASE, which can be constructed from the NXT or EV3 Lego kits[1]. The virtual model of the robot was identical to the physical robot; the visualization of the motion and the verification of the correct programming operation take place in the 3D environment. The introductory phase of the course focused on the knowledge of robotic kits and software tools used for programming. Then, the students were gradually introduced to the NXT-G environment and the Bricx development one, both used for the full-time education form. The participants were divided into groups to program a robot, built from the LEGO Mindstorms kit. The goal of the project was to set forth a program which used the automatic control of the robot's movements, based on values measured by sensors. Moreover, students would learn about the general requirements of virtual labs and about the possibility of using them in teaching programming languages. In the practical part of the course, they would become familiar with the ROBOTC language and with the RVW virtual laboratory, both used for the distance course. The final phase was focused on working both with tutorials and instructions from Lego and free guides on the web, in order to gain both teaching methodology and working practices.

Kaya and colleagues (2017) conducted a study within the context of an elementary science teaching methods course, involving 11 PSTs with varying degrees of engineering knowledge. This course lasted 15 weeks and the participants spent 3 weeks (9 hours in total) on the engineering unit. The class began with a 30-minute pre-assessment on Nature Of Engineering (NOE) and with a 10-minute group discussion on some assigned questions. Then, the instructor showed a video describing the engineering and the Next Generation Science Standards (NGSS) Engineering Design Process (EDP). Later, PSTs were introduced to elementary NGSS engineering practices, the NOE and the EiE (2016) EDP steps. This lesson was followed by a one-hour lecture held by a professional chemical engineer. During the second week, PSTs, divided into groups of four, built LEGO EV3 robots and completed two programming challenges, by following the EiE EDP steps. *Maze challenge* required to build and code a robot able to autonomously explore a coal mine, whilst *Draw a letter* aimed at building and coding a robot that can autonomously draw a letter to signal changes in elevation. PSTs were given a quick demo about how to code, run the motors, and interact with the robot using the EV3 software. Throughout the final week, the instructor showed the NOE poster and explicitly discussed NOE aspects with the PSTs. He asked each group to reflect on their engineering experience with ER from the perspective of NOE aspects, providing specific examples, in order to internalize, rather than memorize, the meanings of these aspects. The instructor continued with a discussion about promoting equitable access to engineering education. The unit ended with the NOE post-assessment and the written reflections both of PSTs on the EDP.

[1] https://www.lego.com/en-us/product/lego-mindstorms-ev3-31313 (consulted on 14.11.2021)

Kucuk and Sisman describe two training experiences held within an elective course on Robotics in Education. The first training (Kucuk & Sisman, 2018) lasted 13 weeks and was attended by 15 PTSs from different departments (CEIT, Talented Education, Elementary Education, Department of Science Education); the second one (Sisman & Kucuk, 2019) lasted 10 weeks and was attended by 30 future elementary school teachers. In both of them, the participants were divided into groups of three to four that worked cooperatively, using the Robotics Dream ER kits[2]. They also followed the same course structure. The first weeks were focused on designing and programming activities: after a short theoretical introduction to ER, the groups designed robots by following steps in the Robotics Dream guidebook. Afterward, instructors introduced various pedagogical approaches for teaching robotics to children, focusing on the Creative Thinking Spiral Instructional Model (Kucuk & Sisman, 2018; Sisman & Kucuk, 2019) and the Engineering Design Process (Kucuk & Sisman, 2018). Each group prepared robotics activities for elementary (Kucuk & Sisman, 2018; Sisman & Kucuk, 2019) and middle school stages (Kucuk & Sisman, 2018), choosing a pedagogical approach, and illustrated them. For the final project, the groups created their original robots to be used for educational purposes, determined by the PTSs. They created a project based on their ideas. They tested and played with their creations. Then, they shared the project both with their classmates and instructor. Finally, they reflected on their whole experience which led them to imagine new ideas and new projects.

The paper by Giacomassi Luciano et al. (2019) wants to investigate whether the introduction of Robotics in a Physics class could engage future Physics teachers, through hands-on experiences. The idea is that if the PSTs were influenced, they could later influence their future students with their teaching practices. It is necessary not only to introduce the technology, but also the methodology. In order to understand that, 25 students of the Physics course of the State University of Maringá (UEM) were invited to attend this research, submitted and funded by the Research Committee of the UEM. Their actions can be divided into three phases: (1) *deconstructing ideas phase*: they provided several reflective moments of the teaching practice (throughout the memory of the personal remembers of the student's life); (2) *students constructionists' phase*: they allowed students to really understand the new methodological practice, they approached Arduino[3]and robotics workshops; (3) *the teacher-building action phase*: they allowed the students to set a robotic workshop through Arduino platform (using the learned skills) for the Workshop in the XXV Academic Week of Physics of the UEM. The project ended with the students' reflection and evaluation of the Academic week.

The study mentioned in Yuan et al. (2019) can be seen as an examination of the integration of robotics in the design lessons for PSTs. The aim was to understand the reason behind their lessons' design and their use of robotics into elementary classrooms. The 19 participants were all majoring in early childhood education, and they were attending an undergraduate elementary education course. The course objectives included designing technology-enhanced activities for elementary students, introducing PSTs to the engineering design process, and conducting research on age-appropriate instructional strategies and principles. The learning model was made up of 4 steps: an introduction to ER, an activity with assembled and programmed robots in groups, an

[2]https://www.robotis.us/dream/ (consulted on 14.11.2021)
[3]https://www.arduino.cc/ (consulted on 14.11.2021)

individual design of lessons for elementary classes and, finally, the creation of a poster presenting what they had learned and how they were able to use robotics for their future classes.

4.1.2 ISTs

The essay by Santos et al. (2016) describes a two-day face-to-face training on how to use and integrate robotics in teaching. The participants were split into two groups and each group had a different training schedule and location. They used Lego Mindstorms (EV3) kits to complete the activities. The training was based on the Lego 4C framework: Connect, Construct, Contemplate, and Continue. The content covered in the first day of the training referred to the basics of the Robot Educator: introduction to Lego Mindstorms (EV3) technology/hardware and software environment; introduction to the four C methodology for learning; program to navigate in all directions; develop a smart robot. On the second day, teachers engaged in more advanced tasks and discussions on how to use robotics in the curriculum. In particular, they focused on: curriculum (Robotic Educator), data logging, designing engineering projects, and, finally, exploring curriculum and lesson plan opportunities. The trainer explained the content and the steps of assembling and programming the robots. Then, teachers used the software and the kit to engage in hands-on activities. They worked in pairs and followed the multimedia tutorials to program the robots.

The article by González and Muñoz-Repiso (2017) shows the advances of a study oriented to the formation of programming abilities, computational thinking, and collaborative learning in an initial education context, using ICT resources and educational robot programming. The group involved in the study was composed of 8 teachers and six groups of students (131 in total) from urban areas. In the first training session *My first steps in Robotics*, teachers learned about the characteristics and the educational opportunities of the BeeBot robotic kit[4], experimenting with the scenarios through a problem-solving approach. They could see how the robot is constituted and verify its possible movements, learning work environment similar to the one that will be used with the students. Then, in the experimental part, teachers performed basic robot movement exercises, giving sequential programming instructions through the buttons located at the top of the robot. Instructors designed a carpet or a stage on which the robot had to move and a poster showing all the possible movements. Several types of didactic aids were indeed used during this training day, such as videos, posters, scenarios or mats, and letters with examples of sequences.

Leonard and colleagues (2017) present in their report the results of the final year of a three-year research project on computational thinking. The report describes the Year-3 study, which blended game design and robotics to provide elementary school teachers with a sound curriculum. This would allow them to engage students from both rural and urban communities in computational thinking at high levels. The project involved teachers to implement Scalable Game Design (SGD) and LEGO EV3 robotics during after-school clubs. Several teachers were familiar with robotics, but few had previously worked with game design. All participants received the same training, which consisted in two logistics meetings and an 8-week course on game design and robotics. Game design was taught by a computer scientist, who was a member of the research team. Lesson plans focused primarily on creating *mazes, Frogger*, and *PacMan games* using SGD. Robotics was

[4] https://www.terrapinlogo.com/beebot.html (consulted on 14.11.2021)

taught by a science educator, who was also a member of the research team. Lesson plans focused on using LEGO EV3 robotics kits to make the *basic car, gyro boy*, and *sumo bot*. MINDSTORMS® programming controlled the robot's movements and the use of ultrasonic, colour, and touch sensors.

In the paper by Castro et al. (2018) we read about the Edu.Ro.Co. course: an ER training course designed for teachers of different school levels and almost 24% of them had had previous ER experiences in the classroom. This course lasted 8 months and was composed of four modules, performed in 32 hours. *Module I* was a theoretical introduction of the ER and a moment of reflection: "does the involvement in ER activities shown by the children automatically imply the development of a learning environment? If a child is engaged in ER activities, and he/she is enthusiastic and very absorbed in them, can we assume that he/she is learning?" (p. 673). *Module II* was a practical introduction: an initial lesson part in which the researchers showed some practical use-case, followed by a laboratory-phase part, in which the teachers experimented some specific robots, according to the age-ranged school levels (Beebot, Pro-bot[5], Lego Mindstorm EV3). During these laboratories, teachers had the opportunity to start to use the robot and become familiar with it. *Module III* was conducted online: a Moodle platform was created in order to share contents, research materials, and information about ER. Moreover, in this platform teachers gave their feedback about their experiences and researchers provided a unique template useful for the realization of an ER project during school time. *Module IV* was dedicated to teachers' feedback and to share both experiences and results.

The paper by Mallik, Borges, Rajguru, and Kapila (2018) describes a PD workshop on the use of robotics in STEM education. This workshop was a four-week program consisting of a two-week guided training and a two-week collaborative robotic-product development. It was attended by 18 Math/Science teachers and 33 high-school students from 10 High Schools in New York City and neighbouring regions. During this course, they used VEX Robotics Clawbot kit[6]and Arduino UNO kit, and programmed using Arduino IDE board. The first two weeks of PD workshop were devoted to teaching (1 hour at least) and guided learning through structured projects and hands-on activities (3 hours). For these latter the participants worked in groups consisting of two teachers and three to four students. The researchers designed and used worksheets containing the underlying fundamentals and instructions of the lesson to perform the activity. In the last two weeks of the PD workshop, participants worked on two different projects: (1) the participants were supposed to build a line following robot and (2) they were supposed to come up with a real-world plantation/gardening scenario. The teachers who attended this course had the opportunity to conduct a Robotics course and a robot design project for their students. The students who attended this summer camp could help teachers in the classroom as these activities need significant human resources.

In the paper by Alimisis (2019) we read about the ERASMUS+ project called ROBOESL (2015/17): it introduces ER as a learning tool for 13-17 y.o. students at risk of school failure and early school leaving (ESL). Alimisis developed (pilot) training courses for 20-trainees, with the aim of enabling the (not experienced in ER) teachers to master the technical and the pedagogical skills

[5]https://www.terrapinlogo.com/probot.html (consulted on 14.11.2021)
[6]https://www.vexrobotics.com/276-2600.html (consulted on 14.11.2021)

that are necessary to use the robotic technologies in their schools. The three pilot courses took place in Greece, Latvia, and Italy. The training methodology was designed to support interdisciplinary robotics projects in schools, from a Problem Based Learning (PBL) point of view. It included some peculiar actions: iterative design, selection of tools, making, playing, sharing. The project, and therefore the training, aims at integrating aspects of authentic reality with the learning experience. Each activity started with the teachers familiarization with the learning methodology and educational robotic hardware and software: using some projects they could feel the immediate potential of robotics. Then, the teachers familiarised with the robotics kit (Lego Mindstorms EV). Each robotic-based training activity provided a real-life scenario in order to make the project more meaningful, authentic, and interdisciplinary for the teachers (and therefore for the students). Each activity had its peculiar general and specific pedagogical objectives and some suggestions for the learning methodologies were suggested as recommendations (and not as "cooking recipes"). Moreover, evaluation tools are provided.

The paper by Scaradozzi et al. (2019) describes a training course for ISTs on ER, Coding, and Tinkering. The aim was to introduce these new methodologies and to make the teachers (coming from different teaching areas) experienced. The training course involved groups of about 30 teachers at a time. It combined a preliminary seminar, 4 workshops, and a final seminar. During the preliminary seminar the researchers introduced the course and the Italian PNSD (*Piano Nazionale Scuola Digitale*). During *Workshop 1*, after a brief theoretical introduction, teachers applied the pedagogical vision of Constructionism, ER, and Coding. Then, they applied these ideas working on their first course project, using suitable devices depending on their school level (BeeBot, Scratch Jr[7], Lego WeDo kit[8], Lego Mindstorms EV3 kit). In *Workshop 2* teachers were introduced to Lego 4C (Connect, Construct, Contemplate and Continue) Framework and the TMI (Think, Make, Improve) Model, useful to make a proper consideration on the possible flows and frameworks that has to be adopted while one's designing an educational progression. During *Workshop 3* Digital Storytelling and Classroom Debate were introduced. In *Workshop 4* the trainer introduced Thinkering activities: teachers created inexpensive robots, using waste materials, markers, and motors. Then, a practical activity was introduced, using the Makey Makey board[9]for Kindergarten and Primary teachers and the Arduino board for the others. During the Final seminar a test was assessed on the 184 teachers, out of 400, who accepted to take part in the study.

The paper by Negrini (2019)describes the teachers' training course of the PReSO pilot project. The project aimed at training teachers in ER, in order to introduce children to the computational thinking, ICT, and STEM disciplines through robots, without any obstacles. The project was carried out in the school years 2015/16 and 2016/17 in Ticino (Switzerland) for 5 kindergarten and 12 primary teachers, who did not have any specific knowledge in the ICT field. The research team trained them for 12 half-days, over those two school years. During the first year, the participants followed a training including a theoretical and pedagogical introduction to ER and computational thinking. Then, educational robots, Blue-Bot[10] and Thymio II[11]were introduced and

[7]https://www.scratchjr.org/ (consulted on 14.11.2021)
[8]https://education.lego.com/en-us/elementary/intro/wedo2 (consulted on 14.11.2021)
[9]https://makeymakey.com (consulted on 14.11.2021)
[10]https://www.terrapinlogo.com/blue-bot-family.html (consulted on 14.11.2021)

some designed didactic activities were tested. During the second year, teachers defined a long-term project integrating the robots, in order to pursue various objectives, including the development of computational thinking.

The paper by Alimisi, Loukatos, Zoulias, and Alimisis (2020) presents the workshops for 20 teachers that took place in the frame of the eCraft2Learn (H2020) project 2017/18, whose aim was reinforcing STEM education for 21st century students and teachers. The mentioned workshops were designed to let the teachers experience the activities that later should have been implemented with students. The 20 trainees came from different scientific fields (Science, Technology, Electronics, ICT, Graphic Arts) and they had not been exposed to the eCraft2Learn methodology before. This methodology can be described into five stages: (1) *ideation stage*, where the learner formulated the ideas that he/she would like to develop, by exploring the real world; (2) *planning stage*, where he/she explored the available and needed resources for the project; (3) he/she engaged in the process of making (brainstorming, trial, errors,…); (4) he/she started to build the artefacts and programmed their behaviour; (5) the learners shared the projects with the community (and class). They carried out 5 sessions of 4 hours each. In the first session they focused on the pedagogical ideas and the methodology developed in the course: the Maker Movement and the Do-It-Yourself culture. Moreover, the teachers set up their workstations with Raspberry Pi board[12]and the Arduino kit. During the second, the third and the fourth sessions the trainees experimented with more practical tasks using the robots. The fifth session was used to free experimentations and a specific discussion on the pedagogical issues, considering the forthcoming pilot courses with real students.

4.1.3 PSTs/ISTs

The paper by Agatolio et al. (2017) discusses the new implementation of an introductory training course in ER for PTSs and ISTs learning support teachers (LSTs). The 8 hours course was designed to address these main aspects: methodology, engagement, and familiarization, exemplary experiences, and designing of didactical units. Initially, the authors briefly presented the constructionist methodology, as fruitful to introduce robots in class, and provided some hints to manage the presence of a special-needs student in the class group. Then, the trainees were gradually exposed to the most useful and frequent robots, through various experiences. They started with a simple and immediately rewarding experience, aimed at introducing the most important programming blocks. This implementation required just 4 commands: one loop, one switch, and two alternative move-steering blocks. The other o□ered experiences were: *straight motion* (make the robot move for a certain distance and stop; then repeat for 4-5 times), *polygon* (make the robot paint a regular polygon), *obstacle avoidance* (overtake an obstacle by using the ultrasonic sensor), and *stop and go* (make the robot stop when the obstacle is close enough, and move forward again when it is removed). Part of the practical lab was designed according to the school level. More specifically, with kindergarten and primary school teachers, the authors suggested and showed the use of authoring environments like Scratch, to provide a first robotic-like experience to very young kids. The last part of the course was dedicated to briefly developing a multidisciplinary didactical unit: the class was divided into 5-6 groups of 4-6 people each and every group designed the unit

[11]https://www.thymio.org/ (consulted on 14.11.2021)
[12]https://www.raspberrypi.org/products/ (consulted on 14.11.2021)

around a theme of their choice, considering the presence of a special-needs student. Each group could finally show their developed unit, emphasizing the critical aspects and new potentialities they had thought.

4.2 What feedback did the trainees give about the training? How was it detected?

After reviewing the various training experiences, we wanted to collect some feedback on their structure, content, and implementation. However, only [1], [5], [10], [12] and [13]analyse this aspect. Most of the articles are instead focused on the courses' impacts, which is reported in the following paragraph.

Agatolio et al. (2017) assessed the positive and critical issues of the course via 5 open-ended questions. The participants' answers were coded according to the meaning into super ordinate categories by trained judges. The most frequent categories are reported as follows. As for the positive aspects, the participants named: (1) the *didactic approach* characterized by *practice* (104 excerpts), (2) the *innovative course content* (62 excerpts), (3)the *participants' involvement* into the course (27 excerpts), (4) *team working and cooperation*. As far as the negative aspects of the course were concerned, the participants reported:(1) *lack of time* (66 excerpts), (2) the *complexity of the course contents* (28 excerpts), (3) not fully equipped *lesson rooms* (25 times). The participants also suggested some improvements in these areas; for instance, they suggested increasing the hours of lesson to be able to practice more with robots and to set the course at the beginning of the school year, to better plan their laboratory activities. 73.8% of the participants would recommend the course to a colleague.

Majherová and Králík (2017) examined both the advantages and disadvantages of using physical and virtual approaches for teaching the programming of robot models. In a small group of students, they assessed qualitative results through the observation and a questionnaire, completed at the end of the course. From an analysis of the learning outcomes, the authors drew the following conclusions: the physical approach allows an excellent visibility of a commands sequence for building a program. But this method is only suitable for simple robot motion-control programs. Moreover, the authors considered this method to be time-consuming because much time was necessary to create and verify tasks before their application in the educational practice. They also noted that the mechanical building of a robot took more teaching time compared to the time allowed for creating a program. As for the virtual approach, the use of the programming environment was intuitive, allowing them to fully concentrate on the programming tasks. The virtual board's parameters did not change, and the view could be switched between on different appearances. However, programming took place in a higher-level programming language, so the program seemed to be suitable only for higher stages. Mistakes caused by faulty parts of the robot were avoided. In addition to direct instruction, it was possible to use this method for distance learning or other forms of learning. The virtual environment was the software that fully replaced the Lego kit.

Kucuk and Sisman (2018) carried out a semi-structured interview consisting of 15 questions in the final week of a semester. When the researchers analysed the interviews, they worked together to decide on the themes, categories, and relative codes. Four categories and outstanding dimensions were obtained under the *Course Process* theme, which referred to what the PSTs had experienced when doing the course activities. (1) *Learning process* reflected the PSTs learning experiences comprehensively: facilitation of process through experience, need for focus, cognitive load, learning by enjoyment, flow experience, positive attitude toward programming, developing a product, and programming skills. The second category referred to some (2) *difficulties encountered*: making design mistakes, design steps becoming boring, connecting a port, determining the appropriate codes, complex programming process, problems in adapting to the group. Then, the authors reported the (3) *problem solving methods*: maintaining individual effort and intrinsic motivation high, getting help from either instructors or teammates, and finding online resource materials. Finally, the last category was about (4) *project development process*: peer learning, producing creative ideas, effective and efficient working with the group, associating with real life, writing gamified scenarios, using online communication tools, communication problems, preferring to work individually.

Sisman and Kucuk (2019) aims to reveal PSTs perceptions and experiences in an ER course. Specifically, SMECC (satisfaction, motivation, enjoyment, collaboration, and challenge) levels were investigated in the robotics learning process. Moreover, PSTs' engagements were revealed. Data were collected using a post-activity survey, observation, and interview forms. The post-activity survey consisted of 5 Likert questions and one open-ended question. These revealed the participants' levels of satisfaction, motivation, enjoyment, challenge, collaboration during the class activities. An observation form, made by two observers, was created on previous studies examining the PSTs engagement in the learning process. The interview form was created as based on the literature revealing PSTs' experiences in designing educational robotics. The qualitative data obtained from both observations and interviews were analysed through descriptive and content analysis methods.

Alimisi et al. (2020) prepare a questionnaire for ISTs after the implementation of the workshop, on strong and weak points of the course and, generally, on eCraft2Learn technologies/tools and on the future improvements that this course would lead. This questionnaire was completed by 16 (out of 20) participants. Moreover, trainees made comments during the course, which were periodically scheduled during the training and at the end of each session. ISTs highlighted the following as strong points: the rich variety in the technologies/tools explored during the workshop, the nature and features of these technologies and tools, the pedagogical approach that was followed, the interactive discussions, and the good communication with the trainers/project team. On the other hand, they chose, as a weak point, the time constriction.

4.3 Why can these training experiences be important for the PD of PSTs and ISTs?

The selection and the analysis of the sixteen essays aim at highlighting the importance of the ER training experiences for PSTs and ISTs. Even though all the papers stressed it, for the sake of clarity, we will make separate considerations for the two categories of participants.

PSTs emphasized the relevance of these courses, considered as an important support for their PD (Kucuk & Sisman, 2018; Sisman & Kucuk, 2019). Each future teacher should start to learn about Robotics during his/her undergraduate education (Kucuk & Sisman, 2018; Sisman & Kucuk, 2019), because during that time he/she started to build up his/her professional identity (Giacomassi Luciano et al., 2019). Through this training they adapted to new technology trends, they understood the Pedagogy behind ER and they experienced the usefulness of Robotics. These kinds of experiences, occurred during their education programmes, constituted a critical (and positive) factor as far as their attitudes to Robotics (Agatolio et al., 2017; Sullivan & Moriarty, 2009), Coding (Kucuk & Sisman, 2018; Majherová & Králík, 2017), and STEM were concerned, and to their improvements on this knowledge (Kucuk & Sisman, 2018; Tondeur et al., 2012). These studies have shown that learning robotics motivates PSTs to integrate Robotic Pedagogy into their fields of study (Kucuk & Sisman, 2018; Sisman & Kucuk, 2019). They also encourage PSTs to include ER in their future classroom (Kaya et al., 2017): robotics activities engage students, easily integrate technologies with all the other subjects and are a powerful tool to introduce engineering, coding, and STEM on the generations of the digital age (Kaya et al., 2017).These content-specific training, made by case-based learning, help the future teachers to make solid connections between their knowledge and all the possible specific contexts. Moreover, the PSTs in (Doyle, 1990; Giacomassi Luciano et al., 2019; Han, Eom, & Skin, 2013) show a significant decrease in their personal difficulties in decision-making: ER helps them to increase their autonomy, to deal with their mistakes. They notice a real stimulation of the willpower towards the development of new challenging activities (Giacomassi Luciano et al., 2019).

We understand that the involvement of PSTs can favour the enhancement of the learning process: PSTs are motivated to carry out scientific research (Hadjiachilleos et al., 2013), they gain more self-confidence in how to learn and teach coding languages (Jaipal-Jamani & Angeli, 2017; Kay et al., 2014), they improve their learning and teaching engagement for STEM (Kim et al., 2015; Sisman & Kucuk, 2019). This can be seen as a starting point for a new and positive influence in their future teaching process. The teachers' own personal identity has to be consolidated during his/her professional practice (Giacomassi et al., 2019) and long-life education. If teachers perceive themselves as being incompetent in what they are teaching, they tend to reduce their intent to implement new activities (Adams, Miller, Saul, & Pegg, 2014), probably due to their lack of self-efficacy (self-perception and self-confidence; Mallik et al., 2018). The aim of ER training courses is not just to know, build and programme a new robot, but, furthermore, to enable teachers on the educational benefits that Robotics can bring (Negrini, 2019) since an early stage of education: curiosity, critical thinking, problem solving, creativity. (Alimisis, 2019; Scarradozzi et al., 2016a; Scaradozzi, Sorbi, Pedale, Valzano, & Vergine, 2015). Moreover, several studies report the effectiveness of new approaches, using technologies and new methodologies to teach and learn, that could aid teachers in their path to innovation (Benitti, 2012; Cesaretti et al., 2017; Lee & Lee, 2014; Organization for economic co-operation and development, 2010; Rockland et al., 2010;

Scaradozzi et al., 2016b; Wang, Hsu, Campell, Coster & Longhurst, 2014): improvements are detected comparing the data of pre-post courses (Leonard et al., 2017). Training teachers in ER is an important and positive factor for a successful and motivated introduction of Robotics in school education (Alimisis, 2009), using educational activities mediated by those programmable robots (González & Muñoz-Repiso, 2017).

ISTs' experiences helped them to assimilate and to adopt new methods and good practices (Alimisi et al., 2020): ER is a valid resource and tool (Agatolio et al., 2017) which allows the development of curricular objectives (González & Muñoz-Repiso, 2017). ISTs find the accompaniment of a research team during the training activities (Negrini, 2019) helpful. They appreciate working with other teachers: in some papers ISTs worked together to create a database of materials that can be useful even for other teachers. Furthermore, (Alimisi et al., 2020; Alimisis, 2019; Castro et al., 2018) underline the variance of the teacher's role after the attendance of these courses: ISTs feel themselves much more as coaches (co-designers and co-learners) together with the students, instead of as the intellectual authority of the class.

4.4 How can ER, improved by this kind of courses, actively modify the learning process?

School has a fundamental role in forming individuals: nowadays it is essential to re-think the attitudes towards teachers' education. Methods and activities can not be archaic, in particular, those linked to STEM and engineering education (Giacomassi et al., 2019; Yuan et al., 2019), and they have to be (introduced) updated as early as possible (Kaya et al., 2017).

ER is important for students as it helps them to achieve new technical and meta-cognitive abilities (Negrini, 2019): students' motivation, planning skills, team working and collaboration (Castro et al., 2018; Kucuk & Sisman, 2018), social competencies (Agatolio et al., 2017), problem solving, creativity development (Castro et al., 2018), learning by trial and mistakes (Kucuk & Sisman, 2018; Negrini, 2019). The project-based approach, the *storifying* and *gamification* strategies, the innovative scaffolding mechanisms (*what if experimentation*, *embodiment*) and the connection with real and concrete problems should attract students and encourage them to think (Alimisis, 2019; Kucuk & Sisman, 2018). The hands-on learning activities allow students to actively experience success even after some the occurrence of obstacles (Alimisis, 2019; Mallik et al., 2018). ER can enhance students' motivation to learning STEM, without any differences among their gender nor age nor citizenship (Scaradozzi et. al, 2019)

We understand that this conscious use of ER allows a general integration of students: in Daniela & Strods (2017) the introduction of robotics activities is used to raise self-esteem, motivation, and resilience of young people at risk of leaving school early. Therefore, this new scenario, adaptable to both students' needs and interests (Alimisi et al., 2020), is a powerful tool for promoting all the relevant skills of the future generation of learners, as well as for those who require special needs (e.g. ADHD, mind mental retardation…; Agatolio et al., 2017).

5. Discussion

Looking at the outbreak of ER experiences for students, the review highlights the presence of limited structured training experiences on ER both for ISTs and PSTs. Moreover, a restricted subset of these experiences is properly evaluated: in this case, the participants (PSTs or ISTs) named, as positive aspects, the innovative methodology approach (learn by doing, hands-on activities, …), the team cooperation and the individual involvement. At the same time, they suggested some improvements for future courses in terms (mostly) of time: the majority asked to increase the hours of lessons in order to practice more.

The sixteen selected papers give prominence to the importance of these courses for the creation of a new and updated professional identity and a support for their PD. Through these training both future and present teachers adapted and integrated their knowledge on Robotics and on the Pedagogy behind it, in order to prefer less obsolete methods and activities for the early introduction of engineering and STEM education. The technical and pedagogical knowledge raised enhance the self-efficacy of teachers; as a consequence, teachers will use it more consciously and properly in their classrooms. Moreover, (even prospective) teachers feel self-assured and start to play the role of the co-designers of knowledge in the class, together with the active students.

We understand that the conscious use of ER helps students of all ages to achieve new technical and meta-cognitive abilities, as stated before for the PSTs and ISTs trainees. Moreover, ER enhances students' motivation towards STEM and it helps in terms of inclusion.

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6. APPENDICES

Table 1. List of the reviewed articles.

N	Authors	Title	Year	Source	Database
1	Alimisi, Loukatos, Zoulias & Alimisis	Introducing the Making Culture in Teacher Education: The eCraft2Learn Project	2020	Advances in Intelligent Systems and Computing 946 AISC, pp.27-41	Scopus
2	Giacomassi Luciano, Altoé Fusinato, Carvalhais Gomes, Luciano & Takai	The educational robotics and Arduino platform: Constructionist learning strategies to the teaching of physics	2019	Journal of Physics: Conference Series, 1286(1), 012044	Scopus
3	Alimisis	Teacher Training in Educational Robotics: The ROBOESL Project Paradigm	2019	Technology, Knowledge and Learning, 24(2), pp.279-290	Scopus, EBSCO, WOS
4	Scaradozzi, Screpanti, Cesaretti, Storti & Mazzieri	Implementation and Assessment Methodologies of Teachers' Training Courses for STEM Activities	2019	Technology, Knowledge and Learning, 24(2), pp.247-268	Scopus, EBSCO, WOS
5	Sisman & Kucuk (*)	An educational robotics course: Examination of educational potentials and pre-service teachers' experiences	2019	International Journal of Research in Education and Science 2019 June, 8760991, 5(2), pp.510-531	Scopus
6	Negrini	Teacher Training in Educational Robotics: An Experience in Southern Switzerland: The PReSO Project	2019	Advances in Intelligent Systems and Computing, 829, pp.92-97	Scopus
7	Yuan, Kim, Hill & Kim	Robotics Integration for Learning With Technology	2019	Technology & Teacher Education, 19(4)	EBSCO
8	Castro, Cecchi, Salvini, Valente, Buselli, Menichetti, Calvani & Dario	Design and Impact of a Teacher Training Course, and Attitude Change Concerning Educational Robotics	2018	International Journal of Social Robotics, 10(5), pp.669-685	Scopus, WOS

9	Mallik, Borges Rajguru & Kapila	Fundamental: Analyzing the effects of a robotics training workshop on the self-efficacy of high school teachers	2018	ASEE Annual Conference and Exposition, Conference Proceedings 2018-June	Scopus
10	Kucuk & Sisman (*)	Pre-service teachers' experiences in learning robotics design and programming	2018	Informatics in Education, 17(2), pp.301-320	Scopus, EBSCO, WOS
11	González & Muñoz-Repiso	Development of computational thinking and collaborative learning in kindergarten using programmable educational robots: A teacher training experience	2017	ACM International Conference Proceeding Series Part F132203, 5	Scopus
12	Agatolio, Pivetti, Di Battista, Menegatti & Moro	A training course in educational robotics for learning support teachers	2017	Advances in Intelligent Systems and Computing 560, pp.43-57	Scopus, WOS
13	Majherová & Králík	Innovative methods in teaching programming for future informatics teachers	2017	European Journal of Contemporary Education, 6(3), pp. 390-400	Scopus, WOS
14	Leonard, Unertl, Barnes-Johnson, Stubbe, Mitchell & Ingraham	Developing teachers' computational thinking beliefs and engineering practices through game design and robotics	2017	Conference Papers -- Psychology of Mathematics & Education of North America, pp.1289-1296	EBSCO
15	Kaya, Newley, Deniz, Yesilyurt& Newley	Introducing Engineering Design to a Science Teaching Methods Course Through Educational Robotics and Exploring Changes in Views of Preservice Elementary Teachers	2017	Journal of College Science Teaching, 47(2), pp.66-75	EBSCO
16	Santos, Ali, Khine, Hill, Abdelghani & Qahtani	Teacher perceptions of training and intention to use robotics	2016	IEEE Global Engineering Education Conference, EDUCON 10-13-April-2016,7474644, pp.798-801	Scopus, WOS

Table 2. List of the articles and thematic elements of interests.

N	Nation	Duration	used Robot	Participants nr.	PSTs/ ISTs	Approx. pupils' age
1	Greece	September-October 2017 (5 sessions of 4h)	Raspberry Pi board, Arduino Uno board, Arduino kit	20	ISTs	-
2	Brazil	156 hours	Arduino kit, *Not specified educational robot*	25	PSTs	-
3	Greece, Italy & Latvia	24-28 February, 14-18 June, 18-22 September 2016	Lego Mindstorm EV3 kit	20 each pilot courses	ISTs	13-17 y.o.
4	Italy	May-June 2017	Bee Bot kit, Scratch Jr., Lego WeDo kit, Lego Mindstorms EV3 kit, MakeyMakey board, and Arduino board	184	ISTs	3-19 y.o.
5	Turkey	4h for 10 weeks	Robotis Dream educational robotics kit	30	PSTs	5/6-8/9 y.o.
6	Switzerland	s.y. 2015/16 s.y. 2016/17	BlueBot kit, Thymio II	17	ISTs	4-12 y.o.
7	US	-	*Not specified educational robot*	19	PSTs	6-11 y.o.
8	Italy	from March 2015, for 8 months (32 hours)	BeeBot kit, ProBot kit, Lego Mindstorm EV3 kit	254	ISTs	3-19 y.o.
9	US	4 weeks	VEX Robotics Clawbot kit, Arduino Uno board, Arduino IDE	18	ISTs	14-18 y.o.
10	Turkey	Fall 2017 Semester, 4h for 13 weeks	Robotis Dream educational robotics kit	15	PSTs	Primary and Middle (5/6-12/13 y.o.)
11	Spain	1 day	BeeBot kit	8	ISTs	3-5/6 y.o.
12	Italy	8 hours (2 sessions of 4h)	Scratch Jr., *Not specified educational robot*	196	PSTs ISTs	3-19 y.o.
13	Slovakia	2015/16 a.y.	Lego Mindstorm EV3 kit	13	PSTs	-
14	US	2 logistic meetings + 8 hours	Lego Mindstorm EV3 kit	23	ISTs	9-12 y.o.
15	US	Spring Semester 2015/16 a.y. (3 weeks - 9 hours)	Lego Mindstorm EV3 kit	11	PSTs	-
16	United Arab Emirates	First Semester of 2015/16 a.y. (2 days)	Lego Mindstorm EV3 kit	59	ISTs	11-15/16 y.o.