International Journal of Social Robotics (2018) 10:669–685
https://doi.org/10.1007/s12369-018-0475-6

Design and Impact of a Teacher Training Course, and Attitude Change Concerning Educational Robotics

Emanuela Castro[1] · Francesca Cecchi[1] · Pericle Salvini[1] · Massimiliano Valente[1] · Elisa Buselli[1] · Laura Menichetti[2] · Antonio Calvani[2] · Paolo Dario[1]

Accepted: 18 March 2018 / Published online: 27 March 2018

Abstract
Current initiatives and laboratories concerning Educational Robotics (ER) are often not based on strong pedagogical backgrounds. Additionally, they are carried out by inadequately trained teachers, and are not evaluated properly in terms of effectiveness. Moreover, according to teachers, ER usability is often neglected. The main goal of the present article is to present a training course on ER (Edu.Ro.Co.), grounded in pedagogical insights, and to discuss the results of the course and teacher's opinion about ER in terms of: (i) teachers' attitudes and perceptions of using ER; (ii) the potential impact of ER on students' key competences for lifelong learning; and (iii) strengths and weaknesses of ER. These aspects were analysed by means of questionnaires specifically designed by the authors, and administered before and after the training course. A total of 339 teachers attended the training course and 254 completed the questionnaires. The article describes the methodology utilised in the realisation of the course and analyses the questionnaire's results. In particular, the number of teachers that considered themselves prepared to apply ER significantly improved after the training course. ER is considered by teachers an important tool for the improvement of students' motivation, planning skills, team working, problem solving and creativity development. Finally, the results from questionnaires indicate that teachers consider ER, a method that improves team-working abilities and motivation in the students. In contrast, the main disadvantage is the cost of the robotic kits. Based on these results, new directions for future research in ER are discussed.

Keywords Educational Robotics · Training course · Pedagogy · STEM · Teacher attitude

1 Introduction

Educational Robotics (ER) refers to the use of robots as a tool for teaching, and currently represents one of the most promising educational tools among new technologies [1]. Through the assembly and programming of robots, ER gives students the opportunity to perform learning activities by having fun, while also creating an appealing learning environment, promoting engagement and interest [2]. Constructivism theory considers learning to be an active process, where children are seen as operative constructors of their own knowledge. Through interaction with the environment, each child creates his own representation of the world, merging new information with their prior knowledge [3]. Constructionism theory adds the importance of using concrete objects and concrete problems to solve in order to make the learning process more efficacious [4], passing (simplifying) from a learn-by-doing method to a learn-by-making one. Applying Piaget and Papert's ideas, the manipulation of an artefact (a robot in our case) is crucial to forming an effective student learning process [3,4], especially when 'the learner is consciously engaged in constructing a public entity' [5]. ER is also considered an important tool for favouring the diffusion of technologies in education [6], and is often applied to Science, Technology, Engineering and Math (STEM) activities.

The European Commission (EC) has designed, implemented and funded different initiatives to encourage STEM activities, and many countries, including Italy, have adopted national strategies to improve the quality of STEM teaching [7]. EC initiatives to encourage STEM studies involve teaching methods (the way in which science is taught can

✉ Francesca Cecchi
francesca.cecchi@santannapisa.it

1 The BioRobotics Institute, Scuola Superiore Sant'Anna, Viale Rinaldo Piaggio 34, 56025 Pontedera, Pisa, Italy

2 Department of Educational Science and Psychology, University of Florence, Via Laura, 48, 50121 Florence, Italy

influence students' attitudes and motivation [8]), teachers' professional development (teachers' preparation and engagement in STEM is determinant of students' achievement in this area [9]) and guidance for pupils (the perception of classroom tasks as meaningful and relevant—i.e. motivating—influences students' perceptions of learning being useful for their future [10], affecting their interests). Moreover, pupils' interests influence their choice of future career [11,12].

Regarding ER, such aspects have been dealt with different initiatives, conferences and competitions, such as FIRST Lego League and RoboCupJunior. The European Union has also founded different projects regarding ER, including the Baby Robot project, concentrated on child-robot interaction and communication [13]; the l2tor project, aimed at supporting teaching preschool children a second language [14]; the EMOTE project, with the aim of improving the use of artificial tutors as learning-facilitator tools [15]; and the European Project RoboDidactics, aimed at introducing robotics in didactics to advance learning processes [16]. In 2012, a Public–Private Partnership (SPARC) among the European Commission, industries and academia was signed to facilitate the growth and empowerment of robotics [17]. In the SPARC Strategic Research Agenda, the use of robotics to engage children in science and technology is cited and encouraged.

Within an Italian framework, we can cite other initiatives, such as the Multi-Sectoral Network on Educational Robotics, which aims to support innovative teaching and learning practices through the use of ER. With the purpose of innovating the educational system, different actions have been undertaken. This include in particular the improvement of teachers' training and the introduction of new educational tools. New directives, concerning teachers' continuous training and professional development, include educations that concern new digital and technological resources, including robotics. In Italy, one example of such changes is the new 'Buona Scuola' direction, in which ER is inserted into the education plans of teachers in terms of digital competences [18].

Despite the fact that investment in STEM disciplines is seen as a way to increase innovation, STEM education in schools appears to be inadequate [19]. As in other European countries, the Italian educational system reflects the previously-mentioned scenario. The performances of 15-year-old students in mathematics and science are below average for the nations belonging to the Organisation for Economic Co-operation and Development [20]. Moreover, despite the interest and the commitment of European and national policies concerning the use of technologies in education, an effective introduction of new technological tools in schools is lacking. According to Alimisis [2], most of the technologies currently used in schools, including robots, are not included in educational programs and thus do not support abilities such as problem solving, decision making and communication, which are part of the key competences for lifelong learning, according to the EU [21].

1.1 Related Works

Despite the growing interest in ER within educational settings, teachers' professional STEM curricula concerning ER lack content, knowledge [22] and, most importantly, preparation in both technical and pedagogical terms [23]. The lack of preceding ER training courses and therefore adequate preparation for teachers, lowers the efficacy of ER activities in schools. Moreover, according to the literature, the efficacious employment of educational technologies basically relies on the attitudes of educators [24]. If teachers perceive themselves as being incompetent in what they teach, they tend to reduce their intent to implement activities [25].

Literature concerning ER in teacher education is lacking [9,26]. Training courses for teachers are not a common practice and reports of such sporadic activities are often inconclusive. Some limitations were reported by Kim [9] and are discussed below.

Most ER activities lack a detailed description of the trainer's training in ER. For example, Barker and Ansorge [27] described a pilot study involving a science and technology curriculum concerning robotics, but limited data on the training of the adult assistants were given. When we find information concerning the trainers' training, we can note how much of that training is focused on subjects other than robotics. Often, ER training is part of a more general preparation, including a wider set of new educational technologies, making it difficult to evaluate ER-specific methods and tools. For example, the training reported in work by Kay and colleagues [28] was mainly concentrated on programming activities. Moreover, in such training there is often a lack of theoretical background. Most ER training programs are not based on guidelines derived from learning theories, but rather are built on previous experiences. Nonetheless, there exist some inspiring examples of successful ER training programs. For instance, Alimisis [29] presented the TERECoP project, an ER program including constructivist principles, whereas Elkin and colleagues [30] implemented a robotic curriculum in a Montessori classroom.

Another problem is that most ER activities report on students' activities and children's achievements, while only briefly describing the educators' curriculum, which can be crucial. The main competences of a trainer of ER are not identified, and ER activities are performed by trainers coming from very different backgrounds. Another fundamental point is the lack of attention paid to primary school teachers. Most training in ER involves high school teachers, with only a few studies including primary teachers as targets. This is quite surprising if one considers that a large amount of data concerning ER effects found in the literature is derived from activities carried out in primary schools [6,31].

Another fundamental point involves the disregard of teachers' attitudes and motivation toward ER. Riedo and colleagues [32] carried out a survey with teachers during a robotic festival. The survey included questions on the impact of ER activities. The relationship between teachers' attitudes and motivations toward ER, and its effects on ER utilisation and effectiveness, was not fully investigated, however.

Teachers' perceptions of ER have also been neglected [9,26] in terms of awareness about advantages and disadvantages that the use of a robot in classrooms can bring about. Many studies in the literature concern perceptions and acceptability regarding socially assistive robots, but only a few pioneer examples can be found in the educative environment [33]: Chevalier and colleagues, in the conclusion of their work, stressed the importance of investigating the acceptability of robots not only by pupils, as much of the literature focuses on, but also by teachers, in order to define better strategies for developing robotics in schools [34]. The authors analysed the opinions of 43 teachers attending a training course about Thymio (an educative robot) and reported that the participants had a very strong intrinsic motivation to be trained in ER, reporting that the first cause of not using robots in the classroom is represented by the non-adequate level of a teacher's skills and his low confidence concerning robotics. For this reason, teachers found that ER can be too much time-demanding to be applicable in the classroom, because it may require time to become skilled and able to integrate robots into the curriculum [34]. Kim and colleagues [26] performed a survey on 116 teachers who performed an initial activity with an educational robot, with the purpose of investigating the teachers' perceptions of ER. The results indicated that teachers found robots useful to the school subjects investigated, particularly in improving students' creative learning. Moreover, according to the study, teachers identified ER as being particularly relevant as an inclusive tool for introverted children.

Finally, the strategies of Rusk and colleagues [35] and Alimisis [2] meant for broadening the participation of students with robotics can be taken into account during the realisation of ER training courses for teachers. Rusk and colleagues suggested concentrating activities not only on challenges, but instead on a theme. To do so, the authors suggest organising exhibitions, rather than competitions, in order to promote creativity, collaboration and sharing, while avoiding possible insane competitiveness. Moreover, it was suggested to involve not only the engineering aspect, but also to create an interdisciplinary approach. This can be done by incorporate storytelling, involving students in a narration of what they plan, what they do and how they overcome obstacles. According to psychology, narration is an important psychological mechanism not only because of the cognitive aspect it implies, but also due to its value for social exchange, and because of the mental and emotional values it possesses [36].

Alimisis [2] added further points, underlining the importance of incorporating situated activity, in the sense of asking students to move their body around the robot, to physically programme it and to follow its movement. Such a point is in accordance with the theories of embodied cognition that point out the relationship between cognition and the body [37]. Related to this point is the constructivism/constructionism paradigm, which asks students to autonomously construct and program the robot, instead of utilising ready-made products, stressing the importance of manipulation.

1.2 Goals

On the basis of this analysis, we can conclude that there is a lack in teacher training concerning ER, as well as a need for ready-to-use educational material that may improve teachers' opinions about the potential pedagogical utility and usability of ER and save the excessive time needed to prepare ER classes [9,26]. For this reason, we focused on the importance of the training of ER teachers as a key point in ER diffusion and effectiveness, by developing a specific training course (Edu.Ro.Co.). The approach of the course is based on a strong interaction between theory and practice, and it promotes critical reflection on the possible pedagogical implications of ER. Moreover, the innovation of our course relied on the investigation of teachers' attitudes toward ER, in order to collect fundamental information for new directions for future research in the ER.

In summary, the purposes of this article are twofold:

- To describe the methodology and the structure of an innovative course on Educational Robotics, that can be reutilised in future trainings.
- To discuss the course evaluation questionnaires with respect to: teachers' preparation; the potential impact of ER on students' key competences; and teachers' awareness of the strengths and weaknesses of ER. These aspects were assessed before and after the course to reveal modifications. Such modifications will contribute to the state of the art about teacher's opinion towards ER, not yet fully analysed in the literature.

The article is organised as follows. Section 2 presents the design of a training course concerning ER (Edu.Ro.Co.). Section 3 is then dedicated to the implementation of the course. Finally, Sect. 4 reports the methods utilised and the impact of Edu.Ro.Co. In Sects. 5 and 6 Discussion and Conclusions are presented.

2 Design of the Course (Edu.Ro.Co.)

2.1 The Local Context: The Tuscan Regional Network Concerning ER

The ER training course described in this paper was designed for teachers of different school levels working in the Italian region of Tuscany, who have been active in ER for many years. This context and experience motivated the use of a more rigorous methodology to design a course for teachers, and to assess its impact.

This course started in March 2015, thanks to an agreement among the BioRobotics Institute of Scuola Superiore Sant'Anna, the Tuscany Regional School Office (Ufficio Scolastico Regionale) and the Minister of Education. The objective of the agreement was to introduce and spread the use of robotics in formal education activities throughout Tuscany. A collaboration with the University of Florence (Department of Educational Science and Psychology) was begun to develop a pedagogical framework for ER. The objective of the agreement was to develop, test and evaluate new modalities of education and didactics, such as ER.

The Edu.Ro.Co. training course was attended by 339 teachers from Tuscany, 70% of whom were female and 30% were male. The schools involved in the course represented 30% of the schools present in Tuscany.

2.2 The Pedagogical Background

Because of the methodological uncertainties that usually accompany technological innovation in schools, and because of the risks associated with a naïve constructivism that is often combined with technological innovation (as pointed out in the literature [38,39]), we decided to provide trainee teachers with a structured methodological framework. Based on the literature, we aim to avoid a naïve faith in the importance of experience in the learning process, a trend that, based on a simple interpretation of constructivism theory, underestimates the importance of the structuring and selection of experiences [40].

This risk is even more important when we apply technology in classrooms, particularly those involving robots. According to Papert, manipulation is crucial for an effective student learning process, but can be insufficient without structuration. In order to avoid such risks, a connection between 'technology, pedagogy and content knowledge' has been achieved during the course in line with the TPACK, a framework resulting from 5 years of research on teacher professional development to individuate essential qualities for integrating technology in teaching [41].

Nevertheless, during the training course, we focused on some concrete obstacles that teachers must face when realising ER activities:

1. To clearly individuate the pedagogical potentialities of ER technologies in school activities;
2. To combine the didactic contents and translate them into assessable didactic goals (operationalisation of the goals);
3. To adopt didactic methods that can achieve goals as efficaciously as possible.

All these aspects are usually unclear during the utilisation of ER (and in general, during the utilisation of technologies in class). The emphasis on technologies often risks saturating the attention of educators, and the use of technologies risks becoming an end in itself. A clear and congruent utilisation of technologies in an educational context must be based on a pedagogical goal. The training course Edu.Ro.Co. met the three aspects mentioned above.

Regarding the pedagogical potentialities of ER, we elicited open reflection from trainees, which was monitored through a predefined list of choices, presented at the beginning and at the end of the course (see Table 5: Sectors in which ER can be relevant).

Regarding the second aspect, the training course aimed to enhance trainees' planning skills in didactic activities using technologies. First, during Module II, teachers were furnished with some possible applicative examples and best-cases of ER activities, for different robotic kits and age-ranged children. Afterwards, they were asked to create a didactic project involving ER and had to individuate principle elements to be taken into account during the design of the project in order to ensure its effectiveness. Each project was revised and evaluated by the tutors, and modified on the basis of the feedback received, in order to obtain a final product of value that teachers could use in classrooms (see Module III of Edu.Ro.Co., described in Sect. 3).

Regarding the didactic methods, we utilised a method taken from evidence-based education [39,42] and the efficacy of constructivism, pointing out the risks connected to a naïve constructivism [38]. For this reason, our framework is characterised by the attention given to the circular alternation between moments in which the teacher guides and provides pupils with worked examples, and moments in which pupils experiment autonomously and must justify their choices. The model is substantially in line with Merrill's five principles (Problem, Activation, Demonstration, Application, Integration) [43] and Hattie's indications for an effective didactic (clearness of goals, challenging environment, reduction of fear of mistakes, use of feedback) [39]. This method has also been implemented during an experiment conducted by several teachers. A more detailed description of its effects on children's performances will be reported in a future work.

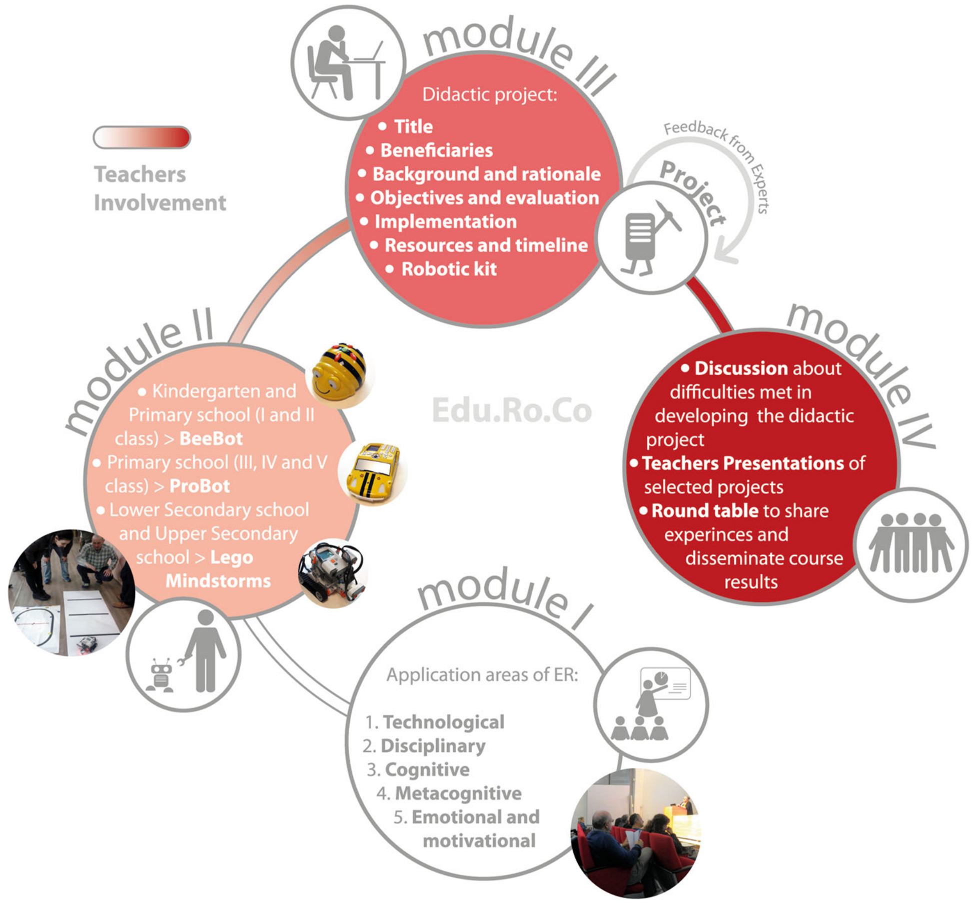

Fig. 1 Structure of the Educational Robotics Course (Edu.Ro.Co.)

3 Implementation of Edu.Ro.Co.

The training course lasted 8 months and consisted of four modules (see Fig. 1) performed successively, for a total of 32 h of training. Module I formed a theoretical framework of ER, Module II gave the chance to practise with robots, Module III resumed the contents learned by the development of an ER didactic project and finally Module IV was dedicated to feedback and sharing. Participation was free. Consent for treatment of personal information was asked before to begin the training course. Modules I, II and IV included 5 h of face-to-face training, whereas Module III was performed online.

3.1 Module I

Module I concerned the pedagogical aspects involved in ER, paying special attention to the methodological and evaluation aspects necessary to implement effective ER interventions in classrooms (see Sect. 2.2). More specifically, thanks to the collaboration with the University of Florence, we promoted the use of ER involving an appropriate educational theory and learning environment. Two main goals were inspected in this module: to reflect on the educational goal of ER and to propose some suggestions for an effective ER didactic.

The module began by introducing teachers to a reflection: does involvement in ER activities shown by children automatically imply the development of a learning environment? If a child is engaged in ER activities, and is enthusiastic and very absorbed in them, can we assume that he is learning?

The module did not give answers to such questions, but rather encouraged open reflection about them. To stimulate such reflection, a list of possible educational goals and pedagogical implications involved in the ER activities was proposed. In particular, five main application areas of ER were individuated:

1. Technological (to utilise ER as a way to teach the principles of technology and robotics, such as programming);
2. Disciplinary (to use ER to consolidate school subjects, such as geometry);
3. Cognitive (to utilise ER to empower children's abilities to, for example, solve problems and plan strategies);
4. Metacognitive (to use ER as a method to improve children's ability to reflect about what they learn and as a tool to spread the scientific approach);
5. Emotional and motivational (to use ER as a learning environment lacking fear of mistakes and anxiety; motivational and useful to improve self-esteem).

After exploring each aspect, based on the presentation of the theoretical aspects behind them (see Sect. 2.2), the module focused on its second goal, asking teachers to reflect on the importance of considering education as a science, based on evidence. For this reason, Hattie's indications for an effective didactic (clearness of goals, challenging environment reduction of fear of mistake, use of feedback) [39] were discussed.

In line with such reflection, the last part of Module I was dedicated to the explanation of how to develop a didactic project utilising technology (particularly ER). To be able to develop a didactic project means having the skills and the instruments to evaluate activities conducted in classrooms, and to eventually adjust actions on the basis of the results gained. Such scheduling avoids the naïve application of constructivism principles we cited in the preceding subsection.

To develop a didactic project, the ADDIE method was proposed. The ADDIE model is a background that presents the steps that instructional creators and training developers use to build effective preparation [44]. It consists of five phases:

- Analysis
- Design
- Development
- Implementation
- Evaluation

3.2 Module II

This module is divided into an initial lesson part followed by a laboratory-phase part. Module II showed different examples of practical applications (possible actions that can be performed in classrooms with children) of the pedagogical context through ER activities [39,42,43], applying the recommendations given during Module I. In other words, we showed teachers some good practical use-cases, proposing ER activities to students as a problem to solve, a challenge task. A scientific approach to the activities was promoted: teachers had to encourage students to identify the problem, propose a hypothesis, experiment, analyse the results, share opinions and finally generalise the conclusions, readjusting Merrill's framework [43].

The practical examples were specifically proposed for distinct age-ranges, as follows:

- Kindergarten and Primary school (I and II class);
- Primary school (III, IV and V class);
- All the classes of Lower Secondary school and Upper Secondary school.

Such age-ranges reflect different students' backgrounds and goals.

The following commercial robotic kits were chosen for the practical example based on the age-range considered: Bee-bot (TTS Group) for Kindergarten and Primary school (I and II class); Pro-bot (TTS Group) for Primary school (III, IV and V class) and Lower Secondary school (I class); and Lego Mindstorm (LEGO) for Lower Secondary school and Upper Secondary school.

The kits were chosen based on our experiences, their diffusion on the local market and in schools, and their usability, cost and versatility. It is worth noting that the core of the course was focused on the pedagogical approach to ER, which is not strictly linked to any specific robotic platform. Our key point consists of shifting the focus from technology to learning principles [2]. That is to say, our course did not aim to propose the best practise with the utilisation of specific kits, but rather to enable the teachers to individuate the best practise with every different kind of robot they would likely utilise.

Bee-bot is a bee-shaped robot (TTS Group) capable of storing a series of commands (up to 40). The programming of the robot is conducted through buttons placed on the back of the Bee-bot: buttons with directional arrows allow the robot to move 15 cm forward or backward, and rotate right or left (90° rotation) in the space; a 'Go'-green button allows the robot to start moving; a 'Cancel' button erases the memory of the robot and a 'Pause' button is used to temporarily stop the robot (http://www.tts-group.co.uk/bee-bot-rechargeable-floor-robot/1001794.html).

Pro-bot (TTS Group) is a race-car shaped robot, programmable via buttons on the board and sensors for touch, light and sound. Pro-bot can be programmed to allow movement of variable distances and rotation of variable angles (http://www.tts-group.co.uk/pro-bot-rechargeable-floor-robot/1009825.html).

Finally, Lego Mindstorm (LEGO) is a kit containing robotic components that are Lego compatible. Regarding the hardware, the kit contains different kinds of sensors (contact, colour/light, ultrasound) and two actuators. A final brick is the control unit that completes the kit. The robot can be assembled in various ways and programmed due to a purposive software (http://www.lego.com/en-gb/mindstorms).

In our practical example, we adapted the ADDIE model so that different steps were individuated in the development of each activity (for a simplification of a possible example, see Table 1):

- Identification of addressee;
- Identification of possible goals (skills that an ER activity can stimulate) achievable with the help of ER. These goals may refer to each of the five areas identified in Module I (but not necessarily for all of them);
- Identification of resources needed (time, materials and class organisation necessary for the activities);
- Design of different ER activities;

Table 1 Example of a possible ER activity following the Edu.Ro.Co. method

Title	Geometry and forms
Age of addressee	Lower secondary school
Goals	*Technological area*:
	to acquire appropriate terms of robotics,
	to observe a reverse engineer approach,
	to acquire principle basis of programming;
	Educational area:
	principles of geometry- the solid
	Cognitive area:
	to stimulate problem solving,
	to analyse movements in the space,
	to utilise symbolic systems (coding)
Resources	Material: pro-bot, pencils, goniometers
	Time: 2 h
	Class organisation: students have to work in small groups, in order to let them expertise as much as possible and in order to promote a collaborative climate. All the children have to program the robot by respecting turns of work
Activity's phases	Phase 1. Problems and goals: how to make Pro-bot design a square?
	Phase 2. Personal recognition of students
	Phase 3. Modelling (teacher tutoring)
	Phase 4. Planning of the solution by students
	Phase 5. Implementation of the solutions
	Phase 6. Reflection about the work done
	Phase 7. Sharing of the results in the classrooms
Evaluation	Questionnaires about:
	Technological area:
	To acquire appropriate terms of robotics: questions about significance of the term sensor, motor, etc
	To acquire principle basis of programming: did the child design a square with Pro-bot?
	Educational area:
	Principles of geometry- the solid: did the child know how a square is build?
	Cognitive area:
	Did the child design a square with Pro-bot? How did he do?

- Design of the evaluation methods for each goal, in order to test the efficacy of the activities proposed.

After the initial lesson, different laboratories concerning ER were undertaken. In such laboratories, teachers had the opportunity to attempt to utilise the robot and become familiar with its utilisation and preparation. The Edu.Ro.Co team showed teachers the basics for the construction and programming of the three robotic kits cited.

3.3 Module III

Module III was conducted online. A Moodle platform was created for this e-learning phase (http://www.roboticaeducativatoscana.net/retemoodle). The platform offered download and upload possibilities, used for different goals. First, the platform was used to share contents, research materials and information about ER (videos, power-point presentations, documents, images), with specific web-pages for each module. The platform was also used to obtain feedback about teachers' experiences with robots. In addition, the e-learning platform was used to test teachers' attitudes toward ER during the course, through apposite questionnaires described in Sect. 4.2.

Finally, the Moodle platform was used to share a template for the realisation of an ER project during school time. The template was developed by Calvani and Menichetti [45] building upon the ADDIE framework, and its structure highlighted the main elements to be considered during the design of an effective didactic project, including the use of new technologies. The template was quite complex, but can be summarised based on its principal points: identification of the project's title and of the beneficiaries; description of the background and rationale; recognition of the objectives and evaluation methods; project's implementation; characterisation of resources needed and creation of a timeline; and description of the robotic kit to utilise. Each teacher filled in the form, and each project was revised and evaluated by the tutors. The intent of Module III was to enable teachers to develop an ER didactic project after being trained in its theoretical (Module I) and practical (Module II) aspects. In order to leave the teachers a product of quality, every project was read and discussed by the team at Edu.Ro.Co., and the feedback given to teachers allowed them to reflect on ways to improve their work.

3.4 Module IV

Module IV was dedicated to teachers' feedback. Specifically, a discussion concerning the main difficulties met by teachers in the development of the didactic project utilising ER was performed. In the second part of the module, a number of teachers, based on a ranking made by the Edu.Ro.Co. team, were invited to present their projects to the other participants and, eventually, share their experiences in class, if the project was implemented. A round table for sharing experiences and disseminating course results was organised. This meeting was purposed to discuss various good examples of ER application in class, with the distinct robots applied to different age ranges of children. We believe that this bottom up procedure was essential for the definition of the protocol in which ER must be applied.

4 Impact of Edu.Ro.Co.

In this section, we describe the materials and methods used to assess the impact of the Edu.Ro.Co. training course and the results of the experience.

4.1 Participants

From the initial sample of teachers registered for the course, 254 teachers (71.7% female and 28.3% male) completed the entire ER training course and thus represent the final sample for the following analysis. Table 2 shows details concerning participants.

The age range of the teachers involved in the course was 29–65 years old (average 49 years old), distributed as follows: 2.4% aged 26–35 years, 31% aged 36–45 years, 43% aged 46–55 years and 22.4% aged 56–65 years. Three subjects did not report their age.

The participants' teaching experience varied between 1 and 40 years, with an average of 19 years. The teachers represented all educational levels in the Italian school system

Table 2 Participants details

Sex			Age		
			No answer	3	1.1%
M	72	28.3%	26–35	6	2.4%
F	182	71.7%	36–45	79	31.1%
			46–55	109	42.9%
			56–65	57	22.4%
Total	254	100.0%	Total	254	100.0%
School			**School experience**		
Kindergarten	15	5.9%	1–10	62	24.4%
Primary	103	40.6%	11–20	80	31.5%
Lower secondary	78	30.7%	21–30	78	30.7%
Upper secondary	58	22.8%	31–40	34	13.4%
Total	254	100.0%	Total	254	100.0%

(see Table 3 for a brief description of the Italian educational system): primary school (40.6%), lower secondary (30.7%), upper secondary (22.8%) and a small part from kindergarten (5.9%).

Overall, 24% of the study population had previous experience with ER in the classroom.

4.2 Evaluation Tools: Questionnaires

Participants in the training course were asked to complete a pre-course questionnaires (T0) and a post-course questionnaires (T1) in order to evaluate the modification of their attitude towards ER, as well as their perception of competences at stake in the utilisation of robots.

All the questionnaires were developed ad hoc for the research purposes and were administered through the e-learning platform Moodle.

Pre- and post-course questionnaires had similar structures, consisting of several sections:

1. A personal details section, in order to describe the profile of the participant (not fully included in the post-course questionnaire).
2. A section on competences perception (see Table 4). Teachers were asked to report on their perceptions of competences in different areas (teaching skills, technical skills, pedagogical skills, planning skills) using a 7-point Likert scale.
3. A survey on didactics and robotics. Part of the survey is reported in Table 5. The survey investigated:
   - Previous experience in ER, explored by multiple choice questions (*'Have you ever utilised ER? If yes, for how long? Which platforms did you utilise?'*). We also asked if teachers carried out

Table 3 Brief description of the Italian educational system

The Italian educational system
Education in Italy is regulated by the Minister of Education, University and Research with a differentiation between public, private and equal ("*paritarie*") schools. Italian educational system is divided into (Dpr 89/2009):
– Pre-Primary education (Kindergarten). The age of pupils is from 3 to 5 years old and the cycle is not compulsory
– I cycle includes Primary education and Lower Secondary school. Primary school consists in 5 years, from 6 to 10 years old. The enrolment is universal. Lower Secondary school lasts 3 years, it is mandatory and students have to pass a national final examination to obtain a Diploma
– II cycle includes Upper Secondary school. Upper Secondary school has a duration of 5 years and is divided into different types:
1. Fine arts schools and institutes (*Istituto d'arte, liceo artistico, liceo musicale e coreutico*);
2. Vocational schools (*Istituto professionale*);
3. Technical schools (*Istituto tecnico*);
4. Academic Upper Secondary schools (*Liceo classico, scientifico, linguistico, delle scienze uman*e)
The completion of such cycle is recommended but not compulsory. By the end of the 5-years cycle a second Diploma is obtained
– Higher Education, including Universities, High artistic formation, Academic higher education. The number of the years, the age of attendance and the criteria of entrance may variate

Table 4 Competences perception section

How much do you feel competent in the following skills (choose a valour from 1-not competent to 7-very competent)	
Pedagogical skills	To be able of individuate critically results that can be achieved in the classroom with the help of ER and set them with the scholastic goals
Planning skills	To be able of realize an appropriate didactic project in terms of goals and evaluation tools; To be able to realize a didactic project that can be shared
Technical skills	To be familiar with basic principles about robotics
Teaching skills	To be able to utilise and take advantage of ER in class, with respect to places, materials, time…

ER activities during the training course period in the post-course questionnaire.
- Sectors in which the use of ER can be relevant. These sectors represent some pedagogical potentialities of ER and are partly taken from Recommendation 2006/962/EC of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning [21]. Answers were given on a 7-point Likert scale.

4. A section meant to measure the teachers' awareness of the strengths and weaknesses of ER, evaluated by multiple choice questions. More than one answer could be given.

4.3 Statistical Analysis

In order to evaluate the teachers' knowledge and attitudes toward ER, a deep analysis of the questionnaires was performed. Statistical Package for Social Sciences, version 22 (IBM SPSS Statistics, IBM Corporation, Armonk, NY) was utilised for statistical analyses.

Non-parametric comparisons (Wilcoxon test) were carried out in order to verify the effect of the ER training course on teachers' perceptions of competences (technical, teaching, pedagogical and planning skills), comparing responses (7- point Likert scale) to the pre-course questionnaire (T0) and post-course questionnaire (T1). A one-tailed Wilcoxon test was used. The research hypothesis was that the median differences between pairs of observations was > 0. In other words, the one-tail-choice reflected the research hypothesis that there would be an improvement in the teachers' competences.

Non-parametric comparisons (Wilcoxon test) were also carried out to verify the changes in teachers' attitudes towards ER during the training course Edu.Ro.Co.. The pre-course questionnaire (T0) and post-course questionnaire (T1) responses were compared on a 7-point Likert scale concerning sectors in which ER can be relevant.

A two-tailed Wilcoxon test was used, when the research hypothesis was that the median differences between pairs

Table 5 Questions from the questionnaires concerning didactics and robotic

What kind of strengths do you find or do you think it is possible to find by organising ER activities?	What kind of weaknesses do you find or do you think it is possible to find by organising ER activities?	How much do you find ER relevant to support following skills (choose a valour from 1-not relevant to 7-very relevant)
• Improvement of student's attention capacities	• The robots cost too much	1. Motivation improvement
• Improvement of student's preparation for the work's world	• ER activities are too much time demanding	2. Self-efficacy
• Attraction of student's attention	• Learn to work with robot is difficult	3. Autonomy and responsibility
• Improvement of student's motivation	• ER kits available in the market are not adequate	4. Capacity to be interdisciplinary and to individuate relationship
• Improvement of student's self-learning capacities	• There is a lack of appropriate teaching methods for ER	5. Planning skills
• Improvement of student's team working capacities	• There is a lack of appropriate evaluation methods for ER's effectivity	6. Metacognitive skills
• Student's learn how to learn from mistakes		7. Digital competence
• It is possible to put in practise theoretical notions	• Head teacher support is missing	8. Mathematical competence and basic competences in science and technology
• Other (to specify)	• Other (to specify)	9. Scientific and technological skills
		10. Social and civic competences
		11. Visual-spatial skills
		12. Communication in the mother tongue
		13. Communication in foreign languages
		14. Cultural awareness and expression
		15. Epistemological
		16. Self-esteem improvement
		17. Diffusion of the technological knowledge
		18. Team working
		19. Problem solving skills
		20. Critical representation of technology
		21. Sense of initiative and Entrepreneurship
		22. Creativity development

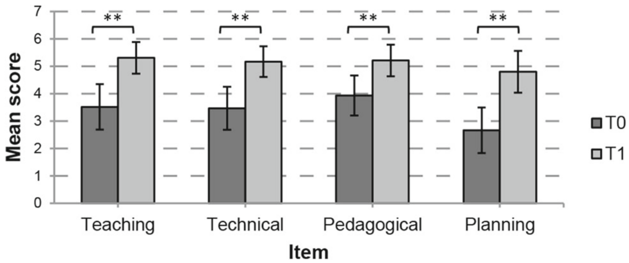

Fig. 2 Results of Wilcoxon test analysis of perceptions of competences

Table 6 Perception of competences Wilcoxon test analysis

Item	*Z*	*p*
Teaching skills	– 11.841	.000
Technical skills	– 12.349	.000
Pedagogical skills	– 11.533	.000
Planning skills	– 10.053	.000

of observations was different from 0. In other words, the two-tail-choice reflected the research hypothesis of a bi-directional change in the teachers' opinions towards ER relevance. This was a result of the open reflection encouraged during the course that describe new teachers' opinions about ER.

McNemar's χ^2 test was utilised in order to verify changes in the teachers' attitudes towards ER during the training course Edu.Ro.Co.. The pre-course questionnaire (T0) and post-course questionnaire (T1) responses to multiple-choice questions about awareness of ER key strengths and weaknesses were compared. The results describe the new teachers' opinions toward ER.

Significance level was $p < .05$ for all the analysis carried out.

4.4 Results

4.4.1 Perception of Competences

Wilcoxon test analysis revealed a significant difference between T0 and T1 concerning competence perceptions (*Teaching skills*: $Z = -11.841$, $p < .001$; *Technical skills*: $Z = -12.349$, $p < .001$; *Pedagogical skills*: $Z = -11.533$, $p < .001$; *Planning skills*: $Z = -10.053$, $p < .001$; see Fig. 2 and Table 6).

4.4.2 Sectors in Which ER Can be Relevant

Descriptive analysis showed that ER was considered relevant in all the sectors that were proposed. The mean scores obtained on the 7-points Likert scale varied from 4.57 for the item 'Epistemological awareness' to 6.04 for the item 'Motivation improvement' in T0, and from 4.63 for the item 'Communication in foreign languages' to 6.05 for the item 'Motivation improvement' in T1.

Wilcoxon test analysis (Fig. 3 and Table 7) revealed a significant decrease from T0 to T1 in the following sectors:

- Planning skills ($Z = -2.246$; $p < .05$)
- Digital competence ($Z = -2.660$; $p < .01$)
- Scientific and technological skills ($Z = -2.238$; $p < .05$)
- Communication in foreign languages ($Z = -3.328$; $p = .001$)
- Sense of initiative and entrepreneurship ($Z = -1.981$; $p < .05$)

Wilcoxon test analysis (Fig. 3) also revealed a significant increase from T0 to T1 in the following sectors:

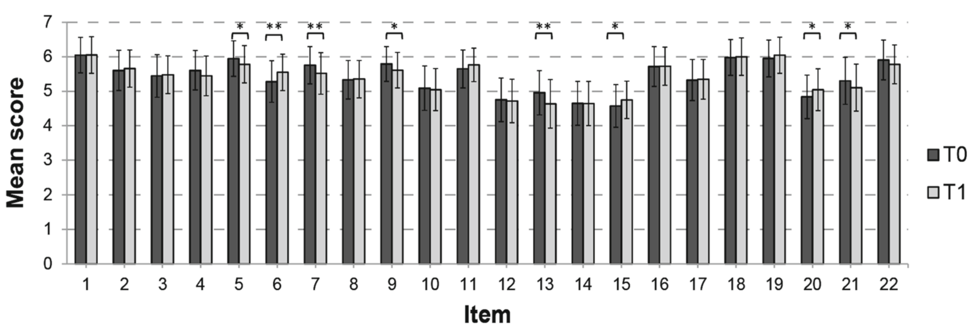

Fig. 3 Results from Wilcoxon test analysis of sectors in which ER can be relevant. Items: 1. Motivation improvement, 2. Self-efficacy, 3. Autonomy and responsibility, 4. Capacity to be interdisciplinary and to individuate relationship, 5. Planning skills, 6. Metacognitive skills, 7. Digital competence, 8. Mathematical competence and basic competences in science and technology, 9. Scientific and technological skills, 10. Social and civic competences, 11. Visual-spatial skills, 12. Communication in the mother tongue, 13. Communication in foreign languages, 14. Cultural awareness and expression, 15. Epistemological awareness, 16. Self-esteem improvement, 17. Diffusion of the technological knowledge, 18. Team working, 19. Problem solving skills, 20. Critical representation of technology, 21. Sense of initiative and entrepreneurship and 22. Creativity development

Table 7 Sectors in which ER can be relevant Wilcoxon test analysis

Item	*Z*	*p*
Motivation improvement	– .027	.975
Self-efficacy	– .270	.776
Autonomy and responsibility	– .633	.512
Capacity to be interdisciplinary and to individuate relationship	– 1.758	.068
Planning skills	– 2.246	.021*
Metacognitive skills	– 3.250	.000**
Digital competence	– 2.660	.005**
Mathematical competence and basic competences in science and technology	– .289	.756
Scientific and technological skills	– 2.238	.019*
Social and civic competences	– .354	.720
Visual-spatial skills	– 1.497	.123
Communication in the mother tongue	– .399	.680
Communication in foreign languages	– 3.328	.000**
Cultural awareness and expression	– .054	.957
Epistemological awareness	– 2.137	.026*
Self-esteem improvement	– .162	.866
Diffusion of the technological knowledge	– .333	.729
Team working	– .194	.840
Problem solving skills	– 1.260	.200
Critical representation of technology	– 2.379	.013*
Sense of initiative and entrepreneurship	– 1.981	.038*
Creativity development	– 1.771	.065

* $p < .05$; ** $p \leq .01$

- Metacognitive skills ($Z = -3.250$; $p = .001$)
- Epistemological awareness ($Z = -2.137$; $p < .05$)
- Critical representation of technology ($Z = -2.379$; $p < .05$)

4.4.3 Awareness Concerning ER Key Strengths and Weaknesses

Given the possibility to choose more than one item from the given list of ER key advantage, each item was highly selected (more than one hundred times by the population, both in T0 and in T1, with the only exception being 'Improvement in the students' preparation for the work world' and 'Other'). Percentages calculated based on the total items selected spanned from 2.67% for 'Improvement in the students' preparation for the work world' to 17.96% for 'Improvement in the students' team working capacities' and 17.12% for 'Improvement in the students' motivation' in the pre-course questionnaire. In contrast, percentages ranged from 1.96% for 'Improvement in the students' preparation for the work world' to 15.68% for 'Improvement in the students' motivation' and 15.34% for 'Students learn how to learn from mistakes' in the post-course questionnaire (the item 'Other' was omitted from the count because of its poor helpfulness). Disadvantages were selected by a minor part of the study population, and no item was selected more than hundred times in either T0 or T1 (only exception was 'The robot costs too much'). Percentages calculated based on the total items selected spanned from 1.36% for 'ER available on the market are not adequate' to 41.41% for 'The robot costs too much' in the pre-course questionnaire, and from 0% for 'Head teacher support is missing' and 'ER available on the market are not adequate' to 50% for 'The robot costs too much' in the post-course questionnaire.

Table 8 Awareness concerning ER key strengths and weaknesses McNemar test analysis

Item	χ^2	sig.
Improvement of student's attention capacities	.750	.387
Improvement of student's preparation for the work's world	1.422	.233
Attraction of student's attention	.011	.918
Improvement of student's motivation	4.494	.033*
Improvement of student's self-learning capacities	2.344	.125
Improvement of student's team working capacities	21.013	.000**
Student's learn how to learn from mistakes	4.628	.031*
It is possible to put in practise theoretical notions	.414	.520
The robots cost too much	21.094	.000**
ER activities are too much time demanding	.507	.477
Learn to work with robot is difficult	12.121	.000**
ER kits available in the market are not adequate		.063
There is a lack of appropriate teaching methods for ER	.463	.497
There is a lack of appropriate evaluation methods for ER's effectivity	2.613	.105
Head teacher support is missing		.000**

* $p < .05$; ** $p \leq .01$

McNemar's test analysis (see Table 8) revealed a significant decrease in the number of teachers that identified 'Improvement of students' motivation' ($\chi^2 = 4.494$; $p < .05$) and 'Improvement of students' team working capacities' ($\chi^2 = 21.013$; $p < .001$) as ER strengths. Meanwhile, there was a significant increase from T0 to T1 in the number of teachers that identified 'Students learn how to learn from mistakes' ($\chi^2 = 4.628$; $p < .05$) as an ER strength (Fig.4).

Moreover,a significant decrease from T0 to T1 was found in the number of teachers that individuated 'Learning to work with robot is difficult' ($\chi^2 = 12.121$; $p < .001$) and 'Head teacher's support is missing' ($p < .001$) as ER weaknesses. In contrast, a significant increase was found in the number of teachers that individuated 'The robots cost too much' ($\chi^2 = 21.094$; $p < .001$) as ER disadvantage (Fig. 5).

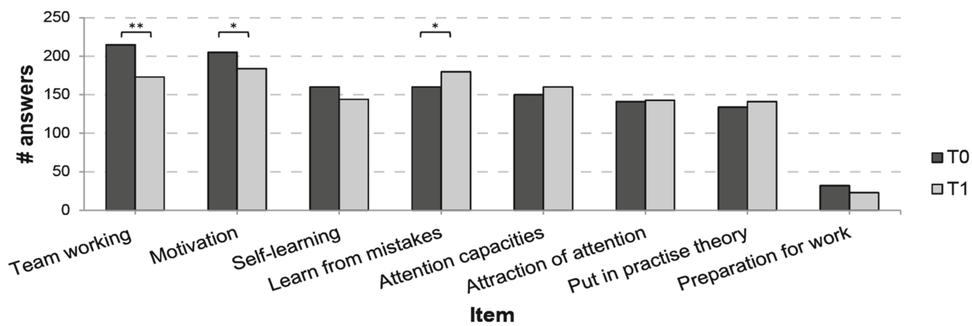

Fig. 4 Results of McNemar's χ^2 test analysis concerning awareness of ER key strengths. Percentages are calculated based on the total number of items selected

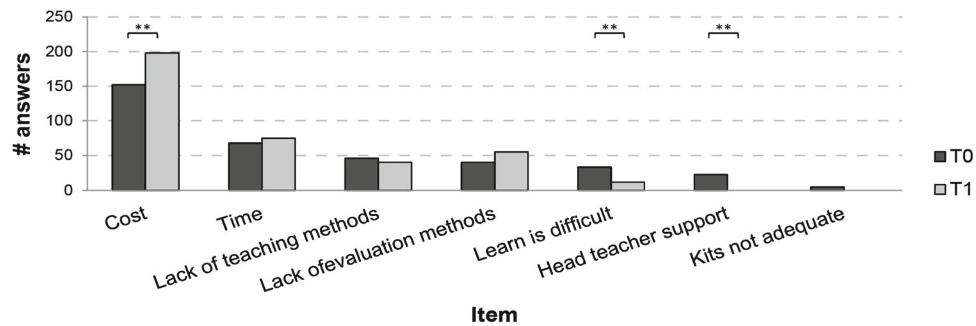

Fig. 5 Results of McNemar's χ^2 test analysis concerning awareness of ER key weaknesses. Percentages are calculated based on the total number of items selected

Finally, based on our survey concerning didactics and robotics, we found that 156 teachers (61.4%) had carried out an ER laboratory experience during the period of the training course.

5 Discussion

The current article presents an approach to teaching Educational Robotics grounded on a pedagogical background and based on a literature analysis about ER training courses. Our approach to ER was used during the training course Edu.Ro.Co., which took place in Italy from November 2015 to May 2016. We trained teachers in ER, stressing the pedagogical and the learning theories beyond the utilisation of robots in educational settings, while encouraging teachers to utilise a method in order to test the efficacy of activities with robots, enhancing the trainees' skills in the implementation of didactic activities with technologies (Module I). We supported this enhancement with practical activities shown and effectuated during Module II, where some possible applicative examples and best-cases of ER activities were shown, for different robotic kits and age ranges of children. Moreover, we then asked teachers to develop a didactic project (explained during Module III) utilising robots, putting into practise the content of the preceding lessons. Finally, feedback concerning the results of Module III were given and shared (Module IV), leaving to teachers (and other possible Moodle users) with many materials for possible future application of ER activities in classrooms.

The novelty of our method consists of going beyond constructivism principles, making an effort to prevent a naïve utilisation of robots in the classroom, guiding teachers to balance instructional guidance and autonomous work during ER activities, stressing metacognitive skills and involving not only robotics, but also other subjects (STEM areas). We intended to integrate technological, pedagogical and psychological aspects to create a learning environment where the robot becomes a 'facilitator' of the learning process. We aim to move from a concentration on technology to one on learning principles [2], in order to leave teachers able to conduct ER activities independently of the robotic kits they would like to use (after, of course, having obtained a knowledge of the new kit in question and having performed an adaptation of our method). In fact, such an approach can be adapted to pupils of different ages and to different robotics kits.

After presenting the Edu.Ro.Co. training course, in order to share our method for future applications, the second aim of our investigation was to evaluate the course with respect to teachers' preparation; the potential impact of ER on students' key competences; and teachers' awareness of the advantages and disadvantages of ER.

We ascertained that the ER training course had a large participation: 339 teachers from Tuscany, accounting for nearly 30% of the schools present in the region. To the best of our knowledge, our course represents the highest number of teachers ever involved in an ER training course, at least in Italy. Eighty-five teachers did not complete the course, likely due to its length. Moreover, the course had pre-established data for each module that may have been incompatible with other teachers' personal commitments. In a future edition of the course, more care will be taken to collect information from teachers who drop out of the course. The data can be considered as evidence of teachers' interests in ER, and of the presence of a large demand for ER training. Moreover, 156 teachers (61.4%) carried out an ER laboratory experience during the period of the training course, putting into practise our teaching and demonstrating enthusiasm and trust in the usability of ER.

The results of Edu.Ro.Co. questionnaires suggest three main ideas:

1. The number of teachers that considered themselves prepared for the utilisation of ER (teaching skills, technical skills, pedagogical skills, planning skills) significantly improved after the training course.
   This data describes the large impact that an ER course can have on teachers' perceptions of their own competences. Classic theory concerning self-efficacy suggests that the perception of competences is strictly correlated with results in terms of performances, engagement and persistence [46]. For this reason, we can speculate that an improved self-perception of competences could lead to efficacious ER activities in the classroom, bringing more effective results in terms of students' learning.
2. ER is considered relevant in many sectors. Our intervention consisted of a discussion concerning possible pedagogical implications for ER (including didactic knowledge, digital competences, cognitive and metacognitive processes, self-esteem and motivation) and a series of demonstrations of how ER can be utilised. The results of our questionnaires showed that all the sectors proposed obtained a medium score ranging from 4.5 to 6 (7 was the maximum score), both in T0 and T1. In particular, independent from changes between T0 and T1, ER was considered an important tool for the improvement of students' motivation, planning skills, team working, problem solving and creativity development.
   From an ER 'based' view (results in T0), a new one was produced, leaving teachers more aware of ER. By the end of the course, in fact, some modifications of teachers' opinions about ER were observed; planning skills, digital competence, scientific and technological skills, foreign language expression and initiative spirit were sectors in which teachers appeared to modify their opinions, giving less importance at T1. This decreasing trend could be due to an initial naïve view of robotics, which then changed with practise (i.e. the identification between robotics and digital competence, or the belief that robotics can solve some disciplinary problem, or teach a foreign language). On the contrary, perception of the relevance of ER in metacognition improvement, epistemological awareness and the critical representation of technology increased. Such results can be read as a first attempt to investigate teachers' view of ER in order to customise future directions in ER research, in terms of ER training course but also commercial kits, scientific goals and ER diffusion in schools.
   Moreover, such results are in line with, but add further information to, a previous study [34], where Swiss teachers of the first, second and third cycles (corresponding to children 4–15 years of age) perceived using robots in teaching as benefits targeting the 'reflective process' (93%) and 'collaboration' (90%), together with other transversal skills, such as 'communication', 'learning strategies' and creative thinking', obtaining an approval of over 70%.
3. Educational Robotics is considered to have many advantages. Based on our T0 results, we can form an idea of teachers' attitudes towards ER. In particular, teachers considered team working abilities and improvement in motivation to be the principal strengths of ER. In contrast, the main weaknesses were considered to be the cost of the robotic kit, often too expensive for the schools, and the great amount of time required for ER activities. Such findings are in agreement with previous results [34,47].
   During Edu.Ro.Co., the views concerning ER strengths and weaknesses partly changed. Teachers realised that learning to use a robot can be a potential tool to improve students' abilities to learn from their own mistakes (learn to learn, a meta-cognitive ability), whereas the potential to motivate students and to teach them how to work in a team was not considered to be a strong point, as previously thought. We believe that this last finding can be explicated by considering the difficulties experienced by teachers in carrying out team working activities. They are often left alone during ER activities, and they may have difficulty managing many groups of pupils working in parallel with robots. Regarding the potential for ER to motivate students, although we observed a decrease in the number of teachers that selected this item from T0 to T1, motivation remained one of the most selected and significant items, both as "Sectors in which ER can be relevant" and both as advantage of ER.

In summary, we believe that such results may be an important starting point for a new view of Educational Robotics, grounded in pedagogical background, learning theories and careful evaluation of the learning implications of activities. Moreover, our work stresses the importance of teachers' preparation and opinions toward ER in realising the effectiveness of new ER. The results of the present study add important information to the state of the art about teacher's attitude towards ER, not yet fully explored in the literature, and fundamental to improve future ER training courses and for the diffusion of ER in the school settings. As reported by a previous study [34], the presence of robots in the classroom is strictly dependent on the ER training opportunities of teachers and the presence of usable pedagogical materials that will save teachers time.

As far as the limitations of our study are concerned, we should first mention that the results of our study are related to the specific robotic kits we decided to use in our training course and therefore can perhaps not be generalised to other robotic tools. Secondly, our population voluntarily attended the Edu.Ro.Co. training course. The group was therefore a well-motivated one and thus when evaluating our results, this aspect should also be taken into account. Moreover, the evaluation tools we used in our analysis were designed ad hoc and were not standardised questionnaires. Finally, the validity of the experience could be improved in the future by adding a control group performing different approaches to ER.

6 Conclusions

This paper presents a training course in Educational Robotics conducted for teachers. Our results show: teachers are interested in the use of robotics in school education, and they can be trained in ER in a short time and in an effective way. Moreover, the presented training course caused teachers to modify their attitudes towards ER, questioning the pedagogical value of robotics and the strengths and weaknesses of ER, and convincing them to abandon a naïve conception of ER, strictly related to a simple constructivism principle utilisation.

We believe that this description of teachers' opinions about ER can represent a first attempt in the study of ER by teachers. In particular, an enhancement in the quality of ER utilisation is possible only by improving teachers' realization concerning the possibility to integrate robotics and educational goals. In other words, it is not sufficient to give children a new technological tool in order to obtain an improvement in the learning process. Particularly relevant in our approach is the focus on metacognitive activities (epistemological awareness): the ability 'to set goals, to detect discrepancies between goals and the current state of mastery, to continuously and accurately monitor ongoing learning behaviour, as well as to initiate regulatory processes to the benefit of task performance' [48]. During our course, we strongly indicated a scientific approach applied to any activity with robots, readjusting Merrill's principles [43]. We encouraged teachers to present the ER activities to children as a challenge activity, a problem to solve, where children are encouraged to think before acting. We emphasised on reflection and freedom from fear of making mistakes as essential parts of the scientific approach.

In conclusion, we believe that our local experience could represent an interesting starting point in the design of effective training courses in ER for teachers. Measuring the impact of such a course could give important insight into the relevance of teacher preparation. Our methodology can be reutilised in future trainings. This work could be integrated into a larger network, involving not only Italian reality but covering all of Europe. Synergies with different experiences could be an effective effort in order to include ER laboratories in schools' curricula, with the attempt to improve STEM abilities in children and in teachers, and to finally demonstrate the effectiveness and efficacy of Educational Robotics [2].

Acknowledgements This work was partially funded by the Tuscany Region. The authors would like to thank all the teachers involved in the training course.

Compliance with Ethical Standards

Funding: This study was partially funded by the Tuscany Region.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

References

1. Benitti FBV (2012) Exploring the educational potential of robotics in schools: a systematic review. Comput Educ 58(3):978–988
2. Alimisis D (2013) Educational robotics: open questions and new challenges. Themes Sci Technol Educ 6(1):63–71
3. Piaget J (1973) To understand is to invent: the future of education. Grossman, New York
4. Papert S (1980) Mindstorms: children, computers, and powerful ideas. Basic Books Inc, New York
5. Papert S, Harel I (1991) Situating constructionism. Constructionism 36(2):1–11
6. Datteri E, Zecca L (2016) The game of science: an experiment in synthetic roboethology with primary school children. IEEE Robot Autom Mag 23(2):24–29
7. Kearney C (2011) Efforts to increase students' interests in pursuing science, technology, engineering and mathematics studies and careers. In: National measures taken by 21 of European Schoolnet's Member Countries. European Schoolnet, Brussels. http://www.fisme.science.uu.nl/publicaties/literatuur/2011_european_schoolnet.pdf
8. Skinner EA, Belmont MJ (1993) Motivation in the classroom: reciprocal effects of teacher behavior and student engagement across the school year. J Educ Psychol 85(4):571
9. Kim C, Kim D, Yuan J, Hill RB, Doshi P, Thai CN (2015) Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. Comput Educ 91:14–31
10. Greene BA, Miller RB, Crowson HM, Duke BL, Akey KL (2004) Predicting high school students' cognitive engagement and achievement: contributions of classroom perceptions and motivation. Contemp Educ Psychol 29(4):462–482
11. Archer L, DeWitt J, Osborne J, Dillon J, Willis B, Wong B (2013) Not girly, not sexy, not glamorous: primary school girls' and parents' constructions of science aspirations. Pedagogy Cult Soc 21(1):171–194
12. Maltese AV, Tai RH (2010) Eyeballs in the fridge: sources of early interest in science. Int J Sci Educ 32(5):669–685

13. Palogiannidi E, Koutsakis P, Losif E, Potamianos, A (2016) Affective lexicon creation for the Greek language. In: 10th edition of the Language Resources and Evaluation Conference (LREC), 23–28 May 2016, Portorož, Slovenia
14. Kennedy J, Baxter P, Belpaeme T (2017) Nonverbal immediacy as a characterisation of social behaviour for human-robot interaction. Int J Soc Robot 9(1):109–128
15. Castellano G, Paiva A, Kappas A, Aylett R, Hastie H, Barendregt W, Bull S (2013, July) Towards empathic virtual and robotic tutors. In: International conference on artificial intelligence in education. Springer, Berlin, pp 733–736
16. Bredenfeld A, Hofmann A, Steinbauer G (2010) Robotics in education initiatives in Europe-status, shortcomings and open questions. In: Proceedings of international conference on simulation, modeling and programming for autonomous robots (SIMPAR 2010) workshops, pp 568–574
17. Bogue R (2014) The future of robotics in Europe. Ind Robot Int J 41(6):487–492
18. Capuzza V, Picozza E, Spirito N (2016) La buona scuola: introduzione alla riforma dell'istruzione italiana. G Giappichelli Editore
19. Osborne J, Dillon J (2008) Science education in Europe: critical reflections, vol 13. The Nuffield Foundation, London
20. https://www.oecd.org/pisa/keyfindings/PISA-2012-results-italy.pdf
21. http://eur-lex.europa.eu/legal-content/IT/TXT/?uri=uriserv:OJ.L_.2006.394.01.0010.01.ITA&toc=OJ:L:2006:394:FULL
22. Greenberg J, McKee A, Walsh K (2013) Teacher prep review: A review of the nation's teacher preparation programs. Available at SSRN 2353894. https://files.eric.ed.gov/fulltext/ED543515.pdf
23. Mataric MJ, Koenig NP, Feil-Seifer D (2007, March) Materials for enabling hands-on robotics and STEM education. In: AAAI spring symposium: semantic scientific knowledge integration. pp 99–102
24. Albirini A (2006) Teachers' attitudes toward information and communication technologies: the case of Syrian EFL teachers. Comput Educ 47(4):373–398
25. Adams AE, Miller BG, Saul M, Pegg J (2014) Supporting elementary pre-service teachers to teach STEM through place-based teaching and learning experiences. Electron J Sci Educ 18(5):1–22
26. Kim KH, Choi HS, Baek JE (2014) A study on the teachers' perception of school curriculum implementation about robot-based education in Korea concept of robot-based education. Adv Sci Technol Lett 59:105–108
27. Barker BS, Ansorge J (2007) Robotics as means to increase achievement scores in an informal learning environment. J Res Technol Educ 39(3):229–243
28. Kay JS, Moss JG, Engelman S, McKlin T (2014, March) Sneaking in through the back door: introducing K-12 teachers to robot programming. In: Proceedings of the 45th ACM technical symposium on computer science education. ACM, pp 499–504
29. Alimisis D, Arlegui J, Fava N, Frangou S, Ionita S, Menegatti E, Pina A (2010) Introducing robotics to teachers and schools: experiences from the TERECoP project. In: Proceedings for constructionism. pp 1–13
30. Elkin M, Sullivan A, Bers MU (2014) Implementing a robotics curriculum in an early childhood Montessori classroom. J Inf Technol Educ Innov Pract 13:153–169
31. Karahoca D, Karahoca A, Uzunboylub H (2011) Robotics teaching in primary school education by project based learning for supporting science and technology courses. Procedia Comput Sci 3:1425–1431
32. Riedo F, Freire M, Bonani M, Mondada F (2012, May) Involving and training public school teachers in using robotics for education. In: Advanced robotics and its social impacts (ARSO), 2012 IEEE workshop on. IEEE, pp 19–23
33. Fridin M, Belokopytov M (2014) Acceptance of socially assistive humanoid robot by preschool and elementary school teachers. Comput Hum Behav 33:23–31
34. Chevalier M, Riedo F, Mondada F (2016) Pedagogical uses of thymio II: how do teachers perceive educational robots in formal education? IEE Robot Autom Mag 23(2):16–23
35. Rusk N, Resnick M, Berg R, Pezalla-Granlund M (2008) New pathways into robotics: strategies for broadening participation. J Sci Educ Technol 17(1):59–69
36. Bruner J, Lucariello J (1989) Monologue as narrative of the world. In Nelson K (ed) Narratives from the crib. pp. 73–97. Cambridge, Mass: Harvard Univ. Press
37. Anderson ML (2003) Embodied cognition: a field guide. Artif Intell 149(1):91–130
38. Tobias S, Duffy TM (eds) (2009) Constructivist instruction: success or failure?. Routledge, Abingdon
39. Hattie JAC (2009) Visible learning: a synthesis of 800+ meta-analyses on achievement. Routledge, Abingdon
40. Prawat RS (1992) Teachers' beliefs about teaching and learning: a constructivist perspective. Am J Educ 100(3):354–395
41. Mishra P, Koehler MJ (2006) Technological pedagogical content knowledge: a framework for teacher knowledge. Teach Coll Rec 108(6):1017
42. Hattie J (2012) Visible learning for teachers: maximizing impact on learning. Routledge, Abingdon
43. Merrill MD (2002) First principles of instruction. Educ Tech Res Dev 50(3):43–59
44. Allen WC (2006) Overview and evolution of the ADDIE training system. Adv Dev Hum Resour 8(4):430–441
45. Calvani A, Menichetti L (2015) Come fare un progetto didattico: gli errori da evitare. Carocci Faber
46. Bandura A (1977) Self-efficacy: toward a unifying theory of behavioral change. Psychol Rev 84(2):191
47. Kradolfer S, Dubois S, Riedo F, Mondada F, Fassa F (2014, October) A sociological contribution to understanding the use of robots in schools: the thymio robot. In: International conference on social robotics. Springer, pp 217–228
48. Gascoine L, Higgins S, Wall K (2017) The assessment of metacognition in children aged 4–16 years: a systematic review. Rev Educ 5(1):3–57

Emanuela Castro was born in Viareggio, Italy, in 1991. She received the Master Degree in Psychology at the University of Pisa on July 2014. Currently she is a Ph.D. Student at the BioRobotics Institute and her research interests are educational robotics and human-robot interaction.

Francesca Cecchi (M'08) was born in Pisa, Italy in 1982. She Received the Master Degree in BioMedical Engineering at University of Pisa on July 2007 and received the Ph.D. in Biorobotics from the Scuola Superiore Sant'Anna in May 2011. Currently she is a senior scientist at the BioRobotics Institute of the Scuola Superiore Sant'Anna and her research fields are neurodevelopmental engineering and educational robotics.

Pericle Salvini graduated in Foreign Languages and Literatures from the University of Pisa in 2000 with a thesis on 'Theatre and Technologies'. In 2005, he completed a Master of Research degree in Theatre Studies at Lancaster University (UK), where he delved into the telepresence artworks of E. Kac, R. Ascott and P. Sermon. In 2008, he received his Ph.D. in Biorobotics Science and Engineering from IMT Lucca Institute for Advanced Studies and Scuola Superiore Sant'Anna

(Italy). He is currently research fellow at the BioRobotics Institute of Scuola Superiore Sant'Anna, Pisa, Italy. His main research interests are in the fields of Human-Robot Interaction and Science and Technologies Studies. He is also involved in activities concerning the use of robots in formal and informal education and art. From 2011 to 2013 he co-chaired the Human-Robot Interaction and Communication Technical Committee of RAS-IEEE.

Massimiliano Valente was born in Livorno, Italy in 1977. He received the master degree in psychology at University of Florence in 2008 and received the Ph.D. in Advanced Robotics in 2012. In his Ph.D. project he undertook a psychophisical approach to perception in immersive virtual reality. Currently he is a post-doc fellow at the BioRobotics Institute mainly in charge of Educational Robotics.

Elisa Buselli is a post-doc fellow at the BioRobotics Institute. She received her Master Degree in Biomedical Engineering (with Honors) from the University of Pisa in October 2007 and in the same year she joined the Scuola Superiore Sant'Anna. During her Ph.D., she worked on capsular endoscopy and on microfluidics and microfabrication techniques. She obtained her Ph.D. in June 2011 and she is currently working in educational robotics field.

Laura Menichetti is an Electronic Engineer (PhD) and she obtained a Master Degree in Adult Education. She was an IBM Executive. Since 2010 her main research interests have been in the fields of digital competence, technology enhanced learning and educational research at the University of Florence.

Antonio Calvani is a Full Professor of Special Pedagogy and Didactics at the Department of Educational Science and Psychology, University of Florence. Since '70th his research interests are related to innovation in education and on the evaluation of the efficacy of didactic activities.

Paolo Dario is a Full Professor of Biomedical Engineering and was until 2017 Director of The BioRobotics Institute of the Scuola Superiore Sant'Anna (SSSA), Pisa, Italy. He has been and is the coordinator of more than 60 European projects, of more than 50 national projects, and of more than 50 industrial projects. Paolo Dario is the editor of two books on the subject of robotics, and the author of more than 500 scientific papers (250 on ISI journals). Paolo Dario is an IEEE Fellow, and he has served as President of the IEEE Robotics and Automation Society in the years 2002–2003, as Co-Chair of the Technical Committees on Bio-robotics and of Robo-ethics of the same Society. Prof. Dario is a Fellow of the European Society on Medical and Biological Engineering, a member of the Board of the International Foundation of Robotics Research (IFRR).