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Pre-service teachers' perceptions towards integrating educational robotics in the primary school

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Abstract

This paper seeks to understand the impact of a training program on 19 pre-service primary school teachers' perceptions towards educational robotics (ER). The training program is based on a reflective process of design and implementation of a learning scenario during the practicum, using a pre-experimental design. Quantitative data were collected through a questionnaire applied at three moments of the intervention: pre-intervention, post-intervention 1 (19 weeks after), and post-intervention 2 (37 weeks after). The results show that the features of the proposed training program positively influenced the pre-service teachers' (PST) perceptions towards ER. Experiencing curricular integration of ER and participation in a reflective process of learning scenario design positively influenced their perceptions in post-intervention 1. After experiencing the integration of ER in the practicum class, PST adjusted their positive perceptions in post-intervention 2. PST also displayed a decrease in neutrality in their perceptions in post-intervention 1 and post-intervention 2. Given the limited sample, it's not possible to generalize these results, however they have implications for initial teacher training programs dedicated to technology integration. PST must be allowed to confront their preconceived perceptions of integrating technology into teaching and learning processes with the reflective process of designing and implementing a lesson plan that integrates technology during the practicum.

Keywords: educational robotics, initial teacher training, learning scenarios, practicum, teacher training program

INTRODUCTION

The integration of technological resources in schools is a growing concern of international institutions (Alexander et al., 2019; European Commission, 2020, 2022; Kuhl et al., 2019; OECD, 2019). In the case of Portugal, in addition to alignment with these international guidelines, programming and educational robotics (ER) appear in the primary school mathematics curricula associated with the development of computational thinking skills (Ministério da Educação [Ministry of Education], 2021a, 2021b, 2021c, 2021d). ER is a subject of growing interest (I) in the scientific community (Anwar et al., 2019; Benitti, 2012; Jung & Won, 2018; López-Belmonte et al., 2021; Oliveira et al., 2023; Sapounidis et al., 2023; Toh et al., 2016; Xia & Zhong, 2018) in areas as diverse as the use of social robots in classrooms (Smakman et al., 2022; Woo et al., 2021), music teaching (Martinez-Roig et al., 2023) or to promote curricular integration (El-Hamamsy et al., 2021; Kim, 2019; Sapounidis & Alimisis, 2021). Integration of ER in classroom settings has the potential to promote meaningful learning (Athanasiou et al., 2019; Zhong & Xia, 2020), such as in the development of computational thinking skills (Dong et al., 2023; Louka & Papadakis, 2023), STEM subjects (Kim et al., 2015; Sapounidis et al., 2023), physics (Addido et al., 2023) and mathematics (Zhong & Xia, 2020), with a growing number of countries

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Contribution to the literature

- Offers an initial teacher training (ITT) program that allows pre-service teachers (PST) to experience the integration of ER in their mathematics teaching practices in a real classroom setting.
- Analyses the influence on primary school PST' perceptions of a training program that integrates ER and the use of learning scenarios in ITT.
- Presents findings that have implications for the integration of ER in ITT programs.

including ER as an optional component in the curriculum (Mangina et al., 2023). Yet Arocena et al.'s (2022) systematic review shows that few studies take place within the classroom, with the majority linked to after-school activities, although many of the interventions are aimed at future implementation in classroom settings. The results of the systematic review by de Uslu et al. (2022) show a trend in ER studies pointing to four ways of using ER: teaching basic programming concepts, structured problems, ill-structured problems, and integration of robotics activities in subject area; with the vast majority of studies dedicated to the subject area of programming.

The tendency for a large proportion of studies to focus on the technological component of ER (robotics, mechatronics, and programming)–or to seek close curricular connections to these areas–as identified by Benitti (2012) still holds (Angeli & Jaipal-Jamani, 2018; Arocena et al., 2022; López-Belmonte et al., 2021; Sapounidis et al., 2023). It is important that research on ER give greater relevance to pedagogical and didactic issues (Alimisis, 2012; Jung & Won, 2018; Oliveira et al., 2023), and seek to further understand its integration in the classroom (Arocena et al., 2022) and how to promote curricular articulation and integration (El-Hamamsy et al., 2021; Kim, 2019; Sapounidis & Alimisis, 2021). The integration of ER in teaching and learning processes enhances the creation of favorable conditions for meaningful learning (Athanasiou et al., 2019; Zhong & Xia, 2020) and for interdisciplinarity (Kuhl et al., 2019; Miller & Nourbakhsh, 2016), and its alignment with the essential digital competencies proposed in the DigCompEdu framework is unquestionable (Heinmäe et al., 2022; Redecker, 2017). However, as with any other technology, the role of the teacher is crucial for the integration of ER in teaching and learning processes to go beyond the simple use of technology in the classroom and for it to become an epistemic tool (NCTM, 2014; Sayaf et al., 2022; Tabach & Trgalová, 2019).

To be able to promote conditions conducive to an adequate integration of technology in the classroom, teachers need to mobilize a set of competencies that allow them to choose, adapt or create resources appropriate to the defined learning objectives (Hegedus et al., 2017). It is not enough to be proficient in the manipulation of technological resources to be able to create didactic situations to promote learning (Tabach & Trgalová, 2019); teachers need to have a deep knowledge of these resources (Koehler & Mishra, 2009) to transform them into epistemic tools that serve the learning objectives (Lopes & Costa, 2019), providing conditions that allow students to interact with mathematical content and receive immediate feedback thus facilitating understanding (Pelletier et al., 2023). Integration of technology into teaching and learning processes is strongly influenced by in-service teachers' acceptance of it (Davis, 1989; Keren & Fridin, 2014; Rafique et al., 2020) and their perceived self-efficacy (SE) (Holden & Rada, 2011). This is also true for ITT students (Abbitt, 2011; Casey et al., 2021; Schina et al., 2021b; Song, 2018). In the particular case of ER, including activities that integrate ER into ITT programs contributes favorably to improvements in PST' acceptance of ER and perception of SE (Casey et al., 2021; Schina et al., 2021a, 2021b).

Enabling PST to experience the integration of technology in practical and contextualized situations (Huang & Zbiek, 2017) contributes to their better understanding of the artefact's potentials and constraints, as well as its relationship with the curriculum. But technological and content knowledge are only part of the potential of ER (Alimisis, 2012; Jung & Won, 2018); it is important to continue research in the field of developing PST didactic knowledge needed to design lesson plans that integrate ER in educational contexts (Alimisis, 2019; Kim et al., 2015). However, a lack of preparation in creating lesson plans negatively influences the integration of ER into teaching practices (Schmid et al., 2021; Tankiz & Uslu, 2022). Having established the importance of ITT including initiatives that integrate ER, and given how a lack of preparation in the creation of lesson plans negatively influences the integration of ER into PST teaching practices, the following research problem emerges: how can ITT contribute to PST being able to promote the appropriate integration of ER into their teaching practice?

In in-service teacher education, the possibility for teachers to articulate training in ER with implementing ER in their teaching practice is highlighted as a success factor (Anwar et al., 2019; Schina et al., 2021a). Although some works in ITT include this feature (e.g., Kucuk & Sisman, 2017; Luciano et al., 2019), this limitation persists (e.g., Angeli & Jaipal-Jamani, 2018; Oliveira et al., 2023; Schina et al., 2021a). Regarding training needs in programming and robotics, in the Portuguese context the teaching community's I stands out especially in training on ER, construction of programmable robots, and lesson plans that allow the integration of these technologies to promote curricular learning (Ramos et al., 2022). To design training programs that integrate ER into ITT, it is important to understand teachers' perceptions of SE and willingness to integrate ER into their teaching practices (Jaipal-Jamani, 2023; Jaipal-Jamani & Angeli, 2017; Khanlari, 2016). To design the lesson plans we chose learning scenarios, a structured planning tool, which is iterative and reflective, favoring the integration of technology in teaching and learning processes (Matos, 2014; Pedro et al., 2019). By allowing participants to take an active role in the iterative and reflective process of designing and implementing the lesson plan (Pedro et al., 2019), we sought to reduce the influence of a lack of preparation in lesson plan creation on the integration of ER in PST teaching practices (Schmid et al., 2021; Tankiz & Uslu, 2022). This study seeks to answer the following research question: Does a training program integrating ER and using learning scenarios in ITT in primary school influence PST perceptions of

(a) potential benefits (PB) and potential obstacles (PO) of integrating ER into their future teaching practice,
(b) I in ER,
(c) problem-solving (PS),
(d) educational robotics knowledge (ERK), and
(e) SE in integrating ER into their teaching practice?

This work is part of a larger study, still in progress, dedicated to developing the didactic knowledge needed to integrate ER in tasks that promote mathematical learning. The main contribution of this paper is the development of a training program that integrates ER and learning scenarios in ITT for primary school. In this way, the present study contributes to the discussion on the importance of ITT to create conditions that allow PST to experience the integration of ER in their teaching practices in a real classroom setting. The design and implementation of learning scenarios that integrate ER in the practicum influenced PST perceptions, contributing to an adjustment in their idealized perception.

THEORETICAL BACKGROUND

The integration of technology into teaching and learning processes influences how to teach and what can be taught (Drijvers, 2015; NCTM, 2014). How teachers have learned the curriculum content they teach is not the same as how they learn to teach it to their students, just as learning curriculum content with technology integration differs from learning to teach curriculum content with technology integration (Niess, 2005; Santos & Castro, 2021). Despite the growing I in ER among the educational scientific community dedicated to pre-school and primary education (Mangina et al., 2023; Sapounidis et al., 2023; Uslu et al., 2022) many teachers still feel unease using ER (Zhong & Xia, 2020). Vasconcelos et al. (2024) sought to understand how PST used ER to promote epistemic agency in science lessons. Their results show that PST had difficulties integrating ER into their lesson plans to promote science inquiry and epistemic agency, suggesting that these difficulties in lesson plan design can be overcome by including additional support and scaffolding in training activities. Participation in professional development training dedicated to integrating ER into teaching practices contributes to teachers' acceptance of this technology, increasing their willingness to integrate it into their teaching practices (Neophytou & Eteokleous, 2022).

In this context, the project of which this study is a part aimed to study how ITT can contribute to the proper integration of ER into the teaching practices of PST who teach mathematics. In doing so, we seek to respond to the identified limitations in curricular integration of ER (Kim, 2019; Sapounidis & Alimisis, 2021) and importance of PST experiencing ER integration in their teaching practices (Oliveira et al., 2023; Schina et al., 2021b). When it comes to ER, it is important to design ITT programs in a way that enables PST to experience the integration of ER in practical and contextualized situations, similar to any other technology (Huang & Zbiek, 2017). Dong et al. (2023) argue that interventions with ER in ITT promote I, development of computational thinking skills, as well as PST perceived SE in the use of ER.

The integration of ER in ITT should therefore include: space for sharing and discussing ideas and experiences; observing peers managing classes that integrate ER; continuous teaching support during the stages of training, planning, and performance; a specific theoretical, practical, reflective and didactic component (Schina et al., 2021a); and, similar to any training program focused on technology integration, the application of lesson plans in a real classroom setting and subsequent reflection (Pedro et al., 2019; Schina et al., 2021a; Song, 2018). Since competency in lesson plan creation influences the integration of ER in PST teaching practices (Tankiz & Uslu, 2022) ITT programs that integrate ER should enable PST to create lesson plans that integrate ER (Kim et al., 2015; Seckel et al., 2022) and implement them during their teaching practices (Kucuk & Sisman, 2017; Luciano et al., 2019; Piedade et al., 2020).

Additionally, PST acceptance of ER also significantly influences the integration of ER into their teaching practices (Casey et al., 2021; Schina et al., 2021b; Song, 2018). As such, it is important that ITT programs that integrate ER take into consideration PST perceptions regarding PB and PO of integrating this technology into their teaching practices (Khanlari, 2016), as well as PST perceptions regarding their SE and willingness to use ER (Jaipal-Jamani, 2023; Jaipal-Jamani & Angeli, 2017; Piedade et al., 2020). In their study dedicated to ITT with ER, Castro et al. (2018) reported that 61.4% of participants implemented tasks with ER in the classroom, registering a positive change regarding perceived SE as well as a change in the perceived potentials and obstacles to integration of ER in their teaching practices, moving from an idealized and quite positive perception to a more realistic perception with lower positive numbers after contacting with ER platform during training and experiencing the integration in their teaching practices. In their study of 214 teachers, Chevalier et al. (2016) have suggested that the relationship between acceptance of ER and teachers' willingness to use ER is influenced by the relationship of the technology to the curriculum, and therefore training that enables teachers to experience and understand curriculum integration can influence these two perceptions. Khanlari's (2019) work with primary school teachers during a workshop dedicated to ER presents as main results reduced neutrality in participants' perceptions and a greater willingness to integrate ER in their teaching practices aiming at the promotion of curricular learning.

In the context of in-service training for primary school teachers, Seckel et al. (2021) report that although there is a positive perception of primary school teachers' willingness to integrate ER into their teaching practice and of how ER can be useful for learning mathematics, they have a less positive perception of actually using ER to teach mathematics. With the participation of 156 teachers, Tzagaraki et al. (2022) conducted a study on teachers' attitudes towards the use of ER in primary school. The authors report that these teachers show a positive attitude towards ER as a catalyst for improvements in learning, and that they recognize the usefulness of ER in improving the effectiveness of teaching and learning. They also identify a high percentage of neutral perceptions in items related to the ease of use of robotics, as well as in items related to the intention to use ER in their own teaching practice.

You et al.'s (2021) study with mathematics and science teachers throughout a professional development program focused on creating lesson plans that integrate ER into curriculum learning, reporting the following main findings: improvements in perceptions of SE and own knowledge of robotics, and perceptions of the potentialities and benefits of ER, as well as in teachers' understanding of the variables that influence an adequate integration of ER in teaching practices. Those authors suggest that hands-on learning and activities of a collaborative nature influenced the involvement of participants in the proposed tasks, highlighting the importance of future studies on the implementation of lesson plans that integrate ER. Papadakis et al. (2021) sought to understand preconceptions towards ER by comparing results obtained from PST and in-service teachers. Those authors state that the acceptance of ER is similar between the two groups, with a negative trend associated to the number of years of experience, and a positive trend associated with knowledge of ER; they therefore suggest that ER should be included in ITT programs. The study by Gavrillas et al. (2024) collected the opinions of 307 pre-school and primary education teachers in urban areas of Greece regarding the integration of ER. As results of this study, we highlight the high proportion of neutral perceptions of the participants, the fact that 32.0% do not consider themselves prepared to integrate ER into their teaching practices, and the fact that 40.7% of participants do not consider themselves capable of using the programming environment of ER platforms.

In the context of ITT and within the scope of a curricular unit, the study by Jaipal-Jamani and Angeli (2017) focused on constructing and programming robots, showing in its results improvements in PST perceptions of SE, computational thinking skills, and knowledge of ER. In a similar context, the study by Román-Graván et al. (2020) involved the participation of pre-school and primary school teachers in an intervention that included tasks designed to allow them to learn to manipulate an ER platform, with the main results being improvements in the perception of willingness to integrate ER into teaching practices; knowledge of ER; I and SE. Kalogiannakis and Papadakis (2022) conducted a study with pre-school PST whose intervention component, supported by the Makey Makey ER platform and the Scratch 3 programming environment, aimed to integrate ER into PST teaching practices. The authors report that, after the intervention, PST felt confident in designing projects that integrated the Makey Makey and the Scratch 3 platforms, as well as their readiness to integrate those two platforms into their future teaching practices. In addition to allowing pre-school teachers to interact with an ER platform, Schina et al.'s (2021b) study allowed participants to experience interdisciplinary tasks integrating ER, providing evidence for improvements in PST perceptions of SE and acceptance of ER. They recommend that ITT programs integrating ER should enable PST to interact with different ER platforms, as well as to explore the robots and associated resources; they also suggest that further studies dedicated to integrating ER into PST practice are needed. The study by Papadakis (2022) on the beliefs of 97 pre-school teachers regarding the integration of ER into classroom practices presents results that show that the participants have a favorable perception towards the integration of ER into pre-school teaching and learning practices. However, 82.5% of the participants point to lack of knowledge as the main obstacle to integrating RE into their daily teaching practices.

Piedade et al.'s (2020) study with computer science PST aimed to create conditions that would allow participants to analyze the pedagogical characteristics and potentialities of several ER platforms, and to create lesson plans that integrate ER into computer science teaching. The main results show high values in PST perceptions of I, SE, and knowledge of ER, as well as PST PS competence. These authors suggest that ITT programs that integrate ER include the use of learning scenarios as one of their features (Carroll, 1999; Matos, 2014) and that PST should participate in collaborative PS tasks. Casler-Failing (2021) reports on a study carried out over two semesters in which mathematics PST created and implemented lesson plans that integrated ER with peers within a mathematics curriculum unit. Those authors report improvements in PST perceived knowledge of robotics and understanding of the integration of ER in mathematics teaching; they suggest that ER should be part of long-term training programs so that PST can experience its use in a contextualized way, as well as create and implement lesson plans that integrate ER in teaching curriculum content. A study by Alqahtani et al. (2022) dedicated to the design and implementation of lesson plans that integrate ER reports improvements in PST perceptions regarding their willingness to integrate ER in their teaching practices and difficulty in manipulating the robots, arguing that the simplicity of the robot used contributed to the improvements in PST perceptions. The same authors suggest that PST should have opportunities to interact and explore the potential of ER during their training.

In light of the above, and as further explained in the next section, this study aims to create conditions for PST to: experience the integration of ER in practical and contextualized situations (Casler-Failing, 2021; Huang & Zbiek, 2017), contacting with different ER platforms (Anwar et al., 2019; Schina et al., 2021b), aiming at increasing their acceptance of ER with the purpose of facilitating proper integration into their teaching practices (Davis, 1989; Rafique et al., 2020), allowing PST to participate in collaborative tasks that integrate ER with their peers (Anwar et al., 2019; You et al., 2021), create and implement learning scenarios in real classroom setting (Tankiz & Uslu, 2022; You et al., 2021), and reflect on this process (Schina et al., 2021b; Seckel et al., 2022). To adjust the intervention design we collected PST perceptions of ER regarding:

(a) SE and willingness to integrate ER into their teaching practices (Khanlari, 2019; Piedade et al., 2020);

(b) PB and PO to integrating ER into teaching practices (Khanlari, 2016; You et al., 2021);

(c) ERK (Piedade et al., 2020; You et al., 2021); and

(d) I in ER (Dong et al., 2023; Piedade et al., 2020).

MATERIALS & METHODS

Study Design

Our study is quantitative in nature with a pre-experimental design, considering that we only use one experimental group, and the sample was not randomly selected (Cohen et al., 2018). A questionnaire was used to collect data on the participants' perception of

(a) PB and PO of integrating ER in their future teaching practice,

(b) I in ER,

(c) PS,

(d) ERK, and

(e) SE in the integration of ER in their own teaching practice.

The data collection process and instrument used is described later. Data was collected at three different moments (pre-intervention, post-intervention 1, and post-intervention 2), with the aim of identifying changes in the participants' perceptions throughout the pedagogical intervention, as detailed later.

Sample

The participants of this study were 19 PST, all female, enrolled in a 1st year class of a master's degree in primary education at a Portuguese higher education institution. Their participation was voluntary, they could withdraw at any time, and their anonymity was ensured through the confidential treatment of the data. 19 PST were distributed into six work groups–five groups with three and one group with four participants–, keeping with the groups already established for the practicum. As part of the practicum, 19 PST had been asked to create lesson plans adapted to the context of the practicum class; we therefore considered that integrating learning scenarios into our study would be the best option allowing to take advantage of the routines of collaborative work already established within each group.

Pedagogical Intervention

The intervention took place during the school year 2021/2022 in two curricular units (mathematics and mathematics didactics) in articulation with the curricular unit of educational practice–responsible for supervising the practicum. This intervention, summarized in **Figure 1**, was developed in two phases, composed of eight stages in total. In designing the stages we sought to create favorable conditions for the development of PST didactic knowledge necessary to design lesson plans that integrate ER (Alimisis, 2019; Kim et al., 2015).

The first phase centered around the design of a hypothetical learning scenario served two purposes:

(a) to allow PST to experience the integration of ER in the teaching and learning processes of mathematical contents of the primary school curriculum and

(b) to participate in the design process of learning scenarios that integrate ER in the teaching of mathematical contents.

By including the learning scenario design process in stage II, we aimed to create conditions for PST to create a hypothetical learning scenario in group task I that would integrate ER in the teaching of mathematical content that was part of the curriculum of the context of the practicum class. Group task I acts as a bridge to phase II, as the work carried out by PST is further developed in group task II (phase II). The steps of examining the context and designing the learning scenarios in stage V build on what has already been done in group task I to be built on and improved in group task II. The main objective of phase II, implementing the learning scenarios in the practicum (primary school classes), is the culmination of the work started in phase I.

Through the questionnaire, we accessed PST perceptions of ER regarding:

(a) PB,

(b) PO to integrating ER into teaching practices,

(c) I,

(d) PS,

(e) ERK, and

(f) SE.

The first application (pre-intervention, identified as M1 hereafter) took place before the start of phase I; the second application (post-intervention 1, 19 weeks later and identified as M2 hereafter) took place after the end of phase I; the third application (post-intervention 2, 37 weeks later and identified as M3 hereafter) took place after the end of phase II.

Phase I

Phase I of our study took place in the first semester–from 29/10/2021 to 17/02/2022–and includes three stages (see **Figure 1**):

(a) construction and deepening of knowledge,

(b) didactic sequences that integrate ER and focus on the adaptation of learning scenarios, and

(c) group task I and discussion.

Stage I included two sessions of constructing and deepening knowledge, each lasting two hours.

The first session was devoted to the theoretical principles underlying the integration of ER in teaching and learning processes, based on TPACK conceptual model (Koehler & Mishra, 2009; Mishra, 2019). The second session focused on learning scenarios, the principles governing the design and implementation of learning scenarios, as well as its different constituent elements: organizational design of the environment; roles and actors; plot, working strategies, performances, and proposals; and reflection and regulation (Matos, 2014; Pedro et al., 2019).

Stage II–from 2 12/11/2021 to 04/02/2022–consisted of a set of four didactic sequences (see **Figure 1**) each operationalized in three two-hour sessions (totaling 24 hours). This stage was supported by three ER platforms of increasing complexity. Super Doc robot, with tangible programming, was chosen for the participants' first contact with ER; in the next didactic sequence we used MindDesigner robot, whose block programming environment has similar commands to Super Doc's making the transition easier; finally, the last two didactic sequences were supported by two different builds of Ring:bit Kit, programmable through the block-based programming environment MakeCode. MakeCode programming environment is similar to Scratch, which the participants had previously been in contact within a curricular unit (information and communication technologies) of the bachelor in basic education program. By including different ER platforms in this intervention (Anwar et al., 2019; Schina et al., 2021b), we

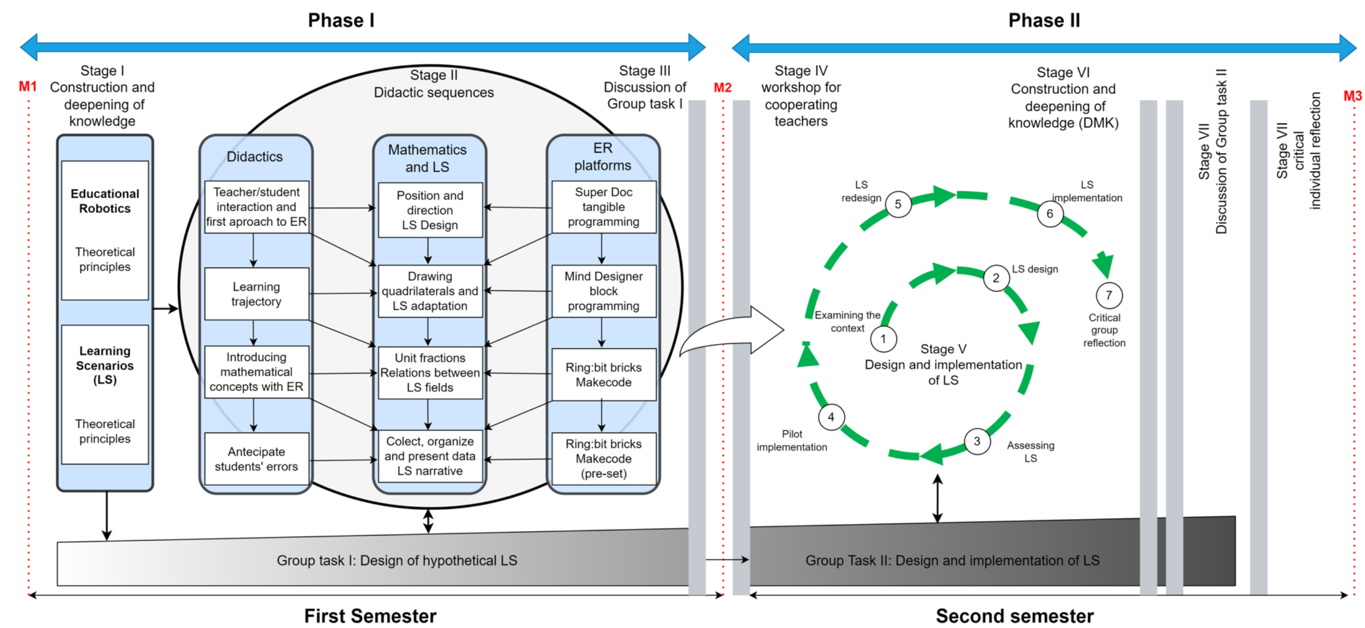

Figure 1. Intervention sequence (Source: Authors' own elaboration, using draw.io software)

sought to contribute to the acceptance of this technology by the participants (Casey et al., 2021; Davis, 1989; Schina et al., 2021a, 2021b). Each of the four didactic sequences in this stage was dedicated to distinct mathematical contents in order to enable PST to experience the integration of ER in practical and contextualized situations (Casler-Failing, 2021; Huang & Zbiek, 2017) and promote curricular articulation and integration (El-Hamamsy et al., 2021; Kim, 2019; Sapounidis & Alimisis, 2021) for each of the primary school years of the context in which PST practicum took place. All didactic sequences followed the same format, allowing PST to experience mathematical tasks that integrate ER and facilitate their understanding of the process of adapting and creating learning scenarios to the specific context of the practicum. At the start of each didactic sequence, a proposed collaborative task that integrates ER (Anwar et al., 2019; You et al., 2021) in learning mathematical content in primary school was explored. This was followed by the exploration of the design process of the learning scenarios created by the teacher/researcher for each didactic sequence through a set of written tasks. This learning scenario would then be adapted by the groups to the respective practicum context (Kim et al., 2015; Pedro et al., 2019; Seckel et al., 2022) with the design of a hypothetical learning scenario.

Finally, stage III consisted of group task I and its discussion. In group task 1, the groups had to create a hypothetical learning scenario adapted to the practicum context. The participants should justify their decision-making regarding the relevance of ER platform chosen for integration, strategies, and methodologies, integrating these decisions in the constituent elements of the proposed learning scenarios (Matos, 2014; Pedro et al., 2019). The first part of group task I was developed throughout the semester in tutorial mode, and the discussion was conducted in two sessions, lasting two hours each. After the discussion, the groups proceed to the reformulation of group task I based on the contributions of peers and the teacher/researcher.

Phase II

Phase II took place during the second semester–from 16/03/2022 to 22/06/2022–and follows five stages, picking up from phase I (see **Figure 1**): stage IV) preparation of the co-operating teachers, stage V) design and implementation of the learning scenarios, stage VI) construction and deepening of knowledge, stage VII) group task II and discussion, and stage VIII) individual critical reflection.

Stage IV took the form of a workshop for the cooperating teachers with the participation of PST groups. The aim of the workshop was to familiarize the cooperating teachers with ER platforms used in the study, the principles of learning scenario design and implementation, and how the implementation of the learning scenarios created by the groups was expected to take place during the practicum.

Stage V focusing on design and implementation of the learning scenarios–from 06/04/2022 to 17/05/2022–involved seven distinct steps (see **Figure 1**):

1. **Examining the context:** Based on their knowledge of the practicum class and the mathematics curriculum, the groups (working autonomously) looked for situations that justify the integration of ER in tasks that potentially promote mathematical learning (El-Hamamsy et al., 2021; Kim, 2019; Sapounidis & Alimisis, 2021).
2. **Designing the learning scenarios:** Using learning scenarios (Matos, 2014; Pedro et al., 2019; Piedade et al., 2020), the groups create lesson plans for implementation in a real classroom setting (Angeli & Jaipal-Jamani, 2018; Casler-Failing, 2021; Kim et al., 2015; Kucuk & Sisman, 2017; Luciano et al., 2019; Piedade et al., 2020; Tankiz & Uslu, 2022; You et al., 2021). In addition to the groups' autonomous work, the teacher/researcher monitored the design of the learning scenarios during a two-hour classroom session.
3. **Assessing the learning scenarios:** PST took an active role in the reflective process of creating lesson plans that integrate ER into curriculum tasks, with the support of the teacher/researcher. In this way, we sought to minimize the impact of their lack of experience in preparing lesson plans that integrate ER into their teaching practices (Schmid et al., 2021; Tankiz & Uslu, 2022). Before the pilot implementation of the learning scenarios, each group discussed the design of their learning scenarios with the teacher/researcher in tutorial mode.
4. **Pilot implementation:** This step was designed to allow each group to test the implementation of the learning scenarios created in a simulated lesson with their peers, allowing PST to experience classroom management integrating ER (Casler-Failing, 2021; Huang & Zbiek, 2017), as well as to observe their peers (Schina et al., 2021b). Each pilot implementation was the subject of discussion upon its completion, with the groups collecting feedback from peers and the teacher/researcher for further reflection (Pedro et al., 2019).
5. **Redesigning the learning scenarios:** Based on reflection on the pilot implementation, the redesign of the learning scenarios took place (Matos, 2014; Pedro et al., 2019; Piedade et al., 2020) in tutorial mode.
6. **Implementing the learning scenarios in the practicum:** In articulation with the curricular unit of Educational Practice, the learning scenarios

Table 1. Item set for dimensions PB & PO

Dimension	Items
PB	Q1. Using robotics in elementary schools can help students to become lifelong learners. Q2. Using robotics in elementary schools can help students in the process of scientific inquiry. Q3. Using robotics elementary schools can help students improve their skills of initiating and planning, performing and recording, analyzing and interpreting. Q4. Using robotics in elementary mathematics helps students to improve their mathematical reasoning skills. Q5. Using robotics in elementary mathematics helps students to improve their problem-solving skills. Q6. Using robotics in elementary science subjects helps students to improve their communication skills. Q7. Using robotics in elementary science subjects helps students to improve their teamwork skills. Q8. Overall, students work together more than they do on comparable lessons/units that do not involve robotics technology. Q9. Overall, student work showed more in-depth understanding of content than in comparable lessons/units that do not involve robotics technology. Q10. Overall, student work is more creative than in comparable lessons/units that do not involve robotics technology. Q11. Overall, students are able to communicate their ideas and opinions with greater confidence than in comparable lessons/units that do not involve robotics technology.
PO	Q12. Usually there are not enough educational robots available in elementary schools. Q13. Usually teachers do not have access to adequate and relevant software/hardware in primary/elementary schools. Q14. It is too difficult to schedule time in elementary school's robotics projects to do the assignments. Q15. There are not enough computers available in elementary schools to program the robots. Q16. Elementary students are too young to be able to understand robotics and work with robots. Q17. There is too much course material and many subjects to cover in a year to have time for robotics. Q18. Usually elementary teachers are not sure how to make robotics technology relevant to their subject. Q19. Teachers need to prepare students for the stated outcomes and mandated tests, while using robotics does not prepare them for these tests and outcomes. Q20. Usually elementary teachers do not feel confident enough in their technology skills to use robotics in their classes. Q21. Teachers do not have adequate technical support. Q22. Teachers do not have adequate instructional support.

resulting from the redesign (Kim et al., 2015; Seckel et al., 2022) were implemented in the practicum (Kucuk & Sisman, 2017; Luciano et al., 2019; Piedade et al., 2020). After the implementation, the groups discussed it with the teacher/researcher.

7. **Critical group reflection:** Stage V concluded with a written critical reflection by each group on the whole process of designing and implementing the learning scenarios in a real classroom setting (Piedade et al., 2020; Schina et al., 2021a; Song, 2018).

Stage VI was a construction and deepening of knowledge session in which the critical discussion of episodes of multimodal narratives (Lopes et al., 2019) selected by the teacher-investigator took place. The discussion of these episodes was supported by the didactic-mathematical knowledge conceptual framework (Pino-Fan et al., 2015), aiming at its use in stage VIII.

Similarly to phase I, stage VII corresponded to the preparation of group task II and its discussion.

The pedagogical intervention ended with stage VIII, an individual written task in which participants are asked to critically reflect on the work carried out throughout the intervention (Schina et al., 2021b; Seckel et al., 2022), with particular attention to the design and implementation of learning scenarios (Pedro et al., 2019), establishing connections to the different dimensions of the didactic-mathematical knowledge conceptual framework.

Data Collection

The data collection instrument is divided into the six dimensions. The first two (see **Table 1**)–PB and PO to the integration of ER in teaching practices–are an adaptation of the questionnaire authored by Khanlari (2016). Their translation into Portuguese was validated by external experts with recognized work in the areas of mathematics, statistics, and initial teacher education.

The remaining dimensions presented in **Table 2**–I, PS, ERK, and SE–are an adaptation by Piedade et al. (2020) of the questionnaire devised by Jaipal-Jamani and Angeli (2017), using the Portuguese translation from Piedade and Dorotea (2020).

Each dimension includes a set of items with the following agreement scale: 1-I totally disagree, 2-I disagree, 3-I neither agree nor disagree, 4-I agree, and 5-I totally agree.

Data were collected in three different moments:

Table 2. Item set for dimensions I, PS, ERK, & SE

Dimension	Item
I	Q23. I like learning about new technologies like robotics.
	Q24. I like using scientific methods to solve problems.
	Q25. I like using mathematical formulas and calculations to solve problems.
	Q26. I think careers in science, technology, engineering or math are interesting.
	Q27. I would like to learn more about careers that involve science, technology engineering, and mathematics.
	Q28. I find it interesting to learn about robots or robotics technology.
	Q29.I would like to use robotics to learn mathematics or science.
	Q30. I would use robotics in my classroom teaching.
PS	Q31. I use step-by-step problem-solving processes.
	Q32. I plan before I start to solve a problem.
	Q33. I try new methods to solve a problem when one does not work.
	Q34. I carefully analyze a problem before I begin to develop a solution.
	Q35. In order to solve a complex problem, I break it down into smaller steps.
	Q36. I like listening to others when trying to decide how to approach a task or problem.
	Q37. I like being part of a team that is trying to solve a problem.
	Q38. When working in teams, I ask my teammates for help when I run into a problem or do not understand something.
	Q39.I am confident that I could use a robot to solve problems.
	Q40. I believe that I could work with a robot in a science investigation.
	Q41. I believe that I could fix a software problem if I needed to do so.
	Q42. I like to work with others to complete projects.
ERK	Q43. I have sufficient knowledge about robotics for use in teaching and learning activities.
	Q44. I have sufficient knowledge of coding as it applies to robotics.
	Q45. I have sufficient knowledge of the engineering and design process as it applies to robotics.
	Q46. I have sufficient knowledge to select the most appropriate robot for teaching & learning according to students' ages.
	Q47. I have sufficient knowledge to analyze the pedagogical potentialities of different types of robots.
	Q48. I have sufficient knowledge about block-based programming apps that can be used to teach programming concepts.
SE	Q49. I feel confident that I have the necessary skills to use robotics for classroom instruction.
	Q50. I feel confident that I can engage my students to participate in robotics-based projects.
	Q51. I feel confident that I can help students when they have difficulties with robotics.
	Q52. I feel confident that I can plan and design learning scenarios with robotics.

(a) 15 October 2021 (pre-intervention),

(b) 25 February 2022 (post-intervention 1), and

(c) 29 June 2022 (post-intervention 2).

Individual responses to the questionnaire were supported through the Google Forms platform. Informed consent was obtained, and an e-mail address was made available to answer any questions about the study and the questionnaire. Participant anonymity was ensured by assigning a random number, known only to each PST, used to identify the questionnaires at each collection time to make it possible to establish a relationship between the data collected in M1, M2, and M3.

Statistical Procedures

The description of PST perceptions in the three applications of the questionnaire (M1, M2, and M3) was obtained through descriptive statistics using frequency tables. The characterization of the perceptions was performed in the pre- and post-intervention phases through the mean (M) and standard deviation (SD). PST perceptions of the items in the questionnaire for the dimensions PB, PO, I, PS, ERK, and SE were categorized into positive and negative perceptions depending on whether most answers focused on the more positive (four points and five points) or negative (one point and two points) parts of the scale, with three points being considered as a neutral perception.

The one-way repeated measures ANOVA test was used to compare PST perceptions of the dimensions obtained in the pre-intervention phase (M1), post-intervention phase 1 (M2), and post-intervention phase 2 (M3) after validating its assumptions (Marôco, 2021; Pallant, 2020). The assumption of normality for each dependent variable was assessed using the Shapiro-Wilk test (Marôco, 2021; Pallant, 2020). In cases, where normality was not verified, symmetry analysis was performed using the following condition (Pestana & Gageiro, 2014; Tabachnick et al., 2021):

$$\left|\frac{skewness\ ratio}{error\ of\ the\ skewness\ coefficient}\right| \leq 1.96. \qquad (1)$$

The assumption of sphericity was evaluated using Mauchly's test (Pallant, 2020; Tabachnick et al., 2021). If sphericity cannot be assumed, the degrees of freedom

Table 3. Internal consistency of pre- & post-intervention data

Dimension	Cronbach's alpha			Itens
	M1	M2	M3	
PB	0.739	0.923	0.862	11
PO	0.759	0.862	0.784	11
I	0.897	0.802	0.871	8
PS	0.788	0.847	0.703	12
ERK	0.930	0.858	0.884	6
SE	0.837	0.849	0.947	4

Table 4. Descriptive statistics & comparison between three applications of questionnaire-1 (M1, M2, & M3)

M1	M2	M3	F	p	η_p^2	ES	π
42.37±4.00[a]	50.00±4.41[a, c]	43.32±6.20[c]	22.366	0.001	0.554	Moderate effect	1.00

Note. [a]Comparison M1 vs. M2; [b]Comparison M1 vs. M3; & [c]Comparison M2 vs. M3

obtained by the Greenhouse-Geisser criterion should be considered for the F-statistic of the one-way repeated measures ANOVA table (Tabachnick et al., 2021).

The multiple comparisons of means were performed using the Bonferroni post-hoc test (Field, 2018; Pallant, 2020).

The effect size (ES) was presented as η_p^2 for the one-way repeated measures ANOVA test and interpreted using the following criteria: no effect (ES<0.04), minimum effect (0.04≤ES<0.25), moderate effect (0.25≤ES<0.64), and strong effect (ES≥0.64) (Ferguson, 2009). Apart from ES, the power (π) of the corresponding test is also presented (Pallant, 2020).

The degree of confidence in the collected data, considering the application of the questionnaire in three distinct temporal moments of the intervention, is given by the internal consistency of each of the dimensions (PB, PO, I, PS, ERK, and SE) in the pre- and post-intervention phase assessed through Cronbach's alpha (Pallant, 2020; Pestana & Gageiro, 2014), considering: very good if a≥0.9, good if 0.8≤a<0.9, reasonable if 0.7≤a<0.8, weak if 0.6≤a<0.7, and unacceptable if a<0.6. IBM SPSS statistics software (version 28, IBM USA) was used to perform the statistical analysis, for a significance level of 5%.

RESULTS

Table 3 shows the results for internal consistency of the data collected in the pre-intervention (M1) and post-intervention phases (M2 and M3), concerning PST perceptions of the dimensions PB, PO, I, PS, ERK, and SE. The data in **Table 3** allow us to state that the internal consistency of the data collected presents a degree of confidence a≥0.7, so it is considered a reasonable internal consistency.

The following six subsections present the results of the descriptive statistics for each dimension of the questionnaire (PB, PO, I, PS, ERK, and SE) with M and SD values, and the statistical comparison between the three applications of the questionnaire (M1, M2, and M3), as well as the characterization of PST perceptions regarding the six dimensions of the questionnaire.

Potential Benefits

The data presented in **Table 4** suggest an increase in PST perceptions of PB of integrating ER in teaching practices compared to their initial perception, with statistically significant differences between M1 and M2, as well as between M2 and M3, with a moderate ES. These results allow us to state that there is a positive trend (M2>M1) after phase I in PST perceptions of PB of integrating ER into their teaching practices. However, perceptions are lower (M2>M3) after phase II, while still being higher than M1 (M3>M1).

Table 5 contains the distribution of relative and absolute frequencies of PB dimension. It shows a trend in the differences between M1, M2 and M3: PST perceptions of PB are higher (four points and five points), with a mean value of 90.9% in M2 across the different items in this dimension, and 77.0% in M3 contrasting with the lower value in M1 (71.3%). This trend is particularly evident in the data from M2, with less difference between M1 and M3. For M1, the highest positive perception (five points) has a mean value of 19.6%, becoming the majority in M2 (58.8%), and dropping to 28.7% in M3.

The data suggest that initial perceptions of the contribution of ER to collaborative work (Q7 and Q8) have a more positive trend at M2 in which PST experienced collaborative tasks with ER but decrease to lower than M1 after teaching lessons that integrate ER in collaborative tasks (M3). This negative trend can also be seen when comparing PST perceptions between M2 and M3 in Q6 (contribution of ER to the development of communication skills), as well as Q9, Q10 and Q11 (which concern the students' work in tasks integrating ER).

A decrease in the neutral perceptions (3 points) can also be seen, with a mean value of 23.0% in M1, decreasing by two-thirds in M2 (7.2%) and increasing slightly in M3 (13.4%) to almost half of that in M1. For Q1 through Q5 in M2 the position-taking is absolute, meaning all PST positively perceived PB of ER for the development of learning competencies.

Table 5. Distribution of relative (%) & absolute frequencies of PB dimension

Item	M1: %/n					M2: %/n					M3: %/n				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Q1	0.0/0	0.0/0	26.3/5	57.9/11	15.8/3	0.0/0	0.0/0	0.0/0	42.1/8	57.9/11	0.0/0	0.0/0	10.5/2	63.2/12	26.3/5
Q2	0.0/0	0.0/0	5.3/1	78.9/15	15.8/3	0.0/0	0.0/0	0.0/0	31.6/6	68.4/13	0.0/0	0.0/0	0.0/0	68.4/13	31.6/6
Q3	0.0/0	0.0/0	10.5/2	57.9/11	31.6/6	0.0/0	0.0/0	0.0/0	31.6/6	68.4/13	0.0/0	0.0/0	15.8/3	47.4/9	36.8/7
Q4	0.0/0	0.0/0	5.3/1	63.2/12	31.6/6	0.0/0	0.0/0	0.0/0	15.8/3	84.2/16	0.0/0	0.0/0	5.3/1	57.9/11	36.8/7
Q5	0.0/0	0.0/0	10.5/2	63.2/12	26.3/5	0.0/0	0.0/0	0.0/0	26.3/5	73.7/14	0.0/0	5.3/1	5.3/1	47.4/9	42.1/8
Q6	0.0/0	0.0/0	36.8/7	52.6/10	10.5/2	0.0/0	0.0/0	15.8/3	26.3/5	57.9/11	0.0/0	5.3/1	15.8/3	52.6/10	26.3/5
Q7	0.0/0	0.0/0	10.5/2	42.1/8	47.4/9	0.0/0	0.0/0	5.3/1	21.1/4	73.7/14	0.0/0	5.3/1	5.3/1	42.1/8	47.4/9
Q8	0.0/0	5.3/1	52.6/10	31.6/6	10.5/2	0.0/0	0.0/0	21.1/4	26.3/5	52.6/10	5.3/1	15.8/3	21.1/4	36.8/7	21.1/4
Q9	0.0/0	10.5/2	42.1/8	47.4/9	0.0/0	0.0/0	5.3/1	15.8/3	52.6/10	26.3/5	5.3/1	15.8/3	21.1/4	52.6/10	5.3/1
Q10	0.0/0	15.8/3	26.3/5	42.1/8	15.8/3	0.0/0	5.3/1	10.5/2	36.8/7	47.4/9	5.3/1	15.8/3	26.3/5	26.3/5	26.3/5
Q11	0.0/0	31.6/6	26.3/5	31.6/6	10.5/2	0.0/0	10.5/2	10.5/2	42.1/8	36.8/7	5.3/1	21.1/4	21.1/4	36.8/7	15.8/3
M (%)	0.0	5.7	23.0	51.7	19.6	0.0	1.9	7.2	32.1	58.8	1.9	7.7	13.4	48.3	28.7

Note. 1-I totally disagree; 2-I disagree; 3-I neither agree nor disagree; 4-I agree; 5-I totally agree; & M: mean

Table 6. Descriptive statistics & comparison between three applications of questionnaire-2 (M1, M2, & M3)

M1	M2	M3	F	p	η_p^2	ES	π
35.53±4.31[b]	38.11±6.15	38.79±5.20[b]	2.999	0.062	0.143	Minimum effect	0.546

Note. [a]Comparison M1 vs. M2; [b]Comparison M1 vs. M3; & [c]Comparison M2 vs. M3

Table 7. Distribution of relative (%) & absolute frequencies of PO dimension

Item	M1: %/n					M2: %/n					M3: %/n				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Q12	0.0/0	0.0/0	26.3/5	26.3/5	47.4/9	0.0/0	0.0/0	5.3/1	31.6/6	63.2/12	0.0/0	0.0/0	5.3/1	26.3/5	68.4/13
Q13	0.0/0	10.5/2	42.1/8	31.6/6	15.8/3	0.0/0	5.3/1	15.8/3	36.8/7	42.1/8	0.0/0	0.0/0	21.1/4	26.3/5	52.6/10
Q14	0.0/0	21.1/4	57.9/11	21.1/4	0.0/0	0.0/0	21.1/4	31.6/6	36.8/7	10.5/2	0.0/0	15.8/3	5.3/1	47.4/9	31.6/6
Q15	0.0/0	0.0/0	36.8/7	36.8/7	26.3/5	0.0/0	5.3/1	15.8/3	31.6/6	47.4/9	5.3/1	0.0/0	26.3/5	21.1/4	47.4/9
Q16	10.5/2	73.7/14	15.8/3	0.0/0	0.0/0	42.1/8	47.4/9	0.0/0	5.3/1	5.3/1	47.4/9	47.4/9	5.3/1	0.0/0	0.0/0
Q17	5.3/1	63.2/12	26.3/5	5.3/1	0.0/0	26.3/5	63.2/12	0.0/0	5.3/1	5.3/1	21.1/4	52.6/10	10.5/2	10.5/2	5.3/1
Q18	0.0/0	0.0/0	52.6/10	36.8/7	10.5/2	5.3/1	5.3/1	10.5/2	52.6/10	26.3/5	0.0/0	5.3/1	5.3/1	68.4/13	21.1/4
Q19	10.5/2	68.4/13	15.8/3	5.3/1	0.0/0	31.6/6	57.9/11	10.5/2	0.0/0	0.0/0	36.8/7	52.6/10	10.5/2	0.0/0	0.0/0
Q20	0.0/0	5.3/1	36.8/7	42.1/8	15.8/3	0.0/0	0.0/0	10.5/2	52.6/10	36.8/7	0.0/0	5.3/1	10.5/2	57.9/11	26.3/5
Q21	0.0/0	0.0/0	57.9/11	42.1/8	0.0/0	0.0/0	5.3/1	15.8/3	57.9/11	21.1/4	0.0/0	0.0/0	26.3/5	42.1/8	31.6/6
Q22	0.0/0	0.0/0	42.1/8	47.4/9	10.5/2	0.0/0	10.5/2	0.0/0	63.2/12	26.3/5	0.0/0	5.3/1	15.8/3	42.1/8	36.8/7
M (%)	2.4	22.0	37.3	26.8	11.5	9.5	20.1	10.5	34.0	25.8	10.1	16.7	12.9	31.1	29.2

Note. 1-I totally disagree; 2-I disagree; 3-I neither agree nor disagree; 4-I agree; 5-I totally agree; & M: mean

M1 results showed that PST had a very positive perception (four points and five points) regarding PB of integrating ER in their teaching practices, with a mean value of 71.3%. This rose to 90.9% in M2, decreasing to 77.0% in M3. We can therefore state that PST increased their positive perception of PB of integrating ER in their teaching practices after experiencing ER in a controlled environment during training (M2), returning to values close to M1 when faced with integration of ER in their own teaching practices in a real classroom setting (M3).

Potential Obstacles

Table 6 shows a positive trend in PST perceptions of PO to the integration of ER in teaching practices (M1<M2<M3), with a minimum ES. There are statistically significant differences between M1 and M3.

As for PB dimension, **Table 7** shows a difference in position-taking in PO dimension between M1, M2 and M3, with a decrease in the neutral perception (three points). In M1, the neutral perception starts at a mean value of 30.3%, down in M2 to 10.5%, and rising slightly to 12.9% in M3. Evolution from M1 to M2 is particularly striking, with some items in M1 showing nearly half of PST having a neutral perception (Q14, Q18, and Q21). It is also worth noting the changes in Q16, Q17, and Q22, which at M2 had no neutral perceptions, a significant decrease compared to M1.

Evolution in Q12 and Q13 among M1, M2, and M3 shows that PST perceive that of lack of robots, computers, and software is a significant obstacle to integrating ER in teaching practice. Progressive increase (M1<M2<M3) in negative answers (one point and two points) regarding primary school students being too young to work with ER (Q16) and integration of ER not contributing to learning required for assessment tests (Q19) are relevant. But evolution in Q21 and Q22 among M1, M2, and M3 should be highlighted, with a higher number of positive answers (four points and five points) showing that PST perceived lack of technical support and adequate training as a more significant obstacle. Another relevant result is Q14, where PST perception regarding influence of time management in tasks involving ER evolved to consider this complex variable as a relevant conditioning factor from M1 to M2 and M3.

Table 8. Descriptive statistics & comparison between three applications of questionnaire-3 (M1, M2, & M3)

M1	M2	M3	F	p	η_p^2	ES	π
31.29±0.65[a,b]	33.42±3.19[a]	34.13±3.30[b]	8.941	0.001	0.332	Moderate effect	0.961

Note. [a]Comparison M1 vs. M2; [b]Comparison M1 vs. M3; & [c]Comparison M2 vs. M3

Table 9. Distribution of relative (%) & absolute frequencies of I dimension

Item	M1: %/n					M2: %/n					M3: %/n				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Q23	0.0/0	5.3/1	5.3/1	73.7/14	15.8/3	0.0/0	0.0/0	0.0/0	57.9/11	42.1/8	0.0/0	0.0/0	0.0/0	57.9/11	42.1/8
Q24	0.0/0	10.5/2	26.3/5	52.6/10	10.5/2	0.0/0	0.0/0	15.8/3	68.4/13	15.8/3	0.0/0	5.3/1	10.5/2	52.6/10	31.6/6
Q25	0.0/0	10.5/2	21.1/4	52.6/10	15.8/3	0.0/0	5.3/1	21.1/4	63.2/12	10.5/2	0.0/0	5.3/1	15.8/3	52.6/10	26.3/5
Q26	0.0/0	5.3/1	26.3/5	57.9/11	10.5/2	0.0/0	5.3/1	10.5/2	73.7/14	10.5/2	0.0/0	5.3/1	15.8/3	57.9/11	21.1/4
Q27	0.0/0	10.5/2	21.1/4	52.6/10	15.8/3	0.0/0	5.3/1	21.1/4	63.2/12	10.5/2	0.0/0	5.3/1	21.1/4	52.6/10	21.1/4
Q28	0.0/0	0.0/0	0.0/0	63.2/12	36.8/7	0.0/0	0.0/0	0.0/0	42.1/8	57.9/11	0.0/0	0.0/0	0.0/0	57.9/11	42.1/8
Q29	0.0/0	0.0/0	10.5/2	68.4/13	21.1/4	0.0/0	0.0/0	5.3/1	47.4/9	47.4/9	0.0/0	0.0/0	5.3/1	52.6/10	42.1/8
Q30	0.0/0	0.0/0	15.8/3	57.9/11	26.3/5	0.0/0	0.0/0	5.3/1	36.8/7	57.9/11	0.0/0	0.0/0	15.8/3	26.3/5	57.9/11
M (%)	0.0	5.2	15.8	59.9	19.1	0.0	1.9	9.9	56.6	31.6	0.0	2.7	10.5	51.3	35.5

Note. 1-I totally disagree; 2-I disagree; 3-I neither agree nor disagree; 4-I agree; 5-I totally agree; & M: mean

Table 10. Descriptive statistics & comparison between three applications of questionnaire-4 (M1, M2, & M3)

M1	M2	M3	F	p	η_p^2	ES	π
47.05±4.27[b]	48.68±4.45	49.67±3.35[b]	3.640	0.036	0.168	Minimum effect	0.635

Note. [a]Comparison M1 vs. M2; [b]Comparison M1 vs. M3; & [c]Comparison M2 vs. M3

In M1, PST had a mean value of 38.3% of maximum very positive perception on PO to ER integration in the classroom. In M2 that perception increased to 58.8%, slightly increasing again in M3, with a mean value of 60.3% of positive perception. According to the results, it is possible to state that the intervention reinforced PST perceptions of PO to the integration of ER in teaching practices.

Interest

Table 8, as in PO dimension, shows a positive trend regarding PST I in ER (M1<M2<M3), with statistically significant differences between M1, M2, and M3. PST I in ER increased with each phase of the study, reaching the highest value in M3 (34.13±3.30), with a moderate ES.

As seen in the previous dimensions (PB and PO), **Table 9** shows the difference in position-taking for each item in this dimension between M1, M2, and M3. In addition, there is an overall decrease in the neutral perception (3 points), which has a mean value of 15.8% in M1, down to 9.9% in M2 and rising slightly in M3 to 10.5%. For Q23 (I like to learn about new technologies and robotics) only one PST had a neutral perception in M1, which changed in M2 and M3 to an absolutely positive perception for the whole cohort. Additionally, Q28 (I find it interesting to learn about robots) maintained its initial absolutely positive perception from M1 through to M3.

Items Q29 and Q30 concerning PST willingness to integrate ER into future teaching practices received no negative responses throughout the study. Comparing M1 with M2 and M3, these items got an increase in very positive answers (five points). Regarding I in STEM professions (Q26 and Q27), there was also an increase in the number of positive responses (four points and five points) in M2 and M3 compared to M1.

Overall, the initial perceptions of PST (M1) were already high, with a mean value of 79.0% in positive perceptions (four points and five points). This further increased to 88.2% in M2, and with a slight decrease in M3 to 86.8%.

Problem-Solving

Although **Table 10** shows a positive trend concerning PST perceptions of PS (M1<M2<M3), only the difference between M1and M3 is statistically significant. PST perceptions of their PS skills increased during each phase of the study, reaching the highest value in M3 (49.67±3.35), with a minimum ES.

Similarly to the previous dimensions (PB, PO, and I), **Table 11** also shows a difference in position-taking between M1, M2, and M3, with a decrease in the neutral perception (three points). In M1, the mean value of neutral perception in PS is 21.1%, decreasing in M2 to 14.4%, and again in M3 to 12.3%. Q36 and Q38, which refer to valuing the contribution of peers to the resolution of problems, show an absolutely positive perception throughout the study (M1, M2, and M3).

Q40 (working with robots in science and technology activities) and Q41 (solving software-related problems) show a positive trend from M1 to M3, but no very positive perception (five points) was recorded throughout the study. Q39 (using robots to solve problems) received a single very positive response (5 points), in M3. This positive trend in Q39 represents a relevant change compared to the pre-intervention (M1), with a value of negative perceptions of 36.8% and only 15.8% for positive perceptions. In M2, there are no

Table 11. Distribution of relative (%) & absolute frequencies of PS dimension

Item	M1: %/n					M2: %/n					M3: %/n				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Q31	0.0/0	0.0/0	15.8/3	73.7/14	10.5/2	0.0/0	0.0/0	10.5/2	78.9/15	10.5/2	0.0/0	0.0/0	5.3/1	63.2/12	31.6/6
Q32	0.0/0	5.3/1	31.6/6	47.4/9	15.8/3	0.0/0	0.0/0	15.8/3	63.2/12	21.1/4	0.0/0	0.0/0	5.3/1	63.2/12	31.6/6
Q33	0.0/0	0.0/0	5.3/1	63.2/12	31.6/6	0.0/0	0.0/0	15.8/3	42.1/8	42.1/8	0.0/0	0.0/0	0.0/0	57.9/11	42.1/8
Q34	0.0/0	0.0/0	10.5/2	63.2/12	26.3/5	0.0/0	0.0/0	0.0/0	73.7/14	26.3/5	0.0/0	0.0/0	5.3/1	57.9/11	36.8/7
Q35	0.0/0	5.3/1	0.0/0	57.9/11	36.8/7	0.0/0	5.3/1	10.5/2	63.2/12	21.1/4	0.0/0	0.0/0	5.3/1	52.6/10	42.1/8
Q36	0.0/0	0.0/0	0.0/0	42.1/8	57.9/11	0.0/0	0.0/0	0.0/0	63.2/12	36.8/7	0.0/0	0.0/0	0.0/0	47.4/9	52.6/10
Q37	0.0/0	0.0/0	10.5/2	36.8/7	52.6/10	0.0/0	0.0/0	10.5/2	47.4/9	42.1/8	0.0/0	0.0/0	10.5/2	47.4/9	42.1/8
Q38	0.0/0	0.0/0	0.0/0	36.8/7	63.2/12	0.0/0	0.0/0	0.0/0	47.4/9	52.6/10	0.0/0	0.0/0	0.0/0	36.8/7	63.2/12
Q39	10.5/2	26.3/5	47.4/9	15.8/3	0.0/0	0.0/0	0.0/0	36.8/7	57.9/11	5.3/1	0.0/0	5.3/1	42.1/8	52.6/10	0.0/0
Q40	5.3/1	5.3/1	68.4/13	21.1/4	0.0/0	0.0/0	5.3/1	15.8/3	78.9/15	0.0/0	0.0/0	5.3/1	15.8/3	78.9/15	0.0/0
Q41	0.0/0	21.1/4	52.6/10	26.3/5	0.0/0	0.0/0	10.5/2	47.4/9	42.1/8	0.0/0	5.3/1	5.3/1	36.8/7	52.6/10	0.0/0
Q42	0.0/0	0.0/0	10.5/2	52.6/10	36.8/7	0.0/0	0.0/0	10.5/2	63.2/12	26.3/5	0.0/0	0.0/0	21.1/4	57.9/11	21.1/4
M (%)	1.3	5.3	21.1	44.7	27.6	0.0	1.8	14.4	60.1	23.7	0.4	1.3	12.3	55.7	30.3

Note. 1-I totally disagree; 2-I disagree; 3-I neither agree nor disagree; 4-I agree; 5-I totally agree; & M: mean

Table 12. Descriptive statistics & comparison between three applications of questionnaire-5 (M1, M2, & M3)

M1	M2	M3	F	p	η_p^2	ES	π
11.53±4.11[a,b]	19.37±3.71[a]	18.21±4.21[b]	36.294	0.001	0.668	Strong effect	1.00

Note. [a]Comparison M1 vs. M2; [b]Comparison M1 vs. M3; & [c]Comparison M2 vs. M3

Table 13. Distribution of relative (%) & absolute frequencies of ERK dimension

Item	M1: %/n					M2: %/n					M3: %/n				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Q43	31.6/6	52.6/10	15.8/3	0.0/0	0.0/0	0.0/0	31.6/6	15.8/3	52.6/10	0.0/0	0.0/0	26.3/5	26.3/5	47.4/9	0.0/0
Q44	31.6/6	63.2/12	5.3/1	0.0/0	0.0/0	0.0/0	31.6/6	31.6/6	36.8/7	0.0/0	5.3/1	42.1/8	21.1/4	31.6/6	0.0/0
Q45	36.8/7	63.2/12	0.0/0	0.0/0	0.0/0	5.3/1	52.6/10	21.1/4	21.1/4	0.0/0	15.8/3	52.6/10	21.1/4	10.5/2	0.0/0
Q46	36.8/7	31.6/6	26.3/5	5.3/1	0.0/0	0.0/0	5.3/1	15.8/3	73.7/14	5.3/1	0.0/0	21.1/4	10.5/2	63.2/12	5.3/1
Q47	36.8/7	21.1/4	21.1/4	21.1/4	0.0/0	0.0/0	5.3/1	15.8/3	73.7/14	5.3/1	0.0/0	21.1/4	21.1/4	57.9/11	0.0/0
Q48	26.3/5	47.4/9	21.1/4	5.3/1	0.0/0	0.0/0	36.8/7	31.6/6	31.6/6	0.0/0	0.0/0	31.6/6	31.6/6	36.8/7	0.0/0
M (%)	33.3	46.5	14.9	5.3	0.0	0.9	27.2	21.9	48.2	1.8	3.5	32.5	21.9	41.2	0.9

Note. 1-I totally disagree; 2-I disagree; 3-I neither agree nor disagree; 4-I agree; 5-I totally agree; & M: mean

negative perceptions, and 63.2% for positive perceptions. In M3 the value of negative perceptions rises again to 5.3% (one response) and a value of positive perceptions at 52.6%.

Overall, PST perceptions of their PS skills was already high before the intervention (M1), with a mean value of 72.3% in positive perceptions, further increasing to 83.8% in M2 and 86.0% in M3.

Educational Robotics Knowledge

Table 12 shows an increase in PST perceptions of their ERK compared to the initial pre-intervention (M1<M2 and M1<M3), with statistically significant differences between M1, M2, and M3. PST perceptions of their ERK reached the highest value in M2 (19.37±3.71), showing a strong ES, decreasing slightly in M3 (18.21±4.21).

In contrast to previous dimensions, **Table 13** does not show any overall decrease in neutral perceptions (three points). In M1, neutral perceptions have a mean value of 14.9%, increasing to 21.9% in the post-intervention period (M2 and M3).

The change in Q43 (knowledge about the use of robots in teaching and learning activities) is particularly noticeable, with a positive trend identified throughout the intervention. This item had a negative perception value of 84.2% in M1 and no positive responses. In M2, the value of the positive perception is 52.6%, with a strong reduction in negative perception compared to M1 at 31.6%. In M3, the positive perception decreases slightly to 47.4%, with a further reduction in negative perception compared to M2 at 26.3%. No very negative perceptions (one point) can be found in M2 and M3, contrasting with six responses in M1.

PST perceptions related to the knowledge needed to select the appropriate robot for the context (Q46 and Q47) show a positive trend across M1, M2, and M3. In M1, negative perceptions represented more than half the positive perceptions. In M2, these items each recorded only one negative perception (two points), with a value of positive perceptions of 79.0%, and one very positive response (five points) for each. In M3, the value of positive perceptions accounts for over half of the responses, at 68.5% for Q46 and 57.9% for Q47, contrasting with a value of 21.1% in negative perceptions, which is much lower than M1 but higher than M2.

There is a positive trend for PST perceptions of their programming knowledge to apply to ER (Q44). In M1,

Table 14. Descriptive statistics & comparison between three applications of questionnaire-6 (M1, M2, & M3)

M1	M2	M3	F	p	η_p^2	ES	π
11.79±2.37[a,b]	15.42±0.77[a]	15.58±0.69[b]	36.255	0.001	0.668	Strong effect	1.00

Note. [a]Comparison M1 vs. M2; [b]Comparison M1 vs. M3; & [c]Comparison M2 vs. M3

Table 15. Distribution of relative (%) & absolute frequencies of SE dimension

Item	M1: %/n					M2: %/n					M3: %/n				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Q49	15.8/3	31.6/6	36.8/7	15.8/3	0.0/0	0.0/0	10.5/2	21.1/4	63.2/12	5.3/1	0.0/0	10.5/2	31.6/6	57.9/11	0.0/0
Q50	5.3/1	10.5/2	42.1/8	42.1/8	0.0/0	0.0/0	0.0/0	10.5/2	84.2/16	5.3/1	0.0/0	10.5/2	15.8/3	73.7/14	0.0/0
Q51	15.8/3	10.5/2	52.6/10	21.1/4	0.0/0	0.0/0	0.0/0	26.3/5	63.2/12	10.5/2	0.0/0	15.8/3	10.5/2	73.7/14	0.0/0
Q52	10.5/2	10.5/2	63.2/12	15.8/3	0.0/0	0.0/0	0.0/0	26.3/5	68.4/13	5.3/1	0.0/0	10.5/2	10.5/2	73.7/14	5.3/1
M (%)	11.8	15.8	48.7	23.7	0.0	0.0	2.6	21.1	69.8	6.6	0.0	11.8	17.1	69.8	1.3

Note. 1-I totally disagree; 2-I disagree; 3-I neither agree nor disagree; 4-I agree; 5-I totally agree; & M: mean

the negative perceptions account for almost all responses, with a value of 94.8% and no positive responses. In M2 there was a considerable reduction in negative perceptions, with a value of 31.6% in negative perception and 36.8% in positive perceptions. The results for M3 show that, after experiencing the integration of ER in their teaching practices, negative perceptions (47.4%) again exceeded positive perceptions (31.6%).

Overall, initial PST perceptions (M1) of their own ERK were quite low, with a mean value of 79.8% in negative perceptions. That was reversed in M2, with a mean value of 50.0% in positive perceptions and 28.1% in negative perceptions, while in M3 the mean value in positive perceptions decreased to 42.1% and negative perceptions increased to 36.0%, maintaining the overall dominance of positive over negative perceptions identified in M2.

Self-Efficacy

Similarly to what was identified in PO, I, and PS dimensions, **Table 14** shows a positive trend in PST perceptions of their own SE (M1<M2<M3), with statistically significant differences between M1, M2, and M3. PST perceptions of their SE increased at each phase of the study, reaching the highest value in M3 (15.58±0.69), with a strong ES.

Table 15 shows, as in the dimensions PB, PO, I, and PS, a difference in position-taking between M1, M2, and M3, with a decrease in neutral perceptions (three points). In M1, neutral perceptions have a mean value across items of 48.7%, which decreases in M2 to 21.1%, and further downward in M3 to 17.1%.

PST perceptions of their own SE in using robots in teaching practices (Q49) shows a mostly negative perception (one point and two points) in M1, with a value of 47.4%. This perception shifts in the post-intervention period, with a value for the positive perceptions of 68.5% in M2 and 57.9% in M3.

Q50, which refers to SE in promoting students' involvement in tasks involving ER, showed a low negative perception in M1 (15.8%) and a positive perception of 42.1%. In M2 there were no negative perceptions registered for this item, with the positive perceptions accounting for 89.5% of responses. In M3, positive perceptions decrease slightly (73.7%) with negative perceptions reappearing (10.5%).

PST perceptions of being able to help students overcome difficulties with ER (Q51) were more negative (26.3%) than positive (21.1%) in M1. This relationship was reversed in M2 and M3, with the positive perceptions surpassing negative ones.

As to SE in the design of learning scenarios integrating ER (Q52), M1 showed more negative perceptions (21.0%) than positive perceptions (15.8%). In M2, no negative perceptions were recorded, with positive perceptions accounting for 73.7% of responses. In M3, positive perceptions reach their highest value (79.0%), while negative perceptions return (10.5%).

Overall, we found a balanced mix of negative (mean value of 27.6%) and positive perceptions (mean value of 23.7%) in M1. This balance disappears in M2, with an only residual negative perception (mean value of 2.6%) and a predominantly positive perception (mean value of 76.4%). In M3, positive perceptions decrease to 71.1% and negative perceptions increase to 11.8%, maintaining the superiority of positive perception over the negative perception identified in M2.

DISCUSSION

This study has sought to contribute to the discussion around the role of ITT in enabling PST to promote appropriate integration of ER into their teaching practice. To this end, we designed and implemented a training program supported by recommendations identified in the literature, seeking to respond to known limitations regarding the integration of ER into teaching and learning processes. We have proposed to answer our research question through a pre-experimental design, collecting data on the perception of PST at three different points in time around the intervention.

Integrating ER into ITT programs influences PST perceptions towards the different variables related to this technology (Castro et al., 2018; Jaipal-Jamani & Angeli, 2017; Khanlari, 2019; Schina et al., 2021b), contributing to an appropriate integration of ER into their future teaching practices (Alqahtani et al., 2022; Davis, 1989; Keren & Fridin, 2014; Schina et al., 2021b). In this section we discuss the influence of a training program that integrates ER and the use of learning scenarios in ITT for primary school on PST perceptions regarding:

(a) PB and PO of integrating ER into their future teaching practice,

(b) I in ER,

(c) PS,

(d) ERK, and

(e) SE in the integration of ER in their own teaching practice.

One of the main changes identified in PST perceptions is related to position-taking and a decrease in neutrality in M2 and M3. As mentioned in the theoretical background, Tzagaraki et al. (2022) report a high neutral perception of teachers in items related to ease of use of robotics, as well as items related to intention to use ER. As in the study by Gavrillas et al. (2024), our study identifies high values of neutrality in M1 with PST negative perceptions of SE surpassing positive perceptions. Khanlari's (2016) results show reduced values of neutrality in PB dimension, and almost none in PO dimension. We argue that this discrepancy with our results is related to the sample. Khanlari's (2016) study involved in-service teachers with several years of experience who were familiar with the reality of schools and their classes, while ours involves the participation of PST, most of whom had never had any contact with ER in formal education settings. Participation in tasks that integrate ER in practical and contextualized situations fosters the development of PST knowledge and changes in their attitudes towards the technology used (Huang & Zbiek, 2017; You et al., 2021). Alqahtani et al. (2022) and Casler-Failing (2021) suggest that allowing PST to design and implement lesson plans that integrate ER into their teaching practices leads to changes in their perceptions of ER. We argue that including these characteristics in the design of the training program contributed to the decrease of neutrality identified in PST perceptions in M2 and M3.

Potential Benefits

Several studies report teachers' positive perceptions of PB of ER, such as the study by Tzagaraki et al. (2022). Those authors identify a positive attitude of teachers towards ER as a facilitator of improvements in learning, as well as towards the usefulness of ER in improving the effectiveness of teaching and learning. Regarding PB dimension, the results of this study show a mean initial value of positive perceptions higher than those reported by Khanlari (2019). We argue that this is due to the fact that PST have greater exposure to the use of technology, and that technology is part of their training, which may contribute to their acceptance of the integration of technology in teaching and learning processes and a more favorable attitude towards it (Niess et al., 2009). As in the studies by You et al. (2021) and Castro et al. (2018), there was an increase in the mean value of positive perceptions in the post-intervention phases (M2 and M3) compared to the pre-intervention (M1). Similar to Castro et al. (2018), the very positive and idealized perception in M2 decreased after PST experienced the integration of ER into their teaching practices in M3, with this trend being particularly visible in Q6 through Q11. One recommendation for the design of ITT programs dedicated to the integration of ER is to create conditions that allow PST to design and implement lesson plans that integrate ER into their teaching practices (Casler-Failing, 2021; Piedade et al., 2020; Schina et al., 2021a; Seckel et al., 2022). We argue that including this feature in our training program, allowing PST to experience the reflective process of designing and implementing learning scenarios during the intervention (Matos, 2014; Pedro et al., 2019), contributed to this change in PST perceptions of PB when faced with the integration of ER in a real classroom setting.

The change in some items provides evidence that in M2 PST perceived the integration of ER as a positive contribution to the development of mathematical communication (Q6) and teamwork (Q7 and Q8) skills. We argue that this is due to the intervention's characteristics, in particular PST participation in tasks that integrate ER in activities of a collaborative nature (Anwar et al., 2019; Athanasiou et al., 2019; Kim et al., 2015; You et al., 2021), as well as in the design and discussion of learning scenarios (Matos, 2014; Pedro et al., 2019; Piedade et al., 2020) throughout the didactic sequences of phase I.

Potential Obstacles

In terms of PST perceptions of PO, our results show that PST started to recognize greater complexity in the variables associated with the integration of ER in teaching practices (You et al., 2021). PST perceptions after participating in tasks that integrated ER in a contextualized and practical way in the didactic sequences (Casler-Failing, 2021; Huang & Zbiek, 2017) in M2 were adjusted in M3 after they experienced the integration of ER in their own teaching practices in a real classroom setting (Castro et al., 2018). We argue that allowing PST to experience the reflective process of designing and implementing learning scenarios during the intervention (Matos, 2014; Pedro et al., 2019) contributed to this change in PST perceptions of PO when faced with the integration of ER in a real classroom setting.

There is evidence that in M2 and M3 PST perceived the scarcity of robots, computers, and software in schools as a more significant barrier to the integration of ER in teaching practices (Q12, Q13, and Q15). PST experienced proposals for integrating ER that emphasized the influence of downtime on the development of activities throughout the didactic sequences in phase I. The potentials and constraints of the different ER platforms and how they impact the learning scenario proposals were discussed, supported by TPACK conceptual model (Koehler & Mishra, 2009; Mishra, 2019), seeking to create conditions for PST to conclude that an adequate integration of ER in the teaching and learning processes is necessary so that learning can occur in their future primary school students. Thus, we consider that the reflective component of the design and implementation process of the learning scenarios in phase II (Matos, 2014; Piedade et al., 2020) contributed to the change identified in these items.

The results obtained for Q14 allow us to state that PST started to perceive the influence of time management in tasks that include ER as a more relevant constraint. The intervention design included a pilot implementation of the learning scenarios–in which PST experienced the management of classes integrating ER (Casler-Failing, 2021; Huang & Zbiek, 2017), as well as observing their peers (Schina et al., 2021b). We argue that these features, as well as the implementation of learning scenarios resulting from redesign (Kim et al., 2015; Seckel et al., 2022) in the practicum (Kucuk & Sisman, 2017; Luciano et al., 2019; Piedade et al., 2020) contributed to this change in PST perception.

There was an increase in the very negative responses (strongly disagree, one point) concerning the fact that primary school students were too young to work with ER (Q16) post-intervention (M2 and M3). These results are similar to those reported by Kim et al. (2015), and we agree that the perception of ER platforms being somewhat complex and difficult to manipulate is due to the lack of knowledge and experience with these types of artefacts. Papadakis et al. (2021) hypothesize that some teachers' perceptions about the potential of ER are the result of unfamiliarity with the artefacts. We argue that in our study this pre-conception concerning the fact that primary school students were too young to work with ER was deconstructed through participation in the intervention tasks in which PST contacted with different ER platforms (Anwar et al., 2019; Schina et al., 2021b), as well as by witnessing the students' performance while working with ER platforms during the practicum.

Similar changes occurred in PST perceptions of the integration of ER not preparing students for tests (Q19). In their study, Tzagaraki et al. (2022) report that there is a positive perception among teachers about the contribution of ER to the development of mathematical skills in students. The results presented by Khanlari (2019) show that, after teachers took part in a workshop dedicated to robotics and STEM education, there was an increase in their positive perception about the usefulness of ER for mathematical learning. As stated in the description of the pedagogical intervention, the design of learning scenarios encouraged PST to establish learning objectives with curricular connections (El-Hamamsy et al., 2021; Kim, 2019; Sapounidis & Alimisis, 2021) and strategies to achieve them. The tasks implemented in stage II were interdisciplinary in nature (Athanasiou et al., 2019; Kuhl et al., 2019; Miller & Nourbakhsh, 2016), aiming to make abstract mathematical concepts concrete and explore real-world problems (Anwar et al., 2019). Kalogiannakis and Papadakis (2022) report a willingness by PST to include similar tasks, or tasks with similar characteristics, to those experienced during training in their future teaching practices. In our study PST sought to include the characteristics of the intervention into their own learning scenario proposals. We consider that these aspects of the intervention, by allowing PST to confront their preconceptions about the integration of ER not preparing students for tests with what they have achieved in the design of learning scenarios, influenced the post-intervention change in PST perceptions.

The M2 and M3 changes that occurred in Q21 and Q22 suggest that PST began perceiving the lack of adequate training and technical support as more significant obstacles to the integration of ER in teaching practices. These results are consistent with I voiced by Portuguese teachers in obtaining more training related to ER (Ramos et al., 2022), as well as with the results presented by Tzagaraki et al. (2022), which suggest that obtaining ER-related training increases teachers' I in ER. We claim that participation in this study, experiencing training for SE and knowledge about ER, reinforced PST perceptions of the importance of these variables for adequate integration of ER in their teaching practices.

Interest

The positive trend associated with increased PST I in ER peaked in M3. These results are similar to those reported by other studies in which I in ER increased after an intervention that integrated ER (Alqahtani et al., 2022; Dong et al., 2023; Piedade et al., 2020; Román-Graván et al., 2020). Evidence suggests that there was also an increase in PST I in STEM professions (Q26 and Q27), as also found in previous studies (Kuhl et al., 2019; Miller & Nourbakhsh, 2016).

Regarding PST willingness to integrate ER into their future teaching practices (Q29 and Q30), positive perceptions had a very high mean value already in M1, with a positive trend in M2 and M3, in line with the results presented by other studies (Alqahtani et al., 2022; Jaipal-Jamani & Angeli, 2017; Khanlari, 2019; Piedade et al., 2020; Román-Graván et al., 2020). We argue that the characteristics of this intervention, allowing PST to experience and understand the curricular integration of ER (Casler-Failing, 2021), influenced this willingness to integrate ER into their future teaching practices (Chevalier et al., 2016).

As previously mentioned, results from Tzagaraki et al. (2022) suggest that obtaining ER-related training increases teachers' I in ER. As can be found in similar studies achieving comparable results (Dong et al., 2023), we consider that participation in this intervention integrating ER into ITT contributed to the improvement in PST I in ER.

Problem-Solving

Despite already high values in the pre-intervention (M1), there is evidence of a positive trend associated with PST perceptions of their own PS skills, reaching the highest point in the post-intervention M3. This positive perception is in line with the study by Tzagaraki et al. (2022) about teachers' positive perception of the contribution of ER to the development of PS skills. As for the improvements identified in M2 and M3, these are consistent with those reported by Piedade et al. (2020). The absolutely positive perception in Q36 and Q38 (valuing peer contributions to PS) shows similar values in M1 and M3 for very positive perceptions (five points) and lower values in M2. The intervention design included collaborative PS tasks (Piedade et al., 2020) with each of ER platforms (Anwar et al., 2019; Schina et al., 2021b); however, stage II was the first time that PST took part in collaborative tasks that integrated ER. We claim that the high, and idealized, perceptions in M1 lowered in M2 when PST were confronted with the reality of participating in tasks with these characteristics. The mean values of very positive perceptions increased in M3 after experiencing the pilot implementation of learning scenarios–in which PST experienced the management of classes integrating ER (Casler-Failing, 2021; Huang & Zbiek, 2017) and observed their peers (Schina et al., 2021a)–, and subsequent implementation of learning scenarios resulting from redesign (Kim et al., 2015; Seckel et al., 2022) in the practicum class. We consider that being confronted again with collaborative PS tasks, this time with an ER platform with which they were familiar, contributed to this increase in positive perceptions in M3.

Educational Robotics Knowledge

Results from Papadakis (2022) show that teachers perceive lack of knowledge about ER as the main obstacle to integrating this technology in their teaching practices. Our data on PST perceptions of ERK show a mostly negative perception in pre-intervention. Similarly to the study of Román-Graván et al. (2020), these low values were expected since most PST participants had never had any contact with ER platforms. This predominantly negative perception of ERK was reversed in the post-intervention phases (M2 and M3) in which positive perceptions had a higher mean value than negative perceptions. Given that participating in tasks that integrate ER in practical and contextualized situations fosters the development of PST knowledge regarding ER (Huang & Zbiek, 2017; You et al., 2021), we therefore claim that the increase in positive perceptions was influenced by participation in this training program (Casler-Failing, 2021; Jaipal-Jamani & Angeli, 2017; Piedade et al., 2020; Román-Graván et al., 2020; You et al., 2021).

Regarding PST perceptions of their own knowledge about use of robots in teaching and learning activities (Q43) and knowledge needed to select the appropriate ER platform for the context (Q45 and Q46), the results show a very negative perception in M1. Gavrilas et al. (2024) also report a very negative perception of teachers regarding their ability to choose the appropriate ER platform for the context. In our study, the negative perception identified in M1 was reversed in M2, we claim that this change in PST perceptions was influenced by experiencing the integration of ER in practical and contextualized situations (Casler-Failing, 2021; Huang & Zbiek, 2017) that promote curricular articulation and integration (El-Hamamsy et al., 2021; Kim, 2019; Sapounidis & Alimisis, 2021) supported by different ER platforms (Anwar et al., 2019; Schina et al., 2021b) of increasing complexity. We consider the reduction in the mean value of positive perceptions in M3 to be influenced by the implementation of the learning scenarios resulting from redesign (Kim et al., 2015; Seckel et al., 2022) in the practicum class (Kucuk & Sisman, 2017; Luciano et al., 2019; Piedade et al., 2020), with an adjustment of idealized perception in M2 when faced with the integration of ER in their own teaching practices in real classroom settings (Castro et al., 2018).

Self-Efficacy

PST perceptions of SE in the integration of ER into their teaching practices showed a balance between positive and negative perceptions in M1, similar to the results reported by Gavrillas et al. (2024). The post-intervention (M2 and M3) data shows that there was an increase in positive perceptions, with mean values higher than 70.0%, which is consistent with the results of other studies reporting an improvement in perceptions of SE after participating in training initiatives that integrate ER (Castro et al., 2018; Jaipal-Jamani, 2023; Jaipal-Jamani & Angeli, 2017; Khanlari, 2019; Piedade et al., 2020; Román-Graván et al., 2020; Schina et al., 2021b; You et al., 2021). There was also an adjustment of the idealized perception in M2 when confronted with the integration of ER in teaching practices in a real classroom setting (Castro et al., 2018) in M3. As stated before, the design of the intervention was supported by good practices identified in the literature and recommendations for the design of ITT programs that integrate ER. By doing so, we expected to address some of the limitations associated with the integration of ER in teaching and learning processes. This is the rationale that supports the justification for the changes identified in PST perceptions discussed below.

We claim that the improvement identified in Q49 (SE in using robots in teaching practices) was influenced by PST experiencing the integration of ER in practical and contextualized situations (Casler-Failing, 2021; Huang & Zbiek, 2017) in M2, as well as the implementation of learning scenarios resulting from redesign (Kim et al., 2015; Seckel et al., 2022) in the practicum class (Kucuk & Sisman, 2017; Luciano et al., 2019; Piedade et al., 2020) in M3.

PST considered themselves able to help students overcome difficulties with ER (Q51) post-intervention (M2 and M3). We claim this change in PST perceptions was influenced by having experienced the integration of ER in practical and contextualized situations (Casler-Failing, 2021; Huang & Zbiek, 2017) supported by different ER platforms (Anwar et al., 2019; Schina et al., 2021b) of increasing complexity. We also claim that the pilot implementation of learning scenarios and the implementation of learning scenarios resulting from redesign (Kim et al., 2015; Seckel et al., 2022) in the practicum class (Kucuk & Sisman, 2017; Luciano et al., 2019; Piedade et al., 2020) contributed to this change.

As to the improvement identified in Q52 (SE in the design of learning scenarios integrating ER), we believe that this change in PST perceptions was influenced by

(a) the exploration of the learning scenarios design process and subsequent adaptation to the respective practicum context (Kim et al., 2015; Pedro et al., 2019; Seckel et al., 2022), with the design of a hypothetical learning scenario throughout the didactic sequences of phase I and

(b) the process of redesign and implementation of learning scenarios in phase II (Matos, 2014; Pedro et al., 2019; Piedade et al., 2020).

Limitations

This study presents some limitations. The study sample was made up only of female students, from one specific class and context. As such, it is suggested that future studies use a larger sample from different contexts with the use of stronger inferential statistical analyses, thus allowing generalization of the findings. It is also suggested that future studies include an experimental control group, making it easier to understand the impact of the specific features of the training program on the perception of PSTs about ER. One of the known limitations of integrating ER into ITT was addressed by including the design and implementation of learning scenarios in the practicum. Since it was not possible to create conditions that allowed for more than one cycle of design and implementation of learning scenarios in the practicum, it's to be expected that PST's lack of experience in managing classes that integrate ER conditioned the results of our study. Furthermore, we consider that the influence of this variable may have been amplified by the fact that PST's previous training and experience in the classroom have been strongly impacted by the constraints imposed by COVID-19 in Portugal.

Practical Implications for Initial Teacher Training

Given the size of the sample and its specific context, and without claiming to generalize the results of this study, we believe that our findings have implications for the integration of ER in ITT. There is a need to better understand how PST integrate ER into their teaching practice and how this integration influences their perception of the complex variables related to ER. It is equally important to understand how the design of ITT programs that integrate ER influences the integration of ER into PST teaching practices, and how the possibility of experiencing the integration of ER in their teaching practice continuously influences PST perceptions of the complex variables related to ER. We present a training program that seeks to mitigate known difficulties in integrating technology into ITT, such as in PST beliefs, attitudes and knowledge (Wilson, 2023).

The design of the training program was supported by good practices identified in the literature and recommendations for the design of ITT programs that integrate ER, as detailed in section 3.3 Pedagogical intervention. The design also considered aspects that influence PST integration of ER into mathematics teaching and learning processes. Of those we highlight the influence of lesson plan design competence in PST integration of ER in their teaching practices (Schmid et al., 2021; Tankiz & Uslu, 2022), the need for specific training for the development of teachers' didactic knowledge (Zhong & Xia, 2020), and the importance of allowing PST to experience the integration of ER in their teaching practices during the practicum (Oliveira et al., 2023; Schina et al., 2021b), supported by the reflective process of design and implementation of learning scenarios (Matos, 2014; Pedro et al., 2019; Piedade et al., 2020). By doing so, we expected to foster PST acceptance of ER, thus increasing their willingness to integrate it into their teaching practices (Neophytou & Eteokleous, 2022).

In the context of this study, the implementation of learning scenarios with the practicum classes was the first time that PST experienced the management of a lesson integrating ER, not forgetting that for many of the children in the practicum classes it was also their first contact with ER platforms. As such, we consider it is important that PST have the opportunity to experience the integration of ER in their practice in a way that is not a one-off experience, preferably using different ER platforms of increasing complexity.

We consider that the results of this study have implications for ITT training programs dedicated to integrating technology (not just ER) into teaching and learning processes. The acceptance of technology and the perception of its usefulness in promoting learning influences teachers' willingness to integrate it into their teaching practices. As such, future studies on this subject must include monitoring PST perceptions, creating the conditions for them to confront their preconceived perception of the potential and restrictions of integrating technology into teaching and learning processes with the reality of integrating technology into their teaching practices, thus promoting a reflective process that also considers the lack of PST experience in managing classes that promote the integration of technology.

CONCLUSIONS

Answering our research question, supported by the discussion of results, we claim that the features of the proposed training program positively influenced PST perceptions of

(a) PB and PO of integrating ER in their future teaching practice,

(b) I in ER,

(c) PS,

(d) ERK, and

(e) SE in the integration of ER in their teaching practice.

Experiencing the curricular integration of ER in a contextualized way and participating in the reflective process of hypothetical learning scenario design allowed to deconstruct preconceptions, as well as influencing PST perceptions in the post-intervention M2. The contribution of the process of design and implementation of learning scenarios in a real classroom setting is also considered important, influencing adjustments in the idealized perception formed in M2, when PST were subsequently confronted with the integration of ER in the practicum class in M3.

We expect that the dissemination of the qualitative results of this ongoing study and their cross-referencing with the quantitative data may contribute to the discussion around the integration of ER in PST teaching practices. We expect that the results of the ongoing study, with the analysis of the data collected during the didactic sequences and the design and implementation of the learning scenarios with the practicum classes may contribute to the discussion around the development of didactic knowledge of future primary school teachers necessary for the appropriate integration of ER in their teaching practices.

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