Cultivating Computational Thinking Skills via Educational Robotics Activities in a Blended Learning Environment

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Abstract

There is a significant trend in the integration of Educational Robotics at all educational levels, and along with this, the promotion of Computational Thinking is one of the related learning outcomes of this integration. At the same time, the transfer of face-to-face learning to online or Blended Learning context due to the COVID-19 pandemic has led to the development of several technological tools, such as Educational Robotic simulators and online collaborating environments, to support this transfer. In this field, this PhD research aims to design a framework in which students collaborate in a Blended Learning context while solving Educational Robotic activities to cultivate Computational Thinking skills.

Keywords

Computational Thinking, Educational Robotics, Blended Learning, Robotics Simulators, Secondary Education

1. Introduction

Although Computational Thinking (CT) appeared in the research spotlight as a concept related to Computer Science, it quickly established its presence within main life skills such as reading, writing, and arithmetic [1]. In the last few years, CT has been considered a key concept in education, and many countries worldwide have revised curricula to integrate it across several educational contexts [2].

Due to CT's problem-solving approach, CT cultivation was soon related to Educational Robotics, leading to strong research interest in CT promotion through ER activities [3, 4, 5]. Several frameworks/models have been proposed in the literature to promote CT skills by combining CT with various learning outcomes. Most of them are inspired by Piaget's constructivism theory and Papert's constructionism theory of the additional pedagogical value of interaction with a real object when constructing knowledge [6].

Until the outbreak of the COVID-19 pandemic, the strongest point of this link was ER's experiential and hands-on learning nature. When transferring the activities online, the main advantage was lost, leading to the need to rediscover the frame of CT and ER. Several solutions were available instead of physical robots, such as ER simulators or online collaborative environments [7]. Various ER technologies and good practices have emerged from the research conducted during the pandemic period, which can serve to cultivate CT in a mixed learning context involving face-to-face and online ER activities.

This PhD research aims to design a framework for promoting CT skills through collaborative ER in a Blended Learning (BL) environment.

2. Theoretical Framework

The framework to be developed is determined by the three factors (CT, ER, and BL) and their interrelations. Therefore, 2.1.1 discusses Cultivating Computational Thinking through ER, 2.2 addresses Blended Learning and ER, and 2.3 highlights the emergence and use of ER simulators.

2.1. Cultivating Computational Thinking through ER

A recent review of CT in European compulsory education [2] highlighted visual programming environments and ER as the main trends for cultivating CT. Since the term CT appeared in the literature, programming has been an appropriate vehicle for CT cultivation. Several CT assessment tools are based on programming concepts or activities to evaluate students' CT skills [8, 9]. Although programming is part of an ER project, when referring to CT cultivation through ER in this research, CT is mainly related to ER concepts and not only programming concepts. Several frameworks and methodologies to promote CT through ER have been proposed in the literature. CPG+ [3] and CCPS [5] models shed light on the design of ER environments for cultivating CT. Apart from the type and orchestration of the activities, they suggest that ER environments where activities are supervised and implemented in sufficient

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time lead to more effective CT cultivation. In addition, when working in such environments, students benefit from more guidance [3] and teachers' delayed feedback [10]. Still, the clarification of classroom orchestration remains a major research priority [6].

2.2. Blended Learning and ER

The literature shows ongoing research interest in BL, and its benefits have been widely reported. BL environments are considered effective when they integrate benefits from mixed environments (face-to-face and online) [24, 25]. Regardless of the subject, a BL should incorporate flexibility and interaction, facilitate learning processes, and create an effective learning climate [24]. Various models, such as flipped, flex, self-blend, and rotation, have been proposed [26], and several important challenges have been documented regarding learners' self–regulation and technology competencies [25,26]. During the COVID-19 pandemic, several studies on CT and ER in BL environments start appearing, mainly in higher education.

Regarding the transfer of ER in the BL context, although there are few studies for formal education, methodologies [27] that involve a phase/step in which the student does not have physical contact with the robots are proposed [5, 28]. This characteristic could promote the design of online activities where students continue working without noticing the absence of the physical robot. Regarding methodology, the flipped classroom [7], using instructional videos for every unit or challenge, has been proposed in several studies [7,12]. No models are proposed that include stages implemented remotely, individually, or collaboratively among secondary students.

To address the research gap on the lack of secondary students' experience with ER in effective BL environments, one of this research's expected results will be the evidence-based heuristics about students' current practices on working with ER in different modalities.

2.3. ER Simulators

The use of Robotic Simulators is gaining more ground, and due to their flexibility [11,12], they have been used by a larger population in recent years. In addition, the cost of purchasing and maintaining the robotics kits and the increased time required for implementation [11,12,13] are some of the educators' challenges eliminated using simulators.

Many studies agree that using physical robots over simulators enhances students' engagement [14,15], but regarding the expected learning outcomes, there does not seem to be a significant difference between them [15]. Moreover, the direct feedback that simulators provide is considered a great advantage during students' learning process [16]. Recent reviews describe a variety of ER simulators in the form of a) desktop environments, b) mobile applications, and cloud- based platforms [17,18], highlighting their strengths and weaknesses. Students work in the simulated environment to cultivate CT through realistic missions they must complete [9,12]. Within these missions, students are confronted with situations they may encounter in the real world and make decisions about robot responses based on sensor and motor parameters. The approaches regarding the order of the activities (simulated or with physical robots) differ. There are proposals for engaging students first with the simulators and then with the physical robot, and others that start with the physical robot to increase students' motivation [14]. Most research conducted over the last four years investigating using ER simulators in blended learning environments [19,20] involves mainly university students.

Given the above, a research gap emerges regarding the ER blended learning framework for CT cultivation in secondary education. In addition, the changes in the curricula of Information and Communication Technology subject (ICT) and Robotics classes worldwide highlight the need for helping teachers organise their courses to address the CT's new cognitive goals. Finally, the variety of ER, CT, and BL technologies used during the COVID-19 pandemic and the experience gained need to be evaluated towards extending CT cultivation through ER beyond the classroom environment.

The appropriate combination of them should be considered a new means for enhancing the pedagogical goals of the related fields. This is the expected contribution of the research in the domain of TEL.

3. Goal and research questions

The objective of this PhD research is to design a framework where secondary school students cultivate CT skills through ER activities in a BL context using ER simulators (Figure 1). The main question addressing the aim of the research is:

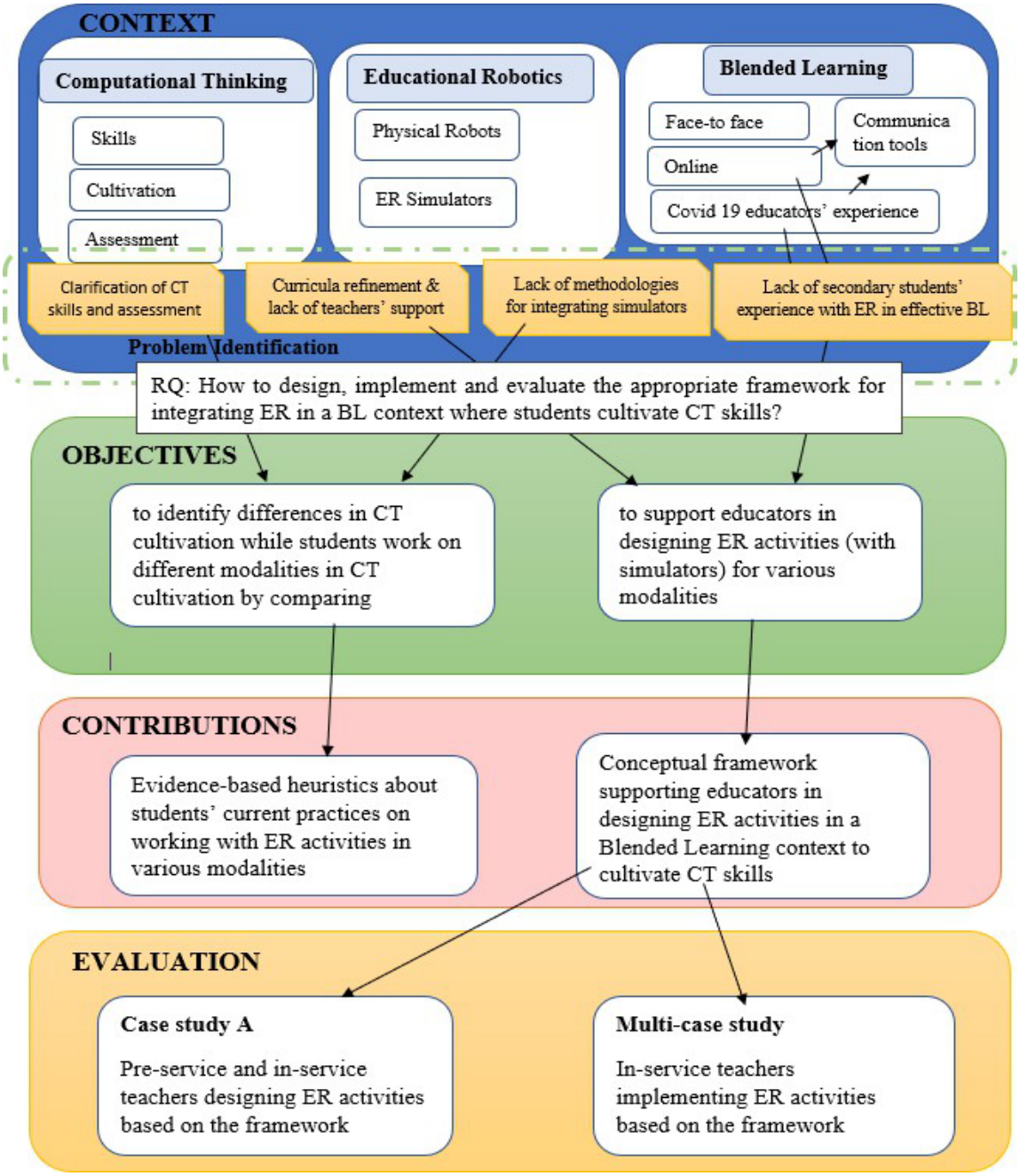

Figure 1. Thesis diagram overviewing the context, the research question, learning objectives, contributions and evaluation

RQ: How to design, implement, and evaluate a framework for integrating ER in BL context (physical robots and simulators) where students cultivate CT skills?

The main question is divided into three sub-questions:

RQ1: How to combine ER activities in ER environments face-to-face in the classroom and remotely?
RQ2: How can CT skills be cultivated when shifting from hands-on activities with physical robots to the ER simulation environment, and what modifications occur during this shift?
RQ3: How does collaboration orchestration affect CT cultivation in both modalities?

4. Methodology

The methodology chosen is Design-Based Research (DBR) [29]. This methodological approach best fits the PhD objectives of solving real-world educational problems through researchers' and practitioners' collaboration. The DBR research process involves four design phases, from identifying the problem to validating the generated principles and artefacts, and it is applied iteratively (see Figure 2).

Several exploratory studies will be implemented based on the DBR approach. The participants will include pre-service and in- service teachers, who are expected to inform design explorations. Students will also be involved in informing implementation explorations. Exploratory studies will use a mixed-method design [20] incorporating quantitative and qualitative data collection and analysis, aiming at a comprehensive approach.

Following the typical four phases of a DBR, the first phase includes conducting a systematic literature review to explore the research context around ER, CT, and BL. The review's primary focus is related to RQ1, including existing practices, available technologies (e.g., ER simulators and online communication platforms), and pedagogical approaches in educational contexts [21]. Furthermore, the first phase includes an exploratory study with practitioners to explore their practices, attitudes, and challenges while designing ER activities with ER simulators for cultivating CT skills, as well as their needs. Educators, working in pairs or triads, will co- design ER activities in two different ER simulators. They will then reflect on their design experience and the critical points analysed in the literature review. Both qualitative and quantitative data will be analysed.

The data from the exploratory study will be analysed during the second phase. The literature review findings and the exploratory study's feedback will help conceptualise two pilot studies with students working on ER activities with ER simulators face-to-face and online.

Both qualitative and quantitative data will be collected and analysed (to explore students' practices and needs). This phase will result in the initial version of a framework accommodating teachers' and students' needs.

In the third phase, the initial version of the framework designed will be implemented (first iteration) with secondary school students attending ER courses as part of the formal curriculum (RQ2). Data that will be collected include student deliverables, analytics from the ER simulator, student perceptions through questionnaires, and audio/ video recordings from student interaction and collaboration (RQ3). After data analysis and further refinements, a second implementation (second iteration) will be carried out.

In the fourth phase, based on the second iteration, the framework will be reconceptualised and evaluated by in-service teachers, and conclusions will be drawn.

5. Current Progress

The research is still in its first phase. The Systematic Literature Review [23] of "ER Simulators, Trends, Methods Applied and Learning Outcomes" is due to conclude soon. Currently, 72 articles from the ERIC and SCOPUS databases are being analysed.

At the same time, an ER activity with two different simulators is designed to trigger the educators' interaction and co-design a framework for using ER activities in various simulators in the BL context. Furthermore, the questionnaire provided at the end of the activity is currently finalised.

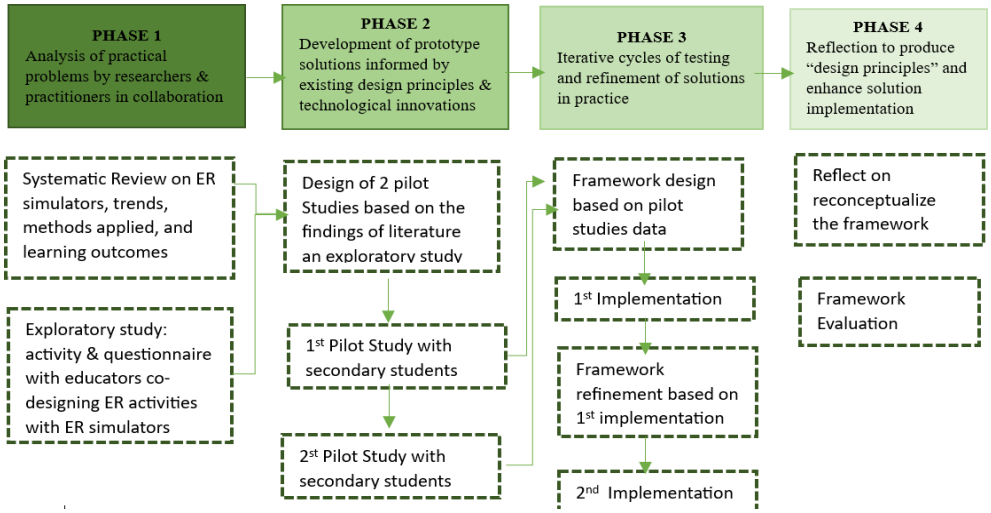

Figure 2. DBR methodology followed.

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