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Education in the 21st Century: Challenges and Perspectives

Aikaterini Dimitriadou
Eleni Griva
Angeliki Lithoxoidou
Alexandros Amprazis
(Editors)

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UNIVERSITY OF WESTERN MACEDONIA
Faculty of Social Sciences and Humanities, Florina

"ST KLIMENT OHRIDSKI" UNIVERSITY - BITOLA
Faculty of Education, Bitola

UNIVERSITY OF "FAN S. NOLI" KORÇË
Faculty of Education and Philology, Korçë

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The authors were asked to produce updated versions of their papers and take into account the discussion that took place after the presentation and the suggestions received from other participants at the Conference. On the whole, the e-Proceedings present a comprehensive overview of ongoing studies in Education Research in Europe and beyond.

The editors carried out a review of the updated versions of the papers that were submitted after the Conference. The editors do not necessarily endorse or share the ideas and views presented in or implied by the papers included in this book.

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Contents

RESEARCH AND PLANNING: A FRAMEWORK FOR PRE-SERVICE PRIMARY EDUCATION TEACHERS IN EDUCATIONAL ROBOTICS

Simos Anagnostakis[1,2]
[1]PhD Candidate, University of Western Macedonia, Greece
&[2]Laboratory Teaching Staff, University of Crete, Greece
sanagn@edc.uoc.gr

Abstract

Educational Robotics (ER) has been regarded as an effective instructional tool in classrooms, particularly for STEM (Science, Technology, Engineering and Math) and demonstrates a significant advantage for students by improving overall learning interest and motivation. In the context of the use of ICT in education, it is of particular interest to investigate whether teachers successfully integrate ER in real day-to-day teaching and what their goals are. This paper is an action research aimed at preparing future teachers of primary education in Greece to teach various subjects/courses through ER activities. Initially, it was necessary to highlight and categorize the characteristics of Educational Robotics that support and relate to the teaching concepts of the course, suggesting what topics the course will include, what kind of activities will be developed, how it will be planned and organized. The issues that arose from the research data about students' knowledge, skills and attitudes led us to design an appropriate undergraduate course for the Department of Primary Education based on the theories of constructivism and constructionism with a hands-on, experiential, revealing way of learning. The course was designed within the general context of increasing the Science and Technology Literacy (STL) of future teachers, as a crucial factor for the modern, technology based society.

Keywords: Educational Robotics, teacher education, primary education, teaching scenarios

1.Introduction

1.1.Technological progress and society

Current societies are dependent on technology, therefore Science and Technology Literacy (STL) are crucial. Due to the rapid developments, the vast majority of people are not literate in modern science and technology (especially in information technology), but this is a prerequisite for the existence of a democratic society of citizens (Michaelides, 2008). Robotics, as an interdisciplinary area is closely dependent and interacts with Information Technology and Communications, Electronics, Artificial Intelligence and others. It is state-of-the-art technology with application in many sectors of at least advanced societies, supporting socio-political and techno-economic upgrades. *(A more comprehensive term for robotics is Mechatronics by combining Engineering with Electronics).*

1.2.Educational Robotics (ER) is the pedagogical utilization of Robotics

Robotics, inevitably, will play an important role in the future. The area we call ER is defined by the following two axes:

- the utilization of the new ICT learning tools,

- the preparation of today's generation of pupils for the requirements of the Scientific and Technological Literacy of the future society that they will live in.

Educational Robotics provides:

- Interesting materials, robotics has become part of our daily lives and it is useful to learn,
- motivation (particularly attractive to the younger generation as it deals with the most advanced technological equipment invented by man),
- cooperative group work,
- discovering learning

ER has been regarded as an effective instructional tool in classrooms, particularly for STEM[1] (Science, Technology, Engineering and Maths) and demonstrates a significant advantage for students by improving their overall learning interest and motivation (Sanders, 2009). Furthermore, it has helped them develop the 21st century skills ('OECD - Education', 2016) Communication, Problem Solving, Critical Thinking, Cooperation, Creativity, Self-guided Learning, Innovation.

We separate Educational Robotics (ER) in the following fields of study: (a) Learning Robotics, vocational and higher education, (b) Learning with Robotics, robots are used as humanlike, and (c) Learning by Robotics, usage of robots for motivation and seen as a challenge.

1.3.Teachers' Education

Teachers in primary education can autonomously support cross-thematic actions in class, due to the fact that they teach all subjects. This element is consistent with the nature of ER and could be used in their training during their undergraduate studies.

Modern approaches for initial teacher education, require a profound change in the way they are taught. The incorporation of Educational Robotics (ER) in curricula of future primary school teachers, both for Science and Technology Literacy (STL) and for the use of new learning tools.

Because pedagogical and didactic knowledge and experience of teachers, coupled with a technological training as recognized in the literature, does not provide them with a sense of full knowledge and provision of ICT implementation in general (Jimoyiannis & Komis, 2007). For ER, *as a de*velopment area which is determined by ICT, it is necessary to seek appropriate training of teachers, thus, facilitating their ability to use it effectively in the educational process.

1.4.Teachers' daily "fears" when using ER in the classroom

Teachers' daily "fears" when using ER in the classroom are (a) complicated materials, (b) duration of the teaching application, (c) teachers' lack of confidence and experience, (d) Lack of technical assistance, (e) lack of constant knowledge upgrade, (f) highly interdisciplinary character of ER, all the aforementioned reduce the probability of use of ER in the classroom. Educational Robotics, as an evolution of the LOGO environment, is imperative to be included in school activities especially in compulsory education, as: subjects aiming at Science and Technology literacy and a teaching environment.

[1]The term STEM had its beginning in the 1990's with the National Science Foundation of the United States introducing the acronym as a shorthand for science, technology, engineering and math.
USA National Science Board, Revisiting the STEM Workforce.

Concerning the preparation of teachers, we developed a course, which was based on our previous research for the general context of increasing the Science and Technology Literacy (STL) of prospective teachers, as a crucial factor for a modern, technologically based society.

1.5.Implementation framework TPACK

As part of ICT, it is required by teachers to have the proper TPACK (Technological Pedagogical Content Knowledge). TPACK refers to the synthesized form of knowledge for the purpose of integrating ICT/educational technology into the classroom's teaching and learning process. As a framework, it has been employed to design teacher education curriculum, to frame literature review pertaining to ICT or educational technology, to unpack ICT-integrated lessons, to design classroom use of ICT and to help teachers work with ICT (Angeli & Valanides, 2009; Chai, Koh, & Chin-Chung, 2013; Jimoyiannis, 2010; Koehler & Mishra, 2005).

2.The Research

The aim of the present research, in the context of utilizing ICT in education, is to investigate whether teachers successfully integrate ER in real day-to-day teaching and which their goals are. A curriculum was designed and evaluated for an undergraduate course in ER for university students (teachers to be) proposing which topics to include, what kind of activities to develop, how the lesson will be planned and organized to lead to the increase of the students' knowledge, and skills and positive attitudes towards ER. The axes to be investigated were:

1. How do they perceive the usefulness of ER as a teaching tool?

2. How do our university students (future teachers) create educational scenarios using ER on topics they want to teach?

3. Do they recognize and incorporate the features and activities of ER in their teaching scenarios?

4. What criteria and objectives do the above options provide and how successful are they?

The objective of this study is the adaptation of appropriate ER activities in order to be consistent with the educational objectives.

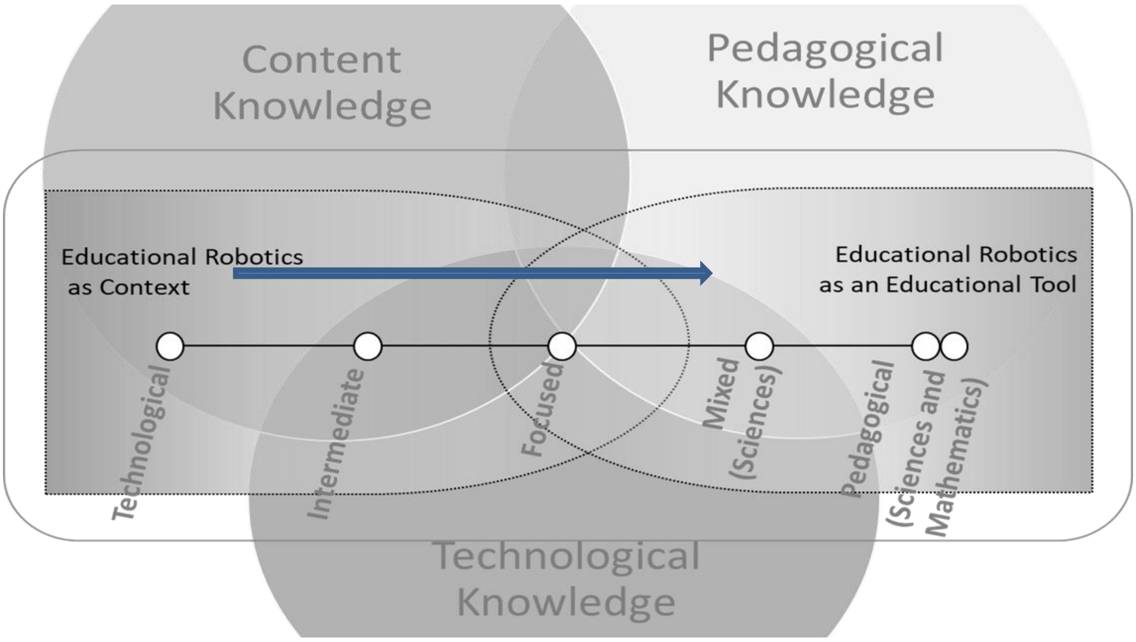
The process of the research (course taught) was the (a) training of future teachers in Educational Robotics, (b) investigation and recordings of knowledge, attitudes and profiles of future teachers, (c) design and individual testing of teaching scenarios with an ER user and questionnaires.

It was necessary to emphasize and categorize the characteristics of ER so as to help teachers integrate them into the teaching process of all courses of the curriculum.

3.Methodology: Action research

3.1.Research design

A concurrent triangulation mixed methods design was used to investigate pre-service teachers' learning, and teaching when utilizing robotics technology (Robson, 2002). Quantitative and qualitative data was collected concurrently from multiple sources: (a) students' reports of ER engagements through weekly journals, (b) videos of robotics activities, (c) lesson plans and (d) students' final questionnaires.



Picture1: Research framework

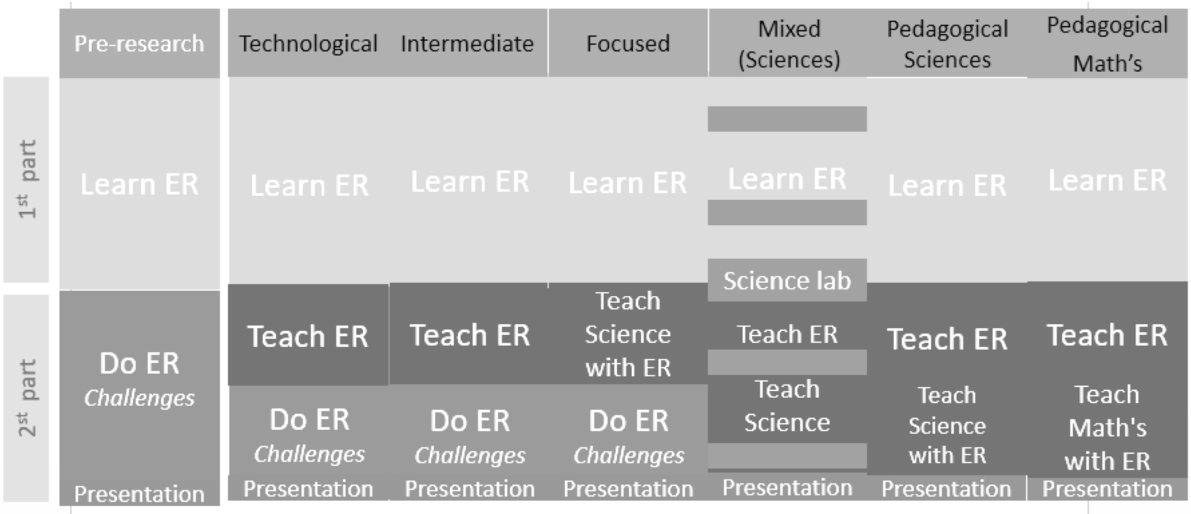
Multiple implementations of the course, with a gradual transformation of its form between two extreme situations; from "*Content Knowledge*" to "*Pedagogical Knowledge***"** as an educational tool based on the TPACK model. This methodology allowed the research and recording of the issues that arose concerning students' knowledge, skills and attitudes in order to carry out the final course planning.

Methodologically, action research is based on previous surveys (Anagnostakis, & Michaelides, 2007) on the development of engagement and familiarization of students with ER, as well as exemplary experiences in challenges and open end projects. Finally designing educational scenarios based on teaching models for ER activities (Alimisis, 2009; Catlin & Blamires, 2010; Komis, Romero, & Misirli, 2016; Lee et al., 2011; Ribeiro, Coutinho, & Costa, 2011).

3.2.Implementation of the research. Course Design - Curriculum Integration

The courses were delivered in intervals of three teaching hours per week for at least 13 weeks. However, students were free to use the laboratory for additional hours, if they wanted to prepare their assigned tasks or for further study. Students worked in groups of two or three. During the first 7 weeks, students were introduced to concepts related to the robots and their programming. They used the equipment to become familiar with the various parts, the sensors, the robot unit and the programming language. In addition, students were also assigned to tasks of constructing specific robots, performing relatively simple tasks, aiming to familiarize themselves with the peculiarities of robot programming, i.e. response in real time specific events.

During the next 5 weeks, students started planning their strategy to participate in an open-end project (i.e. challenge), and to prepare teaching scenarios for teaching (with ER) any school subject, or to prepare two teaching scenarios to teach a school subject of their choice (using ER). The final week was allocated in retrospection and assessment. In all stages students were asked to optimize (at least once) their completed tasks. A logbook was required to be kept in which, after every 3-hour session, they had to fill in retrospectively their task and other comments (e.g. cooperation in the group, problems, etc.).



Picture2: Implementation of the research

During the first three educational interventions; "Technological", "Intermediate", and "Focused" one of the two open projects was replaced by the pedagogical use of ER as a teaching subject and as a teaching tool. Students went through the stages of "Learn ER", "Teach ER", "Teach with ER", and "Do ER". In the 1st and 2nd, the choice of the subjects of the teaching scenarios was their own choice, always within their groups. In the third intervention, we specifically focused on the science cognitive domain, having acquired a number of different sensors connected to their constructions. After the 1st part the undergraduate students selected a phenomenon from the field of Physics, constructed experimental devices using ER and created didactic scenarios.

Enough time was devoted to install and use 3rd-party sensors (compass sensor, color sensor, infrared sensor, pressure sensor (250kPa and 500kPa), flexible sensor, pH sensor, Ultraviolet UVB sensor) for the measurement and control of physical sizes.

In the 4th intervention "**Mixed"**, teaching scenarios for misconceptions about science, we tested a mixed model where students utilized both ER and classical experiments in developing experimental activities for teaching sciences by dividing the semester in both laboratories.

The 5th and 6th intervention was referred to the "Pedagogical Knowledge" and the second part required the creation of group and individual teaching scenarios as deliverables. Students worked again in groups within the thematic units they chose (and they had the sensors at their disposal). For Physics the modules included: 1. Electromagnetism, 2. Energy-matter, 3. Chemistry, 4. Optics, 5. Mechanics, 6. Waves and 7. Thermodynamics. And for Mathematics the modules included: 1. Decimal Numbers 2. Unit Conversions, 3. Measurements, 4. Numerical Operations, 5. Statistics, 6. Geometry, perimeter and area and 7. Geometry Triangle Design.

Students then worked on building and testing their teaching scenarios, which were their sole original ideas. Furthermore, ~~a~~ pilot applications were applied; physics to first year university students, ~~for~~ mathematics to elementary school and gymnasium students.

Materials utilized: The equipment used was LEGO® Mindstorms® NXT. The programming was made on PCs with Windows using the LEGO® MINDSTORMS® Education NXT Software. The participants used the online learning platform Moodle to store their work, videos and pictures.

3.3.Participants

The Participants were 147 students from the Department Primary Education, University of Crete (graduates from this Department are qualified to be appointed as teachers in primary schools) within 6 successive interventions: a. Technological, 31 participants (2011-12), b. Intermediate, 29 participants (2012-13), c. Focused, 19 participants, (2013-14), d. Mixed Sciences, 18 participants (2014-15) e. Pedagogical Sciences, 14 participants, (2015-16), f. Pedagogical Math's, 27 participants (2015-16). The gender of the participants was: female, N=119, 81.0% and male, N=28, 19.0%. The course was taught to students from the 5th semester of studies on. The year of study of participants was 1)3rd, N=77, 52.4%, 2)4th, N=60, 40.8%, 3)> 4th, N=10, 6.8%. The courses were from the field of ICT and Science and not compulsory. In the announcement of the course there was no formal prerequisite of previous attainments or of specific previous knowledge. Most students had already completed basic courses in Science and Methodology of Teaching. The majority was computer literate.

Questioners were administered to every student for self-assessment in the usage of digital context: a. beginner, N=3, 2,0%, b. moderate, N=21, 14.3%, c. good, N=57, 38.8%, d. very good, N=63, 42.9%, e. specialist, N=2, 1.4% f. missing, N=1, 0.7%, and the creation of digital context: a. beginner, N=18, 12.2%, b. moderate, N=40, 27.2%, c. good, N=59, 40.1%, d. very good, N=28, 19.0%, e. specialist, N=2, 1.4%, f. missing, N=0, 0%. Time spent on internet use: a. one hour/day, N=36, 24.5%, b. two hours/day, N=41, 27.9%, c. three hours/day, N=36, 24.5%, and d. more than three hours/day, N=34, 23.1%. The courses were designed primarily to prepare pre-service teachers to integrate hands-on learning in ER activities instruction aimed to provide them with opportunities to experience various types of classroom activities.

3.4.Data collection

The structure of the questionnaire defines basically three modules with 60 questions, structured on the basis of the Likert five-dimensional scale with the following axes: (1) Questions of characteristics and skills of participants. (2) Questions concerning their training (intervention - training) on ER. (3) Questions of self-esteem and attitudes (what they feel they can do or are able to apply in practice within the school class). There were also open questions on the search for issues that may have emerged during the interventions.

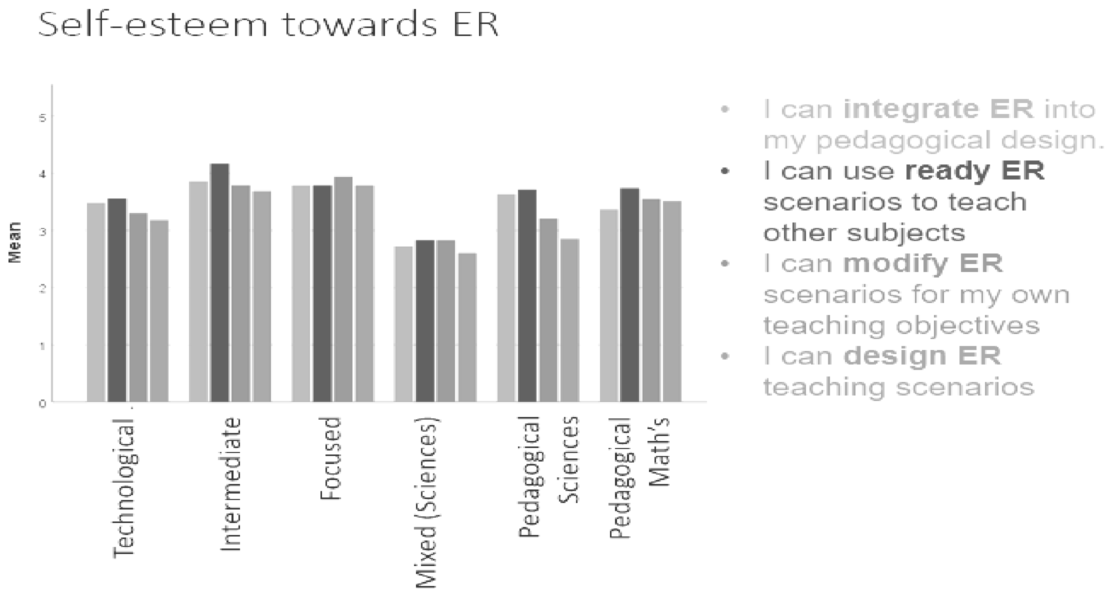
3.5.Data analysis

For the quantitative data, SPSS was used for descriptive analysis and factor analysis performed on ER engagement, interest, learning and self-esteem. Nvivo was used to analyze and categorize students' didactic scenarios, initially as ER elements based on: (a) introductory activity, (b) designing and brainstorming activities (design planning), (c) construction activities, (d) programming activities (coding), (e) check and improvement activities and (f) presentation. Through repeated reading, nodes were removed and revised, and additional nodes about students' experience of performing the robotics activities were added. Furthermore, prior research-driven coding nodes were developed based on objectives of integrating ER into teaching scenarios and the type of strategy. The conclusions are based on the researcher's observations in connection with a questionnaire at the end of the course and the analysis of the students' scenarios. It is also necessary for ER to seek appropriate training of teachers so that they are able to use it effectively in the educational process; both for Hard Sciences and Humanities. 147 questionnaires were collected and analyzed but only 128 were sufficient teaching scenarios from the six courses offered (interventions).

4.Results

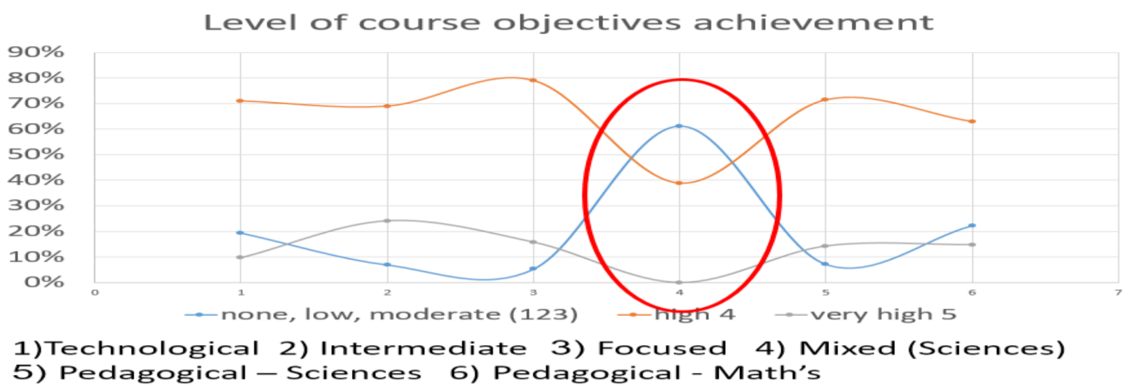
4.1.The students perceived the usefulness of ER as a teaching tool

Descriptive analysis performed on the 147 participants' answers reveal that the average conformation scores for self-esteem embedment, usage, change and design of teaching scenarios with ER. 1) Embedding robotics in my pedagogical design. M=3.49, N=147, SD=.939 (not at all 1.4%, little 17%, moderate 23.1%, a lot 48.3%, very much 10.8%, missing 0%). 2) Usage of ready-to-use ER scenarios for mathematics, language, physics etc. M=3.66, N=147, SD=.933 (not at all 1.4%, a lot 10.9%, moderate 25.2%, very 45.6%, very much 17%, missing 0%). 3) Modification of ready ER scenarios for teaching design M=3,46, N=147, SD=1.002 (not at all 3.4%, little 14.3% moderate 28.6%, a lot 40.8%, very much 19.2%, missing 0%). 4) Design of ER scenarios for teaching math, language, physics, etc. M=3,32, N=147, SD=1.010 (not at all 5.5%, a lot 15.6%, moderate 27.2%, very 43.5%, very much 7.5%, missing .7%).



Picture3: Self-esteem towards Educational Robotics per application

The students noted the level of course objectives achievement as: "High", except the "Mixed" applications (ER and Science Lab), M=3.96, N=147, SD=.939 (not at all 0%, little 2%, moderate 16.3%, very 64.6%, very much 16.3%, missing .7%).



Picture 4: Level of course objectives per application

From the open questions we conclude the positive acceptance of the experiential way that the intervention took place, stressing that the seminar is **very or very interesting**, **fun**, **creative** and **useful**.

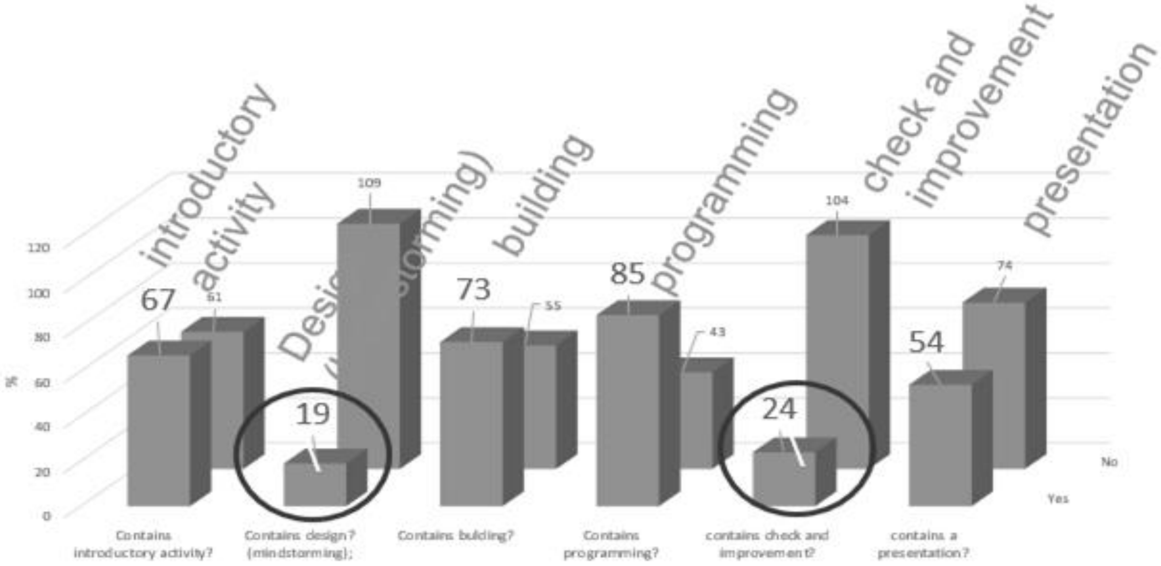
As positive comments the students noted: 1. exploratory learning, constructionism, creativity, 23%, 2. interesting, fun, enjoyable, 18%, 3. familiarity with technology and programming, 17%, 4. teamwork, cooperation, 15%, 5. pedagogical use of technology 8%, 6. practical, hands-on, competitive, 5% and 7. no answer, 13%.

As negative comments they noted: 1. programming difficulties or technological difficulties, 27%, 2. lack of time, tiring, 25%, 3. difficulties with STEM concepts, 15%, 4. there are no negatives, 10%, 5. teaching practice, 5%, 6. boring, disappointing, 5% and 7. no answer, 13%.

Students (future teachers) created educational scenarios using ER on topics they want to teach

The main subject area was (there were also interdisciplinary works): (a) Environmental Study N=4, (b) ICT N=13, (c) Science N=58, (d) Math's N=49, (e) History N=2, (f) Language N=2, total N=128.

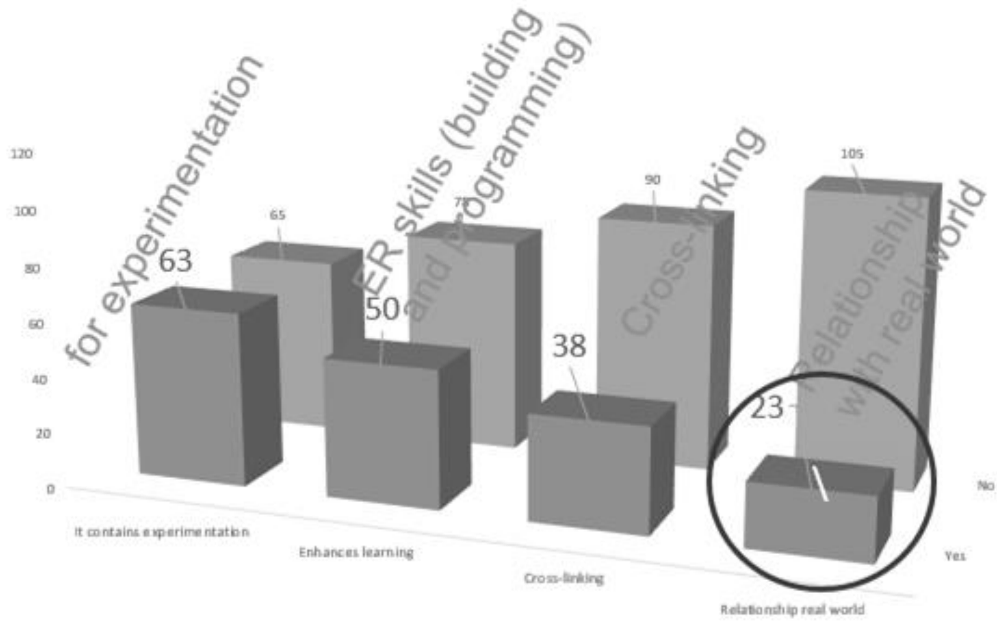
As Picture 5 illustrates, students recognized and incorporated in their teaching scenarios the features and activities of ER, 128 scenarios were categorized as: a. introductory activity N=67 (52%), b. design (brainstorming N=19 (14.8%), c. building N=73 (57%), d. programming N=85 (66.4%), e. check and improvement N=24 (18.7%) and f. presentation N=54 (42%).



Picture 5: Elements of Educational Robotics found in teaching scenarios

4.2.Criteria and objectives the above option provide

Students' objectives for integrating ER into teaching scenarios were: a. experimentation N=63 (67.3%), b. ER (building and programming) N= 50 (39%), c. cross-linking N=38 (29.6%) and d. relationship to the real world N=23 (17.9%).

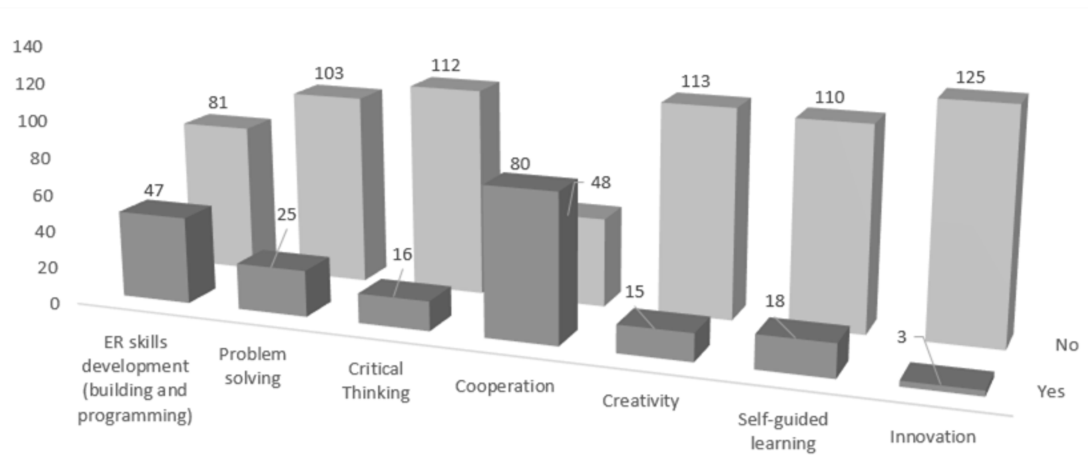


Picture 6:Objectives of integrating ER into teaching scenarios

4.3.Success of teaching scenarios

One of the objectives of this study was the adaptation of appropriate ER activities in order to be consistent with the teaching objectives.

The didactic scenarios were classified as the developmental skills of ER: a. ER skills development (building and programming) N=47 (36.7%), b. Problem solving N=25 (19.5%), c. Critical Thinking N=16 (12.5%), d. Cooperation N=80 (62.5%), e. Creativity N=15 (11.7%), f. Self-guided learning N=18 (14%) and g. Innovation (skills) N=3 (2.3%). The majority of the participants considered the cooperation, the construction and programming as basic skills.



Picture 7: Skills of ER included in teaching scenarios

4.4.Used strategies to design and creation

Students' strategies embedded ER in their works: a. write new ER activities, b. search the Internet for existing activities, c. use and convert the same scenarios that they were taught, d. based on real-world engineering products, e. conversion of a classic experiment for use with ER, f. based on the properties of the sensors, g. create a story, dramatization, h. setting the robot in a supervisory and playful role, i. use of a typical ER scenario (competitions, challenges).

5.Discussion

Prospective teachers only with adequate preparation can incorporate ER activities in the subject areas of primary education especially ICT in Science and Mathematics, in a way that maintains the interest of students, to improve the understanding and usefulness, but also to foster the development of cooperation, problem-solving and creativity skills.

This study is in line with the movement for the promotion of ER through a more general STEM education in the primary level (Holmquist, 2014) and demonstrates that there needs to be substantial training in teacher' education, so that they can successfully teach (and integrate) the concepts and the principles of ER.
The most important findings obtained from the questionnaires, discussions with students, analysis of teaching scenarios and direct observation are summarized as followed:

- It was observed that ER requires from future teachers adequate Knowledge of Content (TPACK model) to connect the properties of ER with the teaching objects (e.g. the principles of sensor operation).
- The educational model preparing teachers should be enriched with additional Science and Technology Literacy.
- There is a difference between what undergraduate students think and what they ultimately "produce".
- There seems to be a low score on technical support.

The results of the research are of interest not only to the principles that define educational policy and want to comprehend the wider implications of the adaptation of robotics in education but also in general in the field of human-robot interactions (Mubin et al., 2013). ER has made clear links with STEM subjects in general. However, it is clear that robots are not only restricted to these domains but they can be applied broadly across the curriculum. Future teachers with appropriate preparation in Science and Technology Literacy (especially in Coding and Engineering) are able to develop and integrate ER activities into their teaching scenarios. We must break the traditional way of teaching by introducing robotic activities to improve the quality of education and learning.

In conclusion, it is of crucial importance that teachers are trained in a different way so that they are not fixed in their ways when it comes to teaching and they are open to change and use innovative and interesting teaching methods and tools, such as ER.

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