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RESEARCH STRATEGY FOR THE EVALUATION OF STUDENTS' SUCCESS IN THE PROJECT "INNOVATIVE EDUCATIONAL ROBOTICS STRATEGIES FOR PRIMARY SCHOOL EXPERIENCES"

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ABSTRACT

Educational robotics has been used for a relatively long time to promote the development of students' computational thinking, but in most cases, such activities are offered as extracurricular activities to students who are interested in robotics and programming or in specific study programmes in higher education. Despite the fact that Seymour Papert developed the programming language LOGO to change the way children learn to use technology as early as 1980, this concept is still not widely used in compulsory education. It should be kept in mind that the inclusion of robotics in the learning process can not only contribute to the development of competencies such as programming and the integration of different components, sensors and actuators but also support the learning of mathematics, physics and chemistry in an innovative way. To support the development of innovative solutions for teaching educational robotics to primary school students, the ERASMUS+ project "Innovative Educational Robotics Strategies for Primary School Experiences" (No. 2019-1-IT02-KA201-063073) was launched, aiming to develop a variety of teaching materials for both students and teachers, to create educational robots for two levels of complexity, and to include these activities in the compulsory schooling process for primary school students. In the initial stage, students acquire basic knowledge of robotics, and at the second level of difficulty, the focus is on marine robots. In order to evaluate the results achieved by all these activities, a design-based research model has been developed that uses several complementary research methods, and this paper describes this model, showing how it organizes data acquisition and uses them to improve materials to offer scientifically proven activities.

Keywords: *educational robotics, robotics-based learning, research methodology, design-based research, marine robots.*

Introduction

Educational robotics has been known around the world since Seymour Papert invented the LOGO programming language (Papert, 1980), which was suitable for children to promote the development of their technology and programming skills, and many years have passed since then. However, for a relatively long time these ideas were used by only a few enthusiasts and were not widely included in educational activities until 1998, when Lego, in close collaboration with Papert, created something completely new and introduced the world to Mindstorms (Waterson, 2015). This can be considered as a renaissance of educational robotics, and since then, a lot of new educational robots have been created and attempts have been made to use robots to develop different competencies (Eguchi, 2014). In most cases, research on the use of educational robotics analyzes the impact of robotics on areas of knowledge such as physics, electronics, mathematics, engineering, computer science and more and on the development of personal knowledge (Alimisis et al., 2019; Alimisis, 2013; Alimisis et al., 2017; Moro et al., 2018). Researchers have also analyzed aspects that should be taken into account to provide inclusive education in practice (Daniela & Lytras 2018), to use robots as support for students with special needs (Matarić & Scassellati, 2016), or to reduce the risk of early school leaving (Daniela & Strods, 2018; Karampinis, 2018; Karkazis et al., 2018).

One of the essential components that educational robotics brings to education is the development of computational thinking, which Wing (2006) considered to be equivalent to the ability to read and the ability to count. A computational thinking framework has been developed under the leadership of Selby and Woollard (2013) from Southampton University (see Table 1).

Table 1. Computational thinking skills (based on Selby & Woollard, 2013)

Skill	**Competencies**
Abstraction	Dealing with complexity by stripping away unnecessary detail
Algorithm	Identifying the processes and sequence of events
Decomposition	Breaking complex artefacts, processes or systems into their basic parts
Generalization	Identifying the patterns and shared by artefacts, processes or systems
Logical analysis	Applying and interpreting Boolean logic
Evaluatio*n*	Systematically (through criteria and heuristics) making proven value judgements

With the growing popularity of robotics in the world, a massive robotics movement has developed that organizes robotics competitions and offers new ideas for using robotics to develop various competencies. However, despite the popularity of robotics, there are still only a few countries where it has crossed the boundary between compulsory education and out-of-school activities. Robotics activities are in most cases organized either in the form of projects or as after-school educational activities. The aim of this project is to develop teaching materials for teachers to acquire the skills of working with educational robotics, and this tactic has been chosen to ensure that teachers themselves change from people 'doing Logo' to becoming 'the spirit of Logo' (Papert, 1999; Scaradozzi et al., 2019a).

In the next phase of the project, teachers have to work with primary school students to teach them certain competencies. The project partners from Università Politecnica Delle Marche are also developing new robotics kits for students to use in their activities. In the initial stage, students need to acquire basic skills in working with robots, anticipating that they are acquiring specific knowledge, and this type of activity also contributes to their learning motivation. In the second phase of the project, students have to work with a more complex robot, learning the skills to work with a marine robot. In such activities, students gradually construct their knowledge and also acquire additional knowledge about the effects of water pressure on various mechanisms and learn information about the purposes for which a marine robot can be used, thus promoting awareness of environmental sustainability (United Nations Development Program, 2015) and ensuring the sustainability of knowledge (Daniela & Strods, 2019). Nowadays, with the development of various technologies and digital solutions, it is important to think not only about the development of computational thinking (Bocconi et al., 2016) but also about the possibilities that robotics knowledge can provide and, in this case, knowledge about the marine ecosystem (Scaradozzi et al., 2019b).

Project context

The project aims to work with primary school students to help them develop computational thinking in its initial stages and, in later stages, to work with a marine robot and develop specific skills. This arrangement of activities is purposefully planned, stipulating that students must first acquire basic knowledge about robotics, and this knowledge can later serve as a basis for constructing new knowledge.

The project involves 6 countries – Italy, Latvia, Greece, Ireland, Croatia and Malta – but activities with students were organized in 4 countries – Italy, Greece, Croatia and Malta – so the knowledge tests for students were translated into Italian, Greek and Croatian to ensure that students could understand the questions asked and were able to answer them. Maltese students answered the questions in English, as English is one of the official languages of Malta, so translation was not necessary.

The second part of the project's activities is focused on teacher training to prepare them to work with educational robotics activities, and the classes were organized into two successive parts. In the first part, the teachers learned the basic principles of working with the basic robotics kit developed for the needs of the project, and in the second stage, they acquired the skills to work with the advanced robotics kit. In addition to learning how to work with the robotics kits developed for the project and how to teach computational thinking and motivate students to become more involved in learning, teachers also had to develop lesson materials to teach students how to use robotics.

Research design

For this project, a design-based research (DBR) model has been chosen (Frey, 2018; Pitso, 2015), which is characterized by successive evaluation cycles where activities are developed, tested and refined and results are evaluated in a real learning context. As a result of this project, a curriculum is being developed for teachers so that they can be prepared for work with primary school students to scaffold the development of computational thinking during educational activities. In parallel, teaching materials for students and research methodologies are being developed that teachers can use to make sure that their activities meet the objectives set for the lessons. DBR was introduced by Brown (1992) and Collins (1992) as a response to critics that laboratory research lacks ecological validity or the ability to approximate real classroom situations.

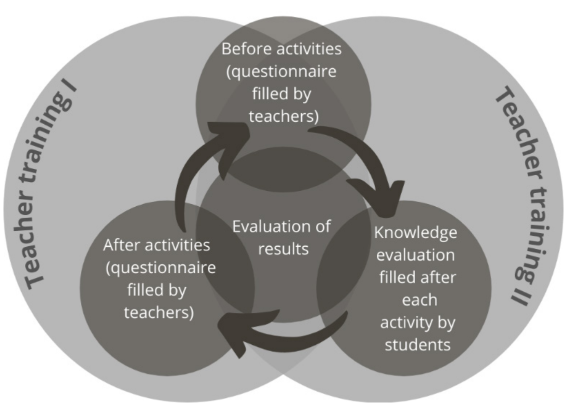

Figure 1. Design-based research model for the project

A specific research design (see Figure 1) was developed for the project, where all activities take place in real time with real project participants, and these activities are measured straight away in order to draw data-based conclusions and immediately decide on the necessary modifications.

Research tools used

In order to assess both the materials developed for teachers and the competencies acquired by teachers during the lessons organized in the project, several tools were developed, where teachers had to complete a knowledge test after learning each knowledge concept so that researchers could make sure that the developed materials were relevant and can serve as scaffolding tools for students in learning with educational robotics. Two tools were also developed for teachers to assess students' computational thinking before and after project activities.

In order to teach students educational robotics with the specific kits developed for the project, 10 learning topics were introduced. To allow researchers to verify students' progress, students had to answer 10 to 18 questions after each learning topic to check both their motivation to learn and the knowledge acquired by them.

All questions were the same for all participant countries to ensure that data can be compared and analyzed in later stages. All questions were entered on the Kahoot website. This tool was chosen for a variety of pedagogical reasons, firstly because of its wide range of features, functionality and design, as it is simple, easy to use and age-appropriate so as not to make primary school students feel bored. It can simultaneously act as a testing and learning assistant to engage and simultaneously support learning. Also, this tool's extensive progress analysis is a great helper for the teacher during the learning process.

Expected outcomes

It is expected that a set of materials will be created in the final phase of the project that can be used both together, performing sequential activities, as well as individually for project results to be used in combination with other types of activities. All developed materials will be freely available and will be as follows:

A training course for teachers will be developed that will consist of two parts: in the first part, teachers will learn the basic principles of working with the basic robotics kit developed for the project; in the second part, they will acquire the competence to work with the advanced robotics kit. The training course can be taken for both full-time and remote learning activities.

Teaching materials will be developed by teachers to work with primary school students to work with the robotics kits created in the project to support the development of computational thinking and understanding of marine robotics.

Research tools have been developed that can be used in other contexts.

Scientific articles on the results of the project will be developed in order to acquaint a wider academic audience with the research methods used and the results obtained.

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References

Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education, 6*(1), 63–71.

Alimisis, D., Moro, M., & Menegatti, E. (Eds.). (2017). *Educational robotics in the makers era* (Advances in intelligent systems and computing 560). Springer Nature.

Alimisis D., Alimisi R., Loukatos D., & Zoulias E. (2019). Introducing Maker Movement in Educational Robotics: Beyond Prefabricated Robots and "Black Boxes". In L. Daniela (Ed.), *Smart learning with educational robotics*. Springer.

Bocconi, S., Chioccariello, A., Dettori, D., Ferari, A., & Engelhardt, K. (2016). *Developing computational thinking in compulsory education*. JRC Publications.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, *2*(2), 141–178.

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in educational technology* (pp. 15–22). Springer Verlag.

Daniela, L., & Lytras, M. D. (2018). Educational robotics for inclusive education. *Technology, Knowledge and Learning, 24*, 219–225. doi:10.1007/s10758-018-9397-5.

Daniela, L., & Strods, R. (2019). Educational Robotics for Reducing Early School Leaving from the Perspective of Sustainable Education. In L. Daniela (Ed.), *Smart learning with educational robotics: Using robots to scaffold learning outcomes* (pp. 43–61). Springer.

Daniela, L., & Strods, R. (2018) Robot as Agent in Reducing Risks of Early School Leaving. In L. Daniela (Ed.), *Innovations, technologies and research in education* (pp. 140–158). Cambridge Scholars Publishing.

Eguchi, A. (2014). Educational robotics for promoting 21st century skills. *Journal of Automation. Mobile Robotics & Intelligent Systems, 8*(1), 5–11. https://doi.org/10.14313/JAMRIS_1-2014/1.

Frey, B. (2018). *The SAGE encyclopedia of educational research, measurement, and evaluation* (Vols. 1–4). SAGE Publications. doi: 10.4135/9781506326139

Karampinis, T. (2018). Activities and experiences through RoboESL project opportunities. *International Journal of Smart Education and Urban Society, 9*(1), 13–24. https://doi.org/10.4018/IJSEUS.

Karkazis, P., Balourdos, P., Pitsiakos, G., Asimakopoulos, K., Saranteas, I., Spiliou, T., & Roussou, D. (2018). To water or not to water. The Arduino approach for the irrigation of a field. *International Journal of Smart Education and Urban Society, 9*(1), 25–36. https://doi.org/10.4018/IJSEUS.

Matarić, M. J., & Scassellati, B. (2016). Socially assistive robotics. In B. Siciliano & O. Khatib (Eds.), *Springer handbook of robotics* (pp. 1973–1994). Springer.

Moro, M., Agatolio, F., & Menegatti, E. (2018). The development of robotic enhanced curricula for the RoboESL project: overall evaluation and expected outcomes. *International Journal of Smart Education and Urban Society, 9*(1), 48–60. https://doi.org/10.4018/IJSEUS.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.

Papert, S. (1999). Introduction. In *Logo philosophy and implementation* (pp. v–xvi). LCSI.

Pitso, T. (2015). Developing creativity in advanced undergraduates: A design-based research approach. In *SAGE Research Methods Cases.* https://dx.doi.org/10.4135/978144627305014549312.

Selby, C., & Woollard, J. (2013) *Computational thinking: The developing definition.* University of Southampton.

Scaradozzi, D., Screpanti, L., & Cesaretti, L. (2019a). Implementation and Assessment Methodologies of Teachers' Training Courses for STEM Activities. *Technology, Knowledge and Learning, 24*, 247–268. https://doi.org/10.1007/s10758-018-9356-1.

Scaradozzi, D., Screpanti, L., & Cesaretti L. (2019b). Towards a Definition of Educational Robotics: A Classification of Tools, Experiences and Assessments. In L. Daniela (Ed.), *Smart learning with educational robotics* (pp. 63–92). Springer. https://doi.org/10.1007/978-3-030-19913-5_3.

United Nations Development Programme. (2015). *Sustainable development goals*. http://www.undp.org/content/undp/en/home/sustainable-development-goals.html.

Waterson, A. (2015, April 10). *Lego mindstorms: A history of educational robots*. Hack Education. http://hackeducation.com/2015/04/10/mindstorms.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33–35.