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The teaching of Robotics to prospective teachers and its application in the classroom

Nikolaos Drakatos * and Antonios Christou

University of Thessaly, Greece.

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Abstract

Research activities are one of the most successful strategies to apply STEM education in complete secondary education. It is carried out by the completion of specific tasks. The professional activity of teachers of science and mathematical disciplines in STEM education is targeted at the formation and development of students' mental, cognitive, and personal qualities. Their level impacts students' ability to advance in a successful specialty STEM industry. It also entails developing the skill and willingness to tackle complicated problems, which is attainable with the proper amount of critical thinking, creativity, cognitive flexibility, teamwork, and the ability to carry out research activities. The nature of the interaction between disciplines and the degree of integration are determined in this article. The place of project activity on robotics in school training is explored, and it defines the skills that are produced as a result of such project activities. The prospect of teaching robotics to future teachers within the context of existing curricula is also examined. STEM education can be defined in a variety of ways, ranging from a straightforward list of "exact" or "engineering" subjects to creative activity. This field has become synonymous with scientific and research work: research and experiments. In this regard, robotics is an effective technique of developing STEM education. The findings revealed that prospective instructors were mostly able to include robots into STEM-based science teaching. Furthermore, prospective teachers proposed that robots be introduced into all classes, particularly science, in order to improve students' problem-solving and algorithmic thinking skills. However, this is a novel instrument, and schools have shown little interest in researching it. As a result, our paper focuses on identifying chances to incorporate the fundamentals of robotics in education. The article developed course standards based on the educational needs of future science, mathematics, and engineering teachers. The study provides an example of project implementation in robotics, describes the stages of execution together with the educational outcomes.

Keywords: STEM; Robotics; Science teaching; Teacher education

1. Introduction

Technology's rapid development in the twenty-first century has made its use necessary in many industries. Technology is now required for good education to take place. The roles of technology innovations in making daily living easier are growing more and more effective (Cömek & Avc, 2016). Although there are numerous causes for this situation, it can be stated that the increased relevance of globalization and the global labor force needs the inclusion of technology in education (Moraiti, Fotoglou and Drigas, 2022). Many countries, large and small, developed and developing, have recently conducted studies on how to successfully employ technology in their education systems (Sayin & Seferoglu, 2016). These researches are mostly concerned with coding and robotics instruction. In recent years, there has been a remarkable surge in interest in robotics, and as a result, robotics has been widely regarded as a tool with numerous significant benefits at all levels of schooling (Chaidi, Kefalis et al., 2021). Similarly, although being a relatively new concept, coding has begun to take a place in preschool and primary school instruction and has swiftly become a part of education.

* Corresponding author: Nikolaos Drakatos

Coding and robotics have been utilized in the teaching of several subjects, particularly scientific education, and in the teaching of various disciplines by merging them together as in the STEM approach, and they have begun to be viewed as an alternative educational instrument. The studies show that robotics can be effective in STEM teaching because they help reduce the abstractness of mathematics and science (Stavridis et al., 2017) and create opportunities for real-world engineering and technology practices. Furthermore, robotics-based STEM teaching, according to Chung, Cartwright, and Cole (2014), is more advantageous than traditional STEM teaching in terms of concretizing abstract concepts, unifying multiple disciplines, ensuring applied learning by connecting theory and practice, and providing a fun and motivating learning environment.

As a result, numerous studies have lately been conducted to investigate the various consequences of robotic use in various courses on teachers, prospective teachers, and students. For example, studies show that the use of robotics has a positive impact on the mathematics performance of primary and middle school students (Kastritsi et al., 2019) science performance of primary (Karahoca, Karahoca & Uzunboylu, 2011) and middle school students, as well as prospective teachers (Stavridis, Papageorgiou et al., 2022) engineering designing skills (Larkins, Moore, Rubbo & Covington, 2013) of middle school students and STEM knowledge. Furthermore, in a study examining teachers' perceptions of the effects of robotics on students, teachers believed that robotics was an effective tool for preparing students for the twenty-first century and improving teamwork, communication skills, social skills, problem solving, and critical thinking (Demertzi et al., 2018).

Similarly, Kim, Kim, Yuan, Hill, Doshi, and Thai (2015) discovered that prospective instructors regard the usage of robots ideal for increasing STEM involvement. This study also found that the usage of robots enhances affective participation, such as curiosity and enjoyment, and that prospective teachers' lesson plans for teaching STEM improve. Rrobotics activities have also been demonstrated to be useful in enhancing self-efficacy in teaching science ideas (Ntaountaki, Lorentzou, et al., 2019) and stimulating computational thinking (Üzümcü, 2019). It is also said that robotics projects improve education quality in terms of teaching process (Tocháek, Lape, & Fuglk, 2016). Furthermore, studies in which Lego education sets are used as robotics activities show that Lego education sets positively affect the academic process skills of middle school students their academic creativeness and their attitude toward science courses (Pappas and Drigas, 2016).

According to these studies, using rapidly developing technology of the twenty-first century in education and other aspects of our lives, as well as practicing interdisciplinary teaching enriched by technological developments (Lytra and Drigas, 2021), has become a necessity in education rather than an alternative way to achieve goals. As a result, it is critical for elementary school teachers to keep up with emerging technologies, particularly in the disciplines of coding and robotics, in order to get the necessary training and to better themselves. It is not enough for teachers to be educated in the subjects that they teach in order to train the work force that our country requires. It is mentioned that robotics may do many tasks throughout the teaching process (Ospennikova, Ershov, & Iljin, 2015), however it should be used as a learning tool since the essential thing is integrating it into the curriculum (Mitsea, Lytra et al., 2020). As a result, the use of robotics in coding and robotics lessons in elementary school is considered in terms of its contribution to the learning processes.

Taking all of this into account, it is critical for teachers and prospective teachers to receive training in robotics and coding in order to use their knowledge and skills in this area effectively in courses, particularly science courses, in order to raise a generation that can keep up with the globalizing world. However, robotics studies focused at future teachers are insufficient, as the majority of coding and robotics research is conducted on elementary and middle school pupils (Yolcu & Demirer, 2017). As a result, in this study, a specific coding and robotics course was established with a focus on future teachers, and prospective teachers were asked to use the knowledge they obtained from this course while teaching sciences using an interdisciplinary approach. As a result, this study is one of the few in the field because it aims to establish the level of prospective teachers' usage of coding and robotics in scientific classes, as well as their opinions on the subject (Stavridis, Falco et al., 2020).

2. Training of future teachers

The findings of the lesson observations and lesson plan analysis demonstrated that prospective teachers were exceptionally capable of integrating STEM-based robotics into the scientific course. As a result, the prospective teachers were deemed successful in incorporating the material and skills they received in robotics into the creation of lesson plans as well as the delivery of lessons based on the plans they created. The ability of prospective teachers to use robotics in science courses with an interdisciplinary approach, in accordance with the subject, acquisition, and level of the curriculum, demonstrated that their elective course "Coding and Robotics in Primary School" was designed in accordance with the objectives and was beneficial to prospective teachers. Future teacher education in the framework of STEM education has its own peculiarities (Papageorgiou, Stavridis et al.,2021). One issue is the difficulty of teachers to fully exploit interdisciplinary research unless they have a thorough understanding of the various disciplines in which integration occurs (Meyer and Land, 2003; Griffiths, 2004). Basic courses should thus receive adequate priority in future teacher preparation programs. In 2010, the European project SITEP (Menter, Hulme, et al, 2010) attempted to compare teacher-training programs. The goal of this study was to gather information on the content of curricula for prospective teachers, as well as to identify skills and competences necessary for professional training.

- The fundamental criterion for evaluating the educational activities of future teachers and future teachers with teaching experience is topic knowledge.
- Self-evaluation and independent professional growth are useful for experienced instructors, but managing self-evaluation for future teachers will be more appropriate.
- Self-learning experiences are frequently transferred to professional tasks. As a result, the employment of diverse techniques and approaches in education will have a good impact on both teachers' teaching and professional activities.
- Cooperation with colleagues (potential colleagues) will be a motivator for professional development.
- The participation of teachers with teaching experience in the formulation and execution of the assessment system will allow for the development of professional standards that will influence the quality of future teacher training.

Robotics is a novel technology that involves investigating interdisciplinary links in numerous subjects through active learning and integration with science, technology, engineering, mathematics, and other disciplines (Stavridis, Papageorgiou et al., 2022). This direction provides students with numerous opportunities to study 21st-century technologies, develops communication skills, spatial imagination, teaches interaction, the ability to make decisions independently, reveals students' creative intellectual potential, and fosters design thinking and creative imagination (Valko and Osadchyi, 2021). Teachers that employ robotics in their classrooms can accomplish a variety of objectives:

- examine the results and look for fresh directions;
- systematic examination;
- collaboration on ideas;
- logical thinking development;
- The development of the ability to establish cause-and-effect links.

Children's robotics builders are getting increasingly popular. Most designers believe that numerous models can be created from a single set at the same time. Children can also express their ingenuity by designing their own unique models (Drigas, Mitsea and Skianis, 2021). The basic innovation of employing robotics in the educational process rests in a shift in fundamental approaches: the incorporation of new information technologies into the learning process, which pushes students to solve diverse logical and design challenges (Drigas and Mitsea, 2020). Each topic is studied through the realization of projects using modern technologies. It should be highlighted, however, that teachers currently have relatively little material to prepare for robotics classes. As a result, the provision of materials for teachers to employ in the preparation and implementation of STEM projects is critical (Valko and Osadchyi, 2021).

- Primary STEM classes, as well as STEM fields and occupations, should be the focus of elementary school resources. This first level provides instruction based on standards, structured queries, and practical assignments that incorporate the four STEM areas. The goal is to inspire students to continue their education because they want to, not because they have to. The emphasis is also on combining STEM learning opportunities within and outside of the school.
- Junior high school courses must be more challenging. The awareness of students in STEM fields and professions, as well as the academic needs in these fields. Students at this level are starting to research STEM vocations.
- Senior school curriculum focuses on the utilization of materials in a complicated and rigorous manner. STEM courses and areas, as well as job preparation, are now available. More emphasis is placed on the combination of STEM possibilities within and outside of the school.

The curriculum of the course "Informatics," which regulates the specifications of using project activities in the classroom: individual and group educational projects are focused on independent activities of students individual, pair, or group (Drigas, Mitsea & Skianis, 2022). Both the educational goal (expanding and deepening students' theoretical knowledge base, giving the results practical significance, their suitability for solving everyday life problems, dierentiation of learning according to students' requests, inclinations, and abilities) and the research goal are met during the implementation of educational projects (Valko & Osadchyi, 2021).

To realize curriculum, we developed course requirements based on the educational needs of future science and mathematics teachers:

- The course content should be appropriate for the level of technical advancement and should inspire students to try new ways in practice.
- The aims should be of practical significance, and the finished product should be the result.
- The task must be imaginative and approach the problem holistically.
- The course curriculum reflects and deepens understanding of current discoveries and trends in science and technology.
- Each task is completed in the order listed below:
    - task formulation for research,
    - research strategy,
    - development of hypotheses,
    - role distribution,
    - theoretical material research,
    - the execution of the action plan,
    - displaying works,
    - results testing and analysis,
    - hypothesis testing
- Course components (problems, questionnaires, and so on) should assist students in seeing the availability of innovations and feeling successful in STEM fields.
- The clarity of the project's preparatory criteria and needs, its evaluation, and the availability of all instructional resources aimed to promote motivation for training.
- Every completed project must pass a public demonstration (protection, competition); the demonstration should be based on evaluation criteria.
- Students should be able to influence course development, communicate their desires for further design work, the level of diculty in learning about projects, and arrange teamwork through the active use of formative assessment approaches.

A holistic perspective of the problem emerges throughout design and research as a complicated scientific work that necessitates the integration of knowledge from multiple fields (e.g., physics, mathematics, geography, algorithmization, programming) and has a socially significant component. For design and research initiatives to be successful, the entire team must work together (Valko & Osadchyi, 2021). The following are the components of the future teacher training program:

- broad disciplines of social and humanitarian orientation, which help to the formation of general culture and the socialization of the prospective teacher's personality;
- the primary disciplines that provide disciplinary instruction (both theoretical and practical);
    - the psychological and pedagogical sciences that prepare potential teachers for educational practice.

3. Robotics-Focused STEM Lessons in the Classroom: Observation Results and Analyses

Based on Rahman, Krishnan and Kapila, 2017, examined the technological, pedagogical, and content knowledge needs perceived by teachers in order to organize and effectively teach math and science lessons utilizing robotics. Table 1 shows the results. One teacher may see numerous requirements for a specific subject of knowledge. It shows also the frequencies of teachers' perceived requirements for technological, pedagogical, and content expertise to organize and effectively teach math and science classes utilizing robotics. We observe that the needs identified are relatively different and there are variances and similarities between science and math sessions as perceived by the teachers. Teachers identified the following as the most critical prerequisites for teaching science and math topics using robotics: i) for technological knowledge items such as: ability to program robots, ability to troubleshoot robot programs, ability to use robots, etc.; ii) for pedagogical knowledge items such as: ability to differentiate between students, ability to provide scaffolds, and ability to form productive student teams, etc.; and iii) for content knowledge items such as: knowledge of the curriculum for specific grades.

Table 1 Teachers' perceptions of the technological, pedagogical, and subject knowledge required to prepare and effectively teach math and science lessons utilizing robotics

Knowledge requirement	Subject	
	Mathematics	**Science**
Technological knowledge	Basic knowledge of how to use base robot (2); ability to download the robot software (1); ability to program the robot or having the programming skills (2); ability to load, run and troubleshoot the program (2); knowledge of using sensors effectively within the program (1)	Use of smart board (1); use of clickers (1); basic knowledge of howto use base robot (1); effective lesson delivering technology (1); base robot programming skills (3); base robot building skills (2); base robot troubleshooting skills (2); data uploading skills to and from the robot (1); ability to take good pictureof robot activities (1); ability to design appropriate work activitysheets (1); ability to analyze and communicate the findings of the activity sheets (1); ability to explainusing power point slides (3)
Pedagogical knowledge	How to scaffold lessons (1), skills of differentiation between students (1); delivery method (1), teaching practice (1); keeping students engaged in the robotics lesson (1); making students to be observant (1);ability to ask questions to students (1); ability to teach many students using a single piece of robot or teaching strategies under resourceconstraints (1)	Scaffolding of topics (2); skills of differentiation between students (4); assessment technique (1), teaching practice (1); classroom management(1); productive student groupingability (2); ability to deliver lecture for extended time (1); ability to change in teaching style (1); skills ofdealing with students' mistakes (1); skills of dealing with equipment disasters (1)
Content knowledge	Math curriculum for the specific grade (3); updates of current math curriculum (1); ability to relate mathconcept with robotics activities (1); basic calculation skills (1); knowledge of linear equation (1)	Knowledge of biology fundamentals (1); college level knowledge ofcontent (1); updates of current science curriculum (1); knowing thesubject matter where students usually struggle (1); knowledge of current science curriculum (1); state exam requirements in science (1); lab skills (1); knowledge of middle school standards (1); knowledge of potential and kinetic energy (1); knowledge of measurement scales(1); knowledge of energy and energy transfer (1); knowledge of gearmechanism (1)

We investigated the relative importance of the technological, pedagogical, and content expertise recognized by the teachers for preparing and effectively teaching the lessons utilizing robotics (Drigas & Karyotaki, 2019). There are considerable variances in the importance of the technological, pedagogical, and content expertise recognized by the teachers for preparing and effectively teaching math and science classes utilizing robotics. The most significant knowledge area for teaching both math and science subjects using robotics is believed to be technological knowledge (TK). We contend that the use of robots in lessons imposes additional responsibilities on teachers to be familiar with robot construction, programming, sensor integration, and troubleshooting, which may increase the perceived importance of knowledge in these areas for successfully teaching robotics lessons. The second most significant knowledge area for teaching math and science topics using robotics is content knowledge (CK) (Rahman, Jayasree and Kapila, 2017). The least important knowledge category for teaching both math and science subjects with robotics is pedagogical knowledge (PK).We hypothesize that because the robot made it easier for teachers to teach the content, it influenced their perception of the importance of pedagogical knowledge . Nonetheless, we believe that effective integration of educational robotics in science and math teaching demands a wide range of suitable pedagogical strategies (Subramaniam, 2009; Ryan and Deci, 2000; Savery and Duffy, 1995).

We investigated the elements that might influence the requirements and relative relevance of technological, pedagogical, and content knowledge as perceived by instructors in order to effectively teach math and science subjects using robotics. Table 2 displays the outcomes. We can see that the factors influencing knowledge requirements are diverse, and that teachers perceive differences and similarities between science and math lessons. The most powerful aspect influencing the requirements and relative relevance of technological, pedagogical, and content knowledge for effectively teaching math and science subjects using robotics is the teaching period or quantity of engagement time with pupils (Angelopoulou and Drigas, 2021). Other influencing elements for math and science lessons include student age or grade, lesson topic matter, student population in class, student habit, and students' prior knowledge (Rahman, Jayasree and Kapila, 2017).

Table 2 The factors that may influence the requirements and relative relevance of technological, pedagogical, and content knowledge perceived by instructors for effectively teaching math and science subjects utilizing robotics.

Factors for teaching mathematics	Factors for teaching science
Student age or grade (2); subject matter of the lesson or content knowledge (2); teaching period or amount of interaction time with students (3); student population (1); student habit (1); curriculum requirements (1); students' prior knowledge (1); base line (1); school atmosphere (1); fault in teaching technique (1); existence of high risk complex learners with multiple disabilities (1); aligning the math topics with robotics activities (1); level of students' understanding of how to work collaboratively (1); students' behavior (1); students' interest in robotics (1)	Student age or grade (2); subject matter of the lesson (2); teaching period (6); student population (2); student habit (2); students' prior knowledge (2); base line (1); necessity of programming (1); availability of technology (1); curriculum requirements (2); maturity level of students (1); level of cooperation among students (1); subject matter (1); materials to purchase and build (1)

Table 3 The precise policies/strategies/programs implemented by instructors and/or their schools to maintain their technological, pedagogical, and content knowledge in order to effectively teach classes utilizing robots

Teachers' own policy/strategy/program	Policy/strategy/program of the schools
Self-study (2); group study (2); attending professional development training (1); self-practice for lab skills (1); self-collaborations with external organizations (1); self-collaborations and relationships with robotics experts (1); self-research on how to introduce robotics (introductory lessons) to the students as a technological component (1); self-brainstorming to find out the lessons aligned to the curriculum that can be taught using robotics (1); reflecting TPACK concepts when developing activity sheets (1)	Arranging professional development workshop (4); considering TPACK in yearly evaluation of the teachers (2); encouragement from school management (2); periodical assessment by school management (1); creating a TPACK atmosphere (1); providing experienced educators and mentors with less experienced teachers (1); allowing differentiation (1); two teachers in a single classroom for complementary supports (1)

We attempted to identify whether teachers and/or their schools used any policy/strategy/program to maintain their technological, pedagogical, and subject expertise in order to effectively teach robotics lessons. This question was not answered by eight of the twenty teachers. Ten of the twelve teachers who responded to this question stated that they and/or their schools had policies/strategies/programs in place to maintain their technological, pedagogical, and content knowledge for effectively teaching robotics lessons, while two teachers stated that they did not have such policies in place (Papoutsi, Drigas and Skianis, 2021). As a result of the response sample, we find that 83.33% of the teachers and/or their schools adopted policies/strategies/programs to implement the TPACK framework, indicating the levels of awareness of the TPACK framework in middle schools (Rahman, Jayasree and Kapila, 2017). Table 3 details the policies/strategies/programs mentioned by instructors in their comments. Table 5's parenthesis reflect the frequency of the policies cited by instructors. The results in Table 5 reveal that both instructors individually and their schools employed strategies to maintain their technological, pedagogical, and subject knowledge in order to effectively teach robotics lessons. In terms of individual policies, we can see that self-study and group study are the two key tactics used by teachers to support TPACK. Organizing PD workshops, including TPACK in yearly teacher evaluations, and providing encouragement to instructors, on the other hand, are significant measures for upholding the TPACK framework in schools.

Using a 7-point Likert scale, it was attempted to determine whether teachers were satisfied/happy with the policies/strategies/programs (i.e., whether those were adequate) implemented by themselves and/or their schools to maintain their technological, pedagogical, and content knowledge for effectively teaching robotics lessons (Rahman, Jayasree and Kapila, 2017).

4. Scope to Improve TPACK Self-Efficacy Among School Teachers for Robotics-Based STEM Lessons

The findings show that instructors' time constraints in their everyday activities, short class duration, and a lack of technology resources such as robots, computers, iPads, and so on are the key barriers for delivering robotics-based courses within the TPACK framework (Kapsi et al., 2020). The analyses' results show that there are significant differences in the requirements for technological, pedagogical, and content knowledge, as well as the factors influencing the requirements and relative importance of technological, pedagogical, and content knowledge perceived by teachers. Thus, the findings support the paper's working hypothesis (Bamicha and Drigas, 2022).

Based on the results of Rahman, Jayasree and Kapila, 2017, we see the following broad potential for improving TPACK self-efficacy among middle school teachers for robotics-focused STEM programs.

4.1. Teachers' Roles

- Teachers should manage their time in their everyday activities and set aside time to prepare for the TPACK framework.
- Teachers should organize their lessons for a particular class hour.
- Teachers should be trained in managing differences and diversity in students' academic preparation and class subjects.
- Teachers should be able to generate cash for robots, laptops, and iPads through their schools, school districts, online philanthropic sources, and so on.
- Teachers should make ongoing attempts to thrive in the TPACK framework.
- Teachers should understand and practice selecting appropriate technology components for a variety of settings.
- The teacher should look into ways to align the curriculum to employ robotics on a regular basis throughout the year.
- Teachers should arouse pupils' interest in technology.
- Before creating and implementing robotics-based activities, teachers should be familiar and experienced with the robotics kits.
- Teachers should do self-study and build learning communities for group work.
- Teachers should attend TPACK professional development on a regular basis.
- Teachers should perform self-practice for lab skills.
- Teachers should increase self-collaborations with external organizations, self-collaborations and relationships with robotics experts, self-research on how to introduce robotics (introductory lessons) to students as a technological component, selfbrainstorming to identify curriculum-aligned lessons that can be taught using robotics, and reflecting TPACK concepts when developing activity sheets.

4.2. School Scope

- Teachers should have access to appropriate classrooms and labs in order to undertake technology-based lessons.
- Schools should encourage and support teachers who aim to teach using the TPACK framework.
- Schools should begin/increase the number of TPACK PD sessions for teachers.
- Schools should incorporate TPACK into teacher evaluations on a yearly basis.
- Schools should encourage instructors to use the TPACK framework in their classroom lessons.
- Schools should undertake TPACK status assessments in their classroom teaching on a regular basis.
- Schools should be serious about developing a TPACK-friendly environment.
- Schools may appoint experienced educators and mentors to less experienced instructors to help them transfer TPACK ideas. Two teachers in a same classroom can provide complementing help.
- Differentiation should be permitted in schools.

5. Conclusion

Finally, it's critical to emphasize the useful and vital function that digital technologies play in the field of education. These technologies, including mobile devices (45-49), a range of ICT applications (50-62), AI & STEM ROBOTICS (63-78), and games (79-81), facilitate and improve educational processes including evaluation, intervention, and learning. Additionally, the use of ICTs in conjunction with theories and models of metacognition, mindfulness, meditation, and the development of emotional intelligence [82-116], as well as with environmental factors and nutrition [41-44], accelerates and improves educational practices and outcomes, particularly for gifted students with ADHD.

In more details, according to research, STEM education develops particular competences that define the potential to innovate, as well as contributing to future teachers' participation in research and understanding/motivation to follow/study new technologies. The future natural science, engineering and mathematics teacher must be able to train important competencies in pupils based on current technological advances and engage them in new activities. For robotics to become an integral part of the educational process, future teachers must be trained to have a long-term interest in its future applications and to demonstrate its benefits as a tool for universal learning. Students and teachers will need extensive training to construct and run this project. The content of the teaching material used in the project's implementation corresponds to the fundamental concepts of disciplines/scientific sections such as classical mechanics and electronics, automatic theory, programming, and mathematical modeling in the curriculum of future natural science and mathematics teachers. The process of planning and implementing a STEM project leads to the development of a scientific approach to problem solving, technological literacy, abilities in the use of new digital technologies, scientific concept integration, and knowledge of interdisciplinary relationships.

According to the study's findings, curricula include disciplines that contribute to the development of skills in each of the fields: scientific, technical, technological, or mathematical. The courses include successful fields. As a result, it is preferable to conduct integrated classes that contribute to the development of a holistic picture of fundamental laws in science study and the production of an image of the world's natural sciences. The inclusion of fields such as 3D modeling, robotics, and the Internet of Things allows for the design of educational processes based on integration and innovation criteria. They provide technological and inventive expertise.

Compliance with ethical standards

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Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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