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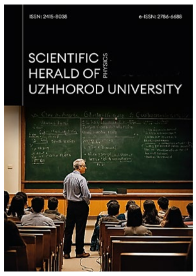

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Methodology of training future teachers of computer science and robotics in interdisciplinary communication

Kaisar Nurlybayev*
Abai Kazakh National Pedagogical University
050010, 13 Dostyk Ave., Almaty, Republic of Kazakhstan

Yessen Bidaibekov
Abai Kazakh National Pedagogical University
050010, 13 Dostyk Ave., Almaty, Republic of Kazakhstan

Indira Bulakbayeva
Republican School of Physics and Mathematics
050040, 36 Bukhar Zhyrau, Almaty, Republic of Kazakhstan

Abstract

Relevance. The relevance of the research is determined by the fact that the development of the educational process in the field of science and technology is necessary to forereach technological achievements in response to the challenges and changes created by the fourth industrial revolution.

Purpose. This study aims to develop a methodology for training future teachers of computer science and robotics, focusing on interdisciplinary communication. It seeks to address the gap between theoretical knowledge and practical applications in educational settings, preparing educators to integrate new technologies effectively amidst the challenges posed by the fourth industrial revolution.

Methodology. This study employs a competency-based approach to develop a methodology for training future teachers in computer science and robotics, emphasizing interdisciplinary connections within educational contexts. It integrates insights from pedagogical research and international collaborations to enhance robotics education in Kazakhstan.

Results. The study found that integrating robotics and computer science within an interdisciplinary framework enhances students' technical education by fostering critical thinking and problem-solving skills. However, it highlighted challenges such as aligning educational goals and overcoming disciplinary boundaries, necessitating careful planning and adaptation in pedagogical practices.

Conclusions. The research concludes that a well-developed methodology for training future teachers in interdisciplinary communication is essential for modernizing educational curricula in response to technological advancements. By integrating robotics and computer science effectively, educators can better prepare students to navigate and contribute to the evolving landscape of science and technology, ensuring relevance and applicability in their future careers.

Keywords: computer technologies; interdisciplinary connections; integration; pedagogical training; educational process.

Introduction

Currently, in Kazakhstan, much attention is paid to methods and approaches in education and in the context of technical education, the teaching of information technologies, as well as programming training. It is very important for every student to develop algorithmic thinking and the ability to solve problems using computers and new technologies. In the public education system of

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*Corresponding author

Kazakhstan, the elements of programming and robotics are not included in the mandatory curriculum. Many students only get acquainted with the elements of programming during their studies, but do not engage in in-depth study of the subject.

According to the experience described in the study [1], students who have received basic knowledge of programming and robotics in high school may be more successful in learning programming in college. It is assumed that students who are first introduced to programming in college are unlikely to have the ability to think abstractly to solve problems.

An important and urgent problem of the modern educational process is the lack of qualified teachers who are able to provide and support the study of the subject in integration with other knowledge from other fields [2]. This also applies to the wide spread of robotics technologies. Thus, there is an urgent task of finding methods and approaches for training future computer science teachers who are able to integrate robotics into their activities and the learning process. Thus, it is necessary to teach and allow introducing elements of new technologies into the school course, to organise extracurricular and elective activities which will make it possible to expand the popularity of necessary skills for the modern world.

In the study [3], scientists pointed out that the introduction of robotics in schools was a problem for the educational community, and even today teachers seem to find this task difficult. The study [4], for example, indicates that many teachers are not aware of the advantages of educational robotics and cannot integrate new methods and approaches into the conventional educational process. Such unwillingness of teachers to use robotics in their classrooms may be due to the lack of specialised training programmes in educational institutions, inadequate content of existing training programmes, or other reasons.

In the study [5], scientists emphasised the importance of providing teachers with special training so that they can teach programming and robotics and feel more confident in this field. This study examines the theory that teacher training is extremely important for the successful integration of educational robotics into the curriculum since it affects the acquisition of digital skills by students, including programming. However, successful integration of the subject requires that teachers understand its potential advantages and know which pedagogical approaches are the best for implementing educational robotics in the classroom [6]. The pedagogical theory of constructivism, which is closely related to educational robotics, will also be considered [7].

It is increasingly recognised that effective and high-quality education in the field of science and technology can be achieved through an interdisciplinary approach to learning in a constructive context. In this context, robotics training is especially useful [8]. Educational robotics is an approach to the development of students' digital skills. However, the question remains whether the teaching staff will be able to meet the expectations and the requirements for the introduction of this new educational resource into their regular educational activities to promote the development of students' digital skills, including programming. To expand research in the field of teacher training in educational robotics, this study proposes a methodology for a teacher training programme based on the characteristics of implemented programmes and best practices [9-10].

The purpose of this work is to study the issue of training future teachers of computer science and robotics, as well as to develop a methodology for their training within this interdisciplinary subject. Achieving this purpose involves solving the following tasks: to determine what skills can be taught in educational robotics and what types of robots in education can be used to study science and technology. The originality of this study consists in reviewing literature on several studies related to the use of educational robotics in the fields of science and technology, as well as developing a methodology for teaching computer science teachers the basics of robotics for integrating these sciences to improve the quality of teaching university students and schoolchildren [11].

The object of the research is the methods of training teachers of interdisciplinary sciences and the integration of knowledge from different fields. It is necessary to start training such specialists at school from a very early age. Children should have the opportunity to discover their potential at school, prepare for life in a high-tech competitive world. According to a study by the authors [12], robotics as a learning tool can be used in elementary, middle, and high schools. Therefore, this educational subject is becoming more relevant. This paper presents a study of the degree of knowledge about educational robotics; existing problems and new tasks; as well as some proposals for the coordination of robotic technologies with learning theories, namely the subject of computer science, to promote cooperation and create networks of researchers and teachers, as well as to create a community of educational robotics in Kazakhstan.

Literature Review

The main problem of the modern educational world is the insufficient number of engineering personnel and the low level of their education. Therefore, it is necessary to popularise the profession of an engineer since the use of robots in everyday life and in production requires users to have modern knowledge in the field of robot control. The school is the first stage at which it is possible to provide initial knowledge and skills in the field of robotics, to arouse students' interest in robotics and the construction of automated systems.

A literature review shows that the subject of robotics is a growing field that can considerably affect the nature of scientific and technological education at all levels, from kindergarten to university. The integration of computer science and robotics can create additional interest among students, as it allows them to gain knowledge for rapidly developing technologies and tools of modernity. The joint study of computer science with robotics has emerged as a unique learning tool that can offer exciting practical classes in an attractive learning environment, arousing students' interest and curiosity [13].

The main theory of educational robotics is constructivism. The paper [14] states that the practical use of the information received is the key for children to build their own conclusions and gain knowledge. The study [15] also notes that the acquisition of knowledge is especially effective in the context when a person consciously participates in the construction of a public object, whether it is a sand castle on the beach or a technological object. The role of teachers is to offer children opportunities to participate in practical research and provide tools for acquiring knowledge in the classroom environment. The educational programme for studying robotics creates a learning environment in which children can interact with the environment and work with real problems.

In this context, robotics can be an excellent tool for teaching children a constructivist approach. Research in this area [13, 16] claims that robotics can potentially influence the training of students in various subject areas (physics, mathematics, engineering, computer science). It can also influence personal development, including cognitive, meta-cognitive, and social skills, such as research skills, creative thinking, decision-making, communication skills, and teamwork skills, all of which are important skills that are necessary at work and in life in the 21st century. Three different approaches to educational robotics are described in the literature [13]:

– thematic approach to the curriculum: the areas of the curriculum are grouped around a special topic for teaching and are studied mainly through queries and communication [17-18];

– project-based approach: students work in groups to explore real problems; this is, for example, the case proposed in the methodology developed by the European project "Teacher Education in Robotics – Enhanced Constructivist Pedagogical Methods" (TERECoP), training teachers in robotic constructivist pedagogical methods [19];

– purposeful approach: children prepare and participate in robotics competitions, which are held mainly outside of school.

At the same time, there is a growing number of promotions and events in Europe, which can be divided into thematic seminars, regional conferences, regional or national tournaments, training courses for teachers, and others.

Materials and Methods

The education sector, especially in the field of science and technology, should prepare students so that they can follow the changes and problems of the industrial revolution 4.0. One of the changes and problems of the fourth industrial revolution is the automation technology. Thus, students should be familiar with this automation technology and be able to use it. One of the main technologies is robots. Robots can be used to study materials in the field of science and technology. The use of robots in the learning process is often called educational robotics.

Over the past decade, robotics has aroused great interest among teachers and researchers as a valuable tool for the development of cognitive and social skills in students from preschool to high school age and to support the teaching of natural sciences, mathematics, technology, computer science, and other school subjects or is used in interdisciplinary educational activities. In the automation process, robots play an important role because of their ability to work according to a given computer programme to perform their tasks. Robots are widely used for the production of various industrial goods. This is because robots can increase the efficiency and performance of manufacturing. The production paradigm is rapidly shifting production from mass to individual. Robots are necessary as a reconfigurable automation technology. Processes such as the stages of product development, production, and assembly are more efficient and effective if robots are used to control these production systems [20].

In recent years, the Ministry of Education and Science of the Republic of Kazakhstan has actively supported the development of new educational programmes and areas. This is how cooperation is conducted with the international centre "Lego Education", which contributes to the equipment of classes and the introduction of an elective course of robotics in educational institutions of the country. However, the introduction of new programmes requires teachers to study the scientific and methodological foundations and master the subject of robotics. In addition, the subject cannot be separated from the holistic training programme, which indicates the expediency of interdisciplinary consideration of the field of robotics with other subjects. The theoretical and methodological basis for this can be the results of pedagogical research of educational activities and the theory of teaching methods. The importance and role of the integration of disciplines in the learning process is determined by the general didactic principle of interdisciplinary connections, within which a unified study of subjects, theories, laws, methods of cognition, and methodological approaches in such disciplines is considered and agreed upon, in addition, common relations and a system of rules are formed. This approach allows considering the questions, problems, and tasks for students who are focused on the application and synthesis of knowledge and skills from different subjects [21].

To fulfil the tasks set, the paper considers a competency-based approach, which obliges the need to expand the principle of interdisciplinary connections. Thus, it is important to focus on purposefully strengthening the links of specific disciplines with other similar ones, but also with those "distant" from it, and on establishing new links within these relations. Taking into account this approach, the teacher has the opportunity to strengthen the connections of his subject with other disciplines, purposefully using, for example, interdisciplinary educational and cognitive tasks or oriented tasks. Interdisciplinary approaches that are presented by these methods help to expand the educational space and create a kind of virtual interdisciplinary educational laboratory, where students, repeatedly using knowledge in each discipline in new conditions outside the discipline itself, develop the ability to apply knowledge in professional activities.

Results

Nowadays, training consists not only of generalising information, knowledge, skills, but a more global purpose is set, which also covers the personal qualities of students: personal and professional competence. These abilities allow the student to independently achieve their goals, make decisions, search for the necessary data, analyse them and extract the necessary information. All these are abilities that are required in the modern, rapidly changing world [22]. Modern science requires new solutions and approaches, and the most considerable and relevant solutions are at the intersection of sciences. Most often, the sciences are complex and their integration and interdisciplinary approach requires rational and serious consideration. An interdisciplinary approach in the form of a research tool can provide considerable internal scientific reflection and methodological dialogue while preserving the integrity of pedagogical science as an independent discipline with its own means and mechanisms of development [23].

The role and importance of the teacher is constantly changing and developing, in addition to the main task – to teach, the tasks of organising and providing the necessary educational environment. It will encourage the child to study and act are also actively included. An example of the organisation of environment and equipment can be a familiar Lego construction kit, in which there are always prepared sets of parts, several instructions. However, there is still the possibility for the child to display creative thinking. And there is also a clearly formulated concept of the educational process.

Based on the constructor, the Lego Design learning technology has emerged, which is one of the most popular pedagogical concepts. It involves the use of three-dimensional objects of the real world, which help to teach and develop the child, organising a subject-game environment. In this environment, children can apply the acquired knowledge in practice, which affects the assimilation of the material and its further use in life. When using the Lego constructor, children actively use not only physical strength but also apply abstract and rational thinking to the same extent. The constructor can help students to implement their ideas, build and fantasise, working enthusiastically and seeing the result. In this way, the constructor allows children to learn while playing.

After analysing the state of the educational environment, it can be concluded that there is a high bar set for the school teacher in the field of subject knowledge, as well as erudition in interdisciplinary sciences to ensure continuous and complete education. Computer science teachers feel the need to study many areas of modern science and technology, this includes programming, computer graphics, telecommunications skills, and much more. In addition, it is necessary to constantly update knowledge since development never stands still in the field of information technologies. One of the main areas is information telecommunications, as they help to form the information culture of schoolchildren. After analysing the literature and materials, it was concluded that to successfully implement educational programmes for a teacher, it is necessary to have the following skills and competencies that allow:

– the use of computer networks to provide students with scientific and educational materials;

– creation and use of software or technical tools together with students for further use in the educational process. There may be robots, drives, or software products for their control;

– creation and use of school management tools and the organisation of the educational process. These can be programmes for intra-school communication and information transfer, entertainment services, or sites for storing information or other data;

– the use of various tools to ensure and optimise the educational process. It may include tools for creating or maintaining schedules, working with wall newspapers or other posters, as well as educational materials.

However, the education of the teachers is currently undergoing a crisis. Young specialists often do not receive proper education and study using outdated materials. This leads to the fact that the school does not correspond to the trends of the developing world and children often graduate unprepared. Changing the approach to education and finding ways to eliminate the knowledge gap will modernise and update the education of teachers in Kazakhstan, which in turn will lead to the development of a new high-quality education for children. For this task, in the course of the study, a methodology was developed for training future computer science teachers who are also able to acquire knowledge about modern technologies and robotics, to integrate this knowledge into the educational process.

The methodology includes a set of interacting components that influence the development of future teacher's competencies, provide the orientation of scientific and subject training to ensure teacher's competence. The components include target, content, adjustment, evaluation, and instrumental and technological means. It is also necessary to identify the competencies that a specialist should have:

– key competencies that include general cultural, communication, information, and self-educational competencies;

– pedagogical, including research, cognitive, psychological, technical, regulatory, and methodological competencies;

– subject areas that include competencies in the field of technologies and basic concepts, information and system, technical, logical, and algorithmic competencies.

The teacher's training should correspond to and be aimed at the development of these competencies. This approach to teacher training is also based on an interdisciplinary approach since many disciplines studied in the training course require knowledge from other fields and subjects. In the modern world, the interaction of subjects and knowledge is inevitable, but in the process of learning, it is necessary to gradually increase the volume and complexity of intersubject connections and obtaining information to ensure maintaining the level of interest and independent growth in the future. Ensuring the implementation of intersubject relations implies an optimal sequence of studying topics that relate to the general data of objects and concepts in different subjects and sections within the subject:

– consistency is a holistic conceptual understanding and the exclusion of contradictions in concepts, representations, objects, and methods;

– high-quality and effective interaction of disciplines, which makes it possible to supplement knowledge, get the most useful experience and the ability to apply the acquired skills in further work.

The developed teaching methodology includes the study of six main disciplines that will allow implementing a systematic approach to the education of future specialists, as well as provide in-depth knowledge in the chosen subject of teaching. The main problem today among the staff is insufficient professional literacy, which entails the inability to cover various disciplines to form a single information field related to the interdisciplinary connections of the subject. The following is a list of subjects and their description for a system approach to training future teachers:

1. Computer networks, the Internet, and other communication technologies. This subject includes information about all technologies of the World Wide Web (WWW), allows understanding how the Internet, services, data transmission work. In addition, the tools for developing websites, applications and services are considered, such as: HyperText Markup Language (HTML), Cascading Style Sheets (CSS), and JavaScript and Java programming languages.
2. Programming languages, databases. One of the main topics of the modern technical world, it is difficult to imagine where programming and knowledge of at least one programming language may not be useful. Thus, the main languages to choose from are: C, C#, C++, Python. Java, R, Personal Home Page (PHP). One more important component is databases, which are represented by large data stores. An important task is to interact with them, extract and add information. Thus, the necessary data for studying are: database architecture and models, the Structured Query Language (SQL), MySQL distributed database management system (Structured Query Language), the creation of client-server applications.
3. Modern scientific technologies in the educational process and life. This section includes familiarisation and immersion in new technologies, provides integration of the educational process and the real world. This is how ontologies, cloud storage, blockchain technologies, and much more can be considered.
4. Robotics. It is important to single out a separate subject that will teach the future educator the basics and deep knowledge. Development, creation, assembly, programming of robots – all these are the stages that a teacher should be able to do. In addition, there should be a possibility for an adequate response to emerging circumstances, as well as a timely search and study of related materials.
5. Information systems – everything that surrounds the user on the Internet is represented with the help of information systems. However, most often these are large examples, such as Internet forums or news sites. Thus, a necessary skill can be the creation of Internet simulators (to test students' knowledge), chats, websites, blogs, or voting.
6. Computer graphics. Working with photos and videos currently occupies a very important place, as well as working with 3D images and models for printing on special printers. Then teaching graphic design and the basic concepts of computer graphics can have a positive impact on the future teacher.
7. The study of modern approaches to education. This area can help the teacher choose their own way of presenting the material or, based on the experience of other colleagues, form their own approach, which will include several existing ones.

An assessment of the development and level of competencies of future teachers after training can be carried out using special competency-oriented tasks. Such tasks involve the practical application of the acquired knowledge, as well as the development of competencies in this area and their direct quantitative assessment. An important requirement of these tasks is the possibility of using the acquired knowledge in the practical activities of the future teacher. The use of approved tasks makes it possible to clearly and transparently evaluate the work of the performer, but allows using flexible solutions with originality and a creative approach to completing tasks. Both theoretical and practical knowledge are evaluated using competency-oriented tasks.

The characteristic feature of these tasks is the relativity of freedom of choice in the methods and means of studying and future teaching when solving the practical task set for the student. For example, a certain small subject area may be given, in which the student can demonstrate the necessary competence. In addition, to assess and track the student's professional path, determine his pedagogical and subject capabilities, the projects aimed at solving professional problems are used. Such projects should be evaluated by independent experts who have teaching experience in different subject areas. Data on students' academic performance and learning capability can be analysed using mathematical statistics to prepare reports and data on the quality of personnel training.

Robots are not the end point for improving the learning process; the real fundamental problem is not in the robot itself, but rather in the curriculum. Robots are just another tool to help, and it is the curriculum that can determine the result of training and the compliance of technologies with learning theories. The relevant educational philosophy, namely constructivism, the curriculum, and the learning environment are among the most important elements that can lead to the success of robotic innovations. The emphasis should shift from technology to integration with learning theories, focusing on the curriculum rather than on technology.

The curriculum is the cornerstone of educational robotics, and it is necessary to include the basic principles of training and establish qualitative and quantitative performance indicators for the expected results and verification of the curriculum. The role of robotics should be considered as a tool for the development of basic life skills (cognitive and personal development, teamwork), using which people can develop their potential, use their imagination, express themselves, and make original and valuable choices in their lives. The benefits of robotics are relevant for all children; and target groups in robotics projects and courses should include the entire class, not only children who are talented in science and technology.

To this end, broader promising projects are needed to develop the above creative skills in all children, regardless of their school performance or gender. Teachers and educators should use different strategies to introduce students to robotics technologies and concepts to provide several ways of getting acquainted and interacting with robotics, and to ensure that there are entry points for involving young people with different interests and learning styles. An iterative plan is necessary for validating various strategies and methodologies through which the implementation of robotics training programmes will take place in practice with subsequent testing, refinement, and continuous improvement. Testing should be based on a system of indicators and a standardised methodology for evaluating clearly measured and defined benefits.

Discussion

Educational robotics, considered as a branch of educational technologies, suffers from the same problems that are well known in conventional education. Next, let us consider and discuss some critical and related emerging problems for the educational robotics community. Studies of legislative bodies (such as the United Nations Economic Commission for Europe, the International and Japanese Robotics Association) show that the growth of the market for personal robots, including those used for entertainment and educational purposes, is large and this trend may continue in the coming decades [16].

However, as noted in a recent report by the Organisation for Economic Co-operation and Development [24], "technology is everywhere except in schools". While experts are optimistic about the development of learning opportunities using technology, skepticism prevails in the scientific community about the ability of the educational system and educational institutions to keep up with changes and become more flexible and dynamic. However, education authorities of some European countries issue documents and directives encouraging the development of educational robotics projects in schools and some new school programmes are enriched with robotics; for example, the computer science training programme in primary grades of high schools in Greece [25].

Despite this fact, the subject of robotics (as well as other digital technologies) is not included in European school curricula. Most experiments related to robotics are not integrated into regular classroom activities; they take place in extracurricular programmes, on weekends or in summer camps [16]. Exceptions can also be found in the literature, there are examples of teachers who could integrate robotics into regular training [17-18]. Teachers who have introduced robotics in schools note that such lessons or special classes at school are more convenient only for some students [26]. Obstacles to the introduction of robotics into the regular school curriculum are the complexity of integrating work with new technologies, the cost of necessary equipment, and the practical work that is required from teachers to deal with discipline and distraction in the classroom and to keep all the equipment in the right place. The problem is aggravated when, combined with the notion that robotics like other science and technology subjects is complex, it is also strongly biased based on gender and does not attract the majority of students [27]. In recent years, there have been proposals for the development of educational programmes, according to which the introduction of robotics can positively affect technological education and attract the interest of students. This is how the programme of "digital manufacturing and creation" in education is being developed. Apparently, this determines the desire to overcome the bias inherited in educational systems and to combine intellectual work in the classroom with students.

The promotion of best practices in education and skills development is one of the key elements of the flagship initiative "Innovation Union" within the framework of the "Europe 2020" strategy. Communication "Innovation Unio" recognises that there are weak points in teaching natural sciences; the skills of future responsible innovators and researchers, as well as active citizens in science, should be formed from an early age. This includes scientific thinking, as well as cross-cutting competencies such as critical thinking, problem-solving, creativity, teamwork, and communication skills. Currently, there are calls in education in Kazakhstan and around the world for the development of educational approaches that will promote the development of creative abilities and ingenuity [27-28]. Modern students grow up in a world that is very different from the world of their parents and grandparents. To succeed in modern society, students must learn to think creatively, systematically, plan and critically analyse, be able to communicate, constantly learn and develop. Appropriate teaching methods, such as constructivism and inquiry-based scientific education [29], can considerably contribute to the development of these skills.

The bodies regulating the educational process often call for actions aimed at increasing the use of problem-based and research-based scientific teaching in primary and secondary schools. However, most of the use of technology (including robotics) in schools today does not support the previously mentioned 21st-century learning skills. In many cases, new technologies simply reinforce the old ways of teaching and learning. The current typical school science laboratories do not seem suitable for developing critical thinking, problem-solving, creativity, teamwork, and communication skills since they are designed for a strict, disciplined approach to completing tasks [27], in which students are usually guided by recipe-style instructions that lead to the "discovery" of predefined concepts.

In accordance with the above question, an important distinction arises between "technical competence", that is, the deep knowledge necessary for professional teachers, engineers, and scientists to perform their work, and "technical literacy", which implies the presence of knowledge, skills, and relationships that are valuable for every citizen [30-31].

In the field of educational robotics, this approach dictates the transition from its simple use for obtaining professional skills by future workers of science, technology, engineering, and mathematics to the fluency or literacy of all individuals, which will make the intellectual and manual advantages of the robotics basics accessible to everyone. If robotic technologies are used in accordance with the above perspective, they can play an important role: to provide a constructive learning experience, to promote the development of basic skills required in the workplace in the 21st century, and to equip new generations with a solid "technological literacy" for better preparation in a creative, intellectual life.

Taking into account the arguments from the literature review, there will be a need to expand the audience and target groups for the use of robotics. Currently, robotics is used very narrowly in educational institutions [32]. Until now, most applications of robotic technologies in education have focused on supporting the teaching of subjects closely related to the field of robotics, such as robot programming, robot construction, or mechatronics [16]. Even in the context of computer science, the use of robotics technologies occupies an extremely unstable position. Most often, teachers are facing the problem of the complexity of building an educational process to ensure the maximum number of students involved.

The lack of necessary equipment only aggravates the problem. However, it is difficult to talk about a lack of equipment when there are no necessary programmes for teaching and integrating these subjects. Most often, teachers themselves develop individual training programmes for some classes if there are students interested in this topic. Thus, the task of involving more students in the topic of new technologies becomes important, which in turn requires broader and more promising educational projects. A wider range of possible training programmes related to programming and robotics can attract young people with a wider range of interests. Solving this problem, it is necessary to develop innovative ways to increase the attractiveness and the profit from projects in the field of robotics.

The researchers in the study [32] propose four strategies for involving a wide range of students in robotics: projects that focus on topics, not just tasks; projects that combine art and engineering; projects that encourage the creation and telling of stories; organisation of exhibitions, participation in competitions. Young people who are not interested in conventional approaches to robotics become motivated. Robotics can be used as a way to tell a story (for example, creating a mechanical puppet theatre) or interact with other disciplines and areas of interest, such as music and art. Different students are attracted to different types of robotic activities: students interested in cars are more likely to be interested in creating motorised vehicles, while students interested in art or music will be more interested in creating artistic robotic creations [16].

The embodiment or personification of robotics is another new and innovative way that can be introduced into robotic activities to make it more meaningful for children. The embodiment experience can be fulfilled when students physically interact with robots, and then programme them to perform certain tasks. In this case, learning develops from personal or individual work to the implementation of knowledge and ideas using robots [33]. Another way to facilitate learning through the implementation is to give students the task of implementing a robotic system, for example, by asking them to reproduce or follow the movements of robots using gestures [34]. Implementation in robotics seems to be a promising path for further research based on modern theories of cognition.

The production of robotic tools is still mainly focused on people using pre-programmed prefabricated robots. The ways of creating and programming robots are a "black box" for their users. Unfortunately, the same "black box" method is very often used in educational robotics applications, where the robot was designed or programmed in advance and is introduced into educational activities as an end or passive tool. The arguments in favour of the "black box" method is often based on the idea that creating and programming a robot is a very difficult task for children. However, it was found that the perceived difficulties of robotics tasks are associated with imperfect design of programmes and tools, and not with cognitive deficiencies of students [27].

Whatever the main misconception, the metaphor of the "black box" is compatible with the conventional educational paradigm of a teacher or a textbook that covers and explains ready-made, ratified and, therefore, indisputable information. In contrast to this approach, constructivism methodologies require a transition to the design of transparent ("white boxes") robots, where users can create and disassemble objects, programme robots from scratch and have deeper structural access to the products themselves, and not just consume ready-made technological products. The metaphor of a white box for building and programming can cause students to think creatively and stimulate participation in the educational process [35].

However, students often get to a "plateau" and become unable to move beyond a certain point, and find that they cannot create something very interesting, starting from scratch every time. Thus, compromises were proposed regarding transparency in the development of robotics tools for training, which led to the so-called "black-and-white box" prospects. In this way, children can participate in meaningful, interesting, and complex constructivist activities by controlling robots and their performance environments [36].

For example, in the case when teachers want to focus on programming concepts in the classroom, without having time for students to design their robots; in this case, teachers should bring robots designed in advance to the classroom to save learning time and provide students with the opportunity to transparently programme and control robots [17]. Finally, the dilemma between the metaphor of "white box" and "black-and-white box" should be solved by teachers in accordance with their educational goals, when they integrate the subject of robotics into their classroom and, more importantly, in accordance with their educational interests and the needs of students.

It should be noted that although robots have a positive educational potential, they are not a panacea for problems in the educational process. There have been studies in the literature that reported a minor effect on students observed in some cases [16]. In any case, the impact of robotics on promoting student learning and skill development should be confirmed with research data. Without confirmation of the direct impact of robotics on the learning and personal development of students, robotics may simply be a new fashion trend. However, there are no systematic assessments and reliable experimental developments in educational robotics. Most of the literature on the use of robotics in education is descriptive in nature and is based on reports of teachers who achieve positive results through individual, small initiatives.

In recent years, there have been disputes and criticism in the scientific society aimed at the idea of a clear lack of quantitative research on how robotics can improve student academic performance. The research [37] indicates the lack of a systematic study of robotic projects and a considerable assessment of the impact of approaches or their compliance with their goals. In other cases, the expected benefits were not clearly measured and defined due to the lack of a system of indicators and a standard methodology for evaluating them. Despite the usually positive educational and motivational benefits, studies show that accurate quantitative studies are absent. Research using robotics in the classroom very often produces results that depend on the perception of teachers or students, rather than strict research plans based on data on student performance [38].

Research should show that projects or courses achieve the set learning goals, analyse children's interest in science and technology, or track the development of higher cognitive or social skills. It is also necessary to know whether courses involving robotics and interdisciplinary approaches related to it affect young children and their further educational career. However, during robotics classes, the students who develop their projects or solve problems usually go in different and unpredictable ways, which makes it difficult for evaluators to monitor their progress. Thus, a monitoring environment was proposed to allow the teacher to monitor and model the learning process based on data coming from a learning situation with insufficient assessment. Data mining methods were tested using reliable information collected in the robotics class and made it possible to obtain useful and interpretable information about student performance [39].

Conclusions

In the light of the above, it becomes obvious that there is a need to rework existing approaches to the integration of educational robotics and other subjects, such as computer science and programming. Robotics can offer great development potential in education, however, the learning benefits for students are not guaranteed by simply introducing the subject of robotics in classrooms since there are several factors that can determine the result; technology alone cannot influence minds. Improving the learning process requires the development of a dynamic and active community of educational robotics, which will contribute to the further development of a network of researchers, teachers, and students.

Existing local and regional education networks, mostly built based on current or past project partnerships, remain small in size and isolated groups suffering from a lack of coordination. However, the development of such innovative networks is considered as the development of high potential, if these networks connect and synchronise their actions into a large information space that includes communities around the world. This community, which will offer well-organised and coordinated collective actions, will have the following goals:

– to create and distribute open educational and technological products and practices (training programmes and resources) for both formal and informal learning environments. Thus reflect the best pedagogical practices and educational research in this field;

– to promote communication and collaboration between researchers, teachers, and students by creating community forums for the exchange of experiences, products, and knowledge;

– to support teacher education, create and manage schools for teachers;

– to encourage and support the practical implementation of robotics training programmes in schools;

– to test and verify educational programmes and methods both at the level of pedagogical education and at the level of the class;

– to provide a focus for educational authorities, scientists, teachers, parents, and children on the latest achievements in the field of educational robotics.

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Conflict of Interest

None.

References

[1] Pásztor A. How can IT be taught playfully with the help of programmable robots? Valencia: INTED; 2008.

[2] Kozhagul A, Bidaibekov Y, Bostanov B, Pak N, Kozhagulova Z. Integration of robotics design into the learning process at school. *Per Tche Quim.* 2020;17(35):404-424.

[3] Chambers JM, Carbonaro M. Designing, developing, and implementing a course on LEGO robotics for technology teacher education. *J Tech Teach Ed.* 2003;11(2):209-241.

[4] Sisman B, Kucuk S. Educational robotics course: Examination of educational potentials and pre-service teachers' experiences. *Int J Res Ed Sci.* 2019;5(2):510-531.

[5] Major L, Kyriacou T, Brereton P. The effectiveness of simulated robots for supporting the learning of introductory programming: A multi-case case study. *Comp Sci Ed.* 2014;24(2-3):193-228.

[6] Bers MU, Seddighin S, Sullivan A. Ready for robotics: Bringing together the T and E of STEM in early childhood teacher education. *J Tech Teach Ed.* 2013;21(3):355-377.

[7] Tocháček D, Lapes J, Fuglík V. Developing technological knowledge and programming skills of secondary schools' students through the educational robotics projects. *Proc-Soc Beh Sci.* 2016;217:377-381.

[8] Anagnostakis S, Michaelides PG. Laboratory of educational robotics – An undergraduate course for primary education teachers. In: Proceedings of the 3rd International Conference on Hands-on Science (HSci 2006). Braga: University of Minho; 2006.

[9] Nurbekova ZhK, Mukhamediyeva KM, Davletova AH, Kasymova AH. Methodological system of educational robotics training: Systematic literature review. *Espacios.* 2018a;39(15):28.

[10] Nurbekova ZhK, Mukhamediyeva KM, Assainova A. Educational robotics technologies in Kazakhstan and in the world: Comparative analysis, current state and perspectives. *Astra Salvensis.* 2018b;11:665-686.

[11] Avdarsol S, Rakhimzhanova L, Bostanov B, Sagimbaeva A, Khakimova T. Criteria-based assessment as the way of forming students' functional literacy in computer science. *Per Tche Quim.* 2020;17(35):41-54.

[12] Touretzky DS, Gardner-McCune C. Calypso for Cozmo: Robotic AI for everyone. In: Proceedings of the 49th ACM Technical Symposium on Computer Science Education. New York: Association for Computing Machinery; 2018.

[13] Eguchi A. What is educational robotics? Theories behind it and practical implementation. In: Gibson D, Dodge B, editors. Proceedings of Society for Information Technology & Teacher Education International Conference 2010. Chesapeake: AACE; 2010.

[14] Piaget J. To understand is to invent. New York: Basic Books; 1974.

[15] Papert S, Harel I. Constructionism. New York: Ablex Publishing Corporation; 1991.

[16] Benitti FBV. Exploring the educational potential of robotics in schools: A systematic review. *Comp Ed.* 2012;58(3):978-988.

[17] Detsikas N, Alimisis D. Status and trends in educational robotics worldwide with special consideration of educational experiences from Greek schools. In: Proceedings of the International Conference on Informatics in Schools: Situation, Evolution and Perspectives. Tallinn: Tallinn University; 2011.

[18] Litinas A, Alimisis D. Planning, implementation and evaluation of lab activities using robotic technology for teaching the phenomenon of motion. In: Proceedings of the 3rd Pan-Hellenic Conference "Integration and Use of ICT in Educational Process". Piraeus: HAICTE & University of Piraeus; 2013.

[19] Alimisis D, editor. Teacher education on robotics-enhanced constructivist pedagogical methods. Athens: School of Pedagogical and Technological Education; 2009.

[20] Alcácerac V, Cruz-Machado V. Scanning the Industry 4.0: A literature review on technologies for manufacturing systems. *Eng Sci Tech Int J.* 2019;22:899-919.

[21] Dabu CM. Computer science education and interdisciplinarity. *Sci Ed Res New Tech.* 2017;31(4):115-127.

[22] Stukalenko N, Murzina SA, Kramarenko BV, Yermekova ZhK, Rakisheva GM. Implementation of competence approach in the professional education of prospective teachers in the higher education conditions. *Int Rev Man Mark.* 2016;6(S3):175-181.

[23] Snopkova EI. The relevance of an interdisciplinary approach in pedagogical research: Scientific rationale. *Int Ed.* 2015;19(1):111-117.

[24] OECD. New millennium learners: a project in progress optimising learning: implications of learning sciences research; 2008. www.oecd.org/dataoecd/39/51/40554230.pdf.

[25] Jimoyiannis A. The new curriculum for informatics literacy in compulsory education: From design to implementation. In: Bratitsis T, editor. Proceedings of the 6th Pan-Hellenic Conference "Didactics of Informatics". Thessaloniki: Hellenic Association of ICT in Education; 2012.

[26] Sullivan FR, Moriarty MA. Robotics and discovery learning: Pedagogical beliefs, teacher practice, and technology integration. *J Tech Teach Ed.* 2009;17(1):109-142.

[27] Blikstein P. Digital fabrication and "making" in education: The democratization of invention. In: Herrmann JW, Bóching C, editors. FabLabs: Of machines, makers and inventors. Bielefeld: Transcript Publishers; 2013.

[28] Resnick M. Sowing the seeds for a more creative society. *Learn Lead Tech.* 2007;35(4):18-22.

[29] Demo GB, Moro M, Pina A, Arlegui A. In and out of the school activities implementing IBSE and constructionist learning methodologies by means of robotics. In: Barker BS, Nugent G, Grandgenett N, Adamchuk V, editors. Robots in K-12 education: A new technology for learning. Hershey: IGI Global; 2012.

[30] Papert S. Computer criticism vs. technocentric thinking. *Ed Res.* 1987;16(1):22-30.

[31] DiSessa AA. Changing minds: Computers, learning, and literacy. Cambridge: MIT Press; 2000.

[32] Rusk N, Resnick M, Berg R, Pezalla-Granlund M. New pathways into robotics: Strategies for broadening participation. *J Sci Ed Tech.* 2008;17:59-69.

[33] Lu CM, Kang S, Huang SC, Black JB. Building student understanding and interest in science through embodied experiences with LEGO robotics. In: Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2011. Waynesville: Association for the Advancement of Computing in Education; 2011.

[34] De Koning BB, Tabbers HK. Facilitating understanding of movements in dynamic visualizations: An embodied perspective. *Ed Psych Rev.* 2011;23:501-521.

[35] Resnick M, Berg R, Eisenberg M. Beyond black boxes: Bringing transparency and aesthetics back to scientific investigation. *J Learn Sci.* 2000;9(1):7-30.

[36] Kynigos C. Black-and-white-box perspectives to distributed control and constructionism in learning with robotics. In: Proceedings of SIMPAR workshops 2008. Piscataway: Institute of Electrical and Electronics Engineers Inc.; 2018.

[37] Bredenfeld A, Hofmann A, Steinbauer G. Robotics in education initiatives in Europe: Status, shortcomings and open questions. In: Menegatti E, editor. Proceedings of International Conference on Simulation, Modeling and Programming for Autonomous Robots (SIMPAR 2010) Workshops. Darmstadt: Springer; 2010.

[38] Barker BS, Ansorge J. Robotics as means to increase achievement scores in an informal learning environment. *J Res Tech Ed.* 2017;39(3):229-243.

[39] Jormanainen I, Sutinen E. Using data mining to support teacher's intervention in a robotics class. In: Proceedings of the 2012 IEEE Fourth International Conference on Digital Game and Intelligent Toy Enhanced Learning. Washington: Institute of Electrical and Electronics Engineers Inc.; 2012.

Методологія навчання майбутніх вчителів комп'ютерних наук і робототехніки в міждисциплінарній комунікації

Кайсар Нурлібаєв
Національний педагогічний університет ім. Абая
050010, пр. Достык, 13, Алмати, Республіка Казахстан

Єссен Бідайбеков
Національний педагогічний університет ім. Абая
050010, пр. Достык, 13, Алмати, Республіка Казахстан

Індіра Булакбаєва
Республіканська школа фізики та математики
050040, вул. Бухар Жирау, 36, Алмати, Республіка Казахстан

Анотація

Актуальність. Актуальність дослідження обумовлена необхідністю розвитку освітнього процесу в галузі науки та технологій для відповіді на виклики та зміни, спричинені четвертою промисловою революцією.

Мета. Це дослідження спрямоване на розробку методології навчання майбутніх вчителів комп'ютерних наук і робототехніки з фокусом на міждисциплінарній комунікації. Воно прагне заповнити прогалину між теоретичними знаннями та практичними застосуваннями в освітніх установах, готуючи вчителів до ефективної інтеграції нових технологій серед викликів, які ставить четверта промислова революція.

Методологія. У цьому дослідженні використовується компетентнісний підхід для розробки методології навчання майбутніх вчителів комп'ютерних наук і робототехніки, з акцентом на міждисциплінарних зв'язках в освітньому контексті. Воно інтегрує висновки педагогічних досліджень та міжнародних співпраць для покращення освіти в галузі робототехніки в Казахстані.

Результати. Дослідження показало, що інтеграція робототехніки і комп'ютерних наук в міждисциплінарному контексті покращує технічну освіту студентів, сприяючи розвитку критичного мислення та навичок вирішення проблем. Однак воно висвітлило виклики, такі як вирівнювання освітніх цілей та подолання дисциплінарних меж, що вимагають уважного планування та адаптації педагогічних практик.

Висновки. Дослідження висновує, що добре розроблена методологія навчання майбутніх вчителів у міждисциплінарній комунікації є важливою для модернізації освітніх програм у відповідь на технологічні досягнення. Шляхом ефективної інтеграції робототехніки та комп'ютерних наук педагоги можуть краще підготувати студентів до навігації і внесення свого вкладу в змінну ландшафт науки та технологій, забезпечуючи актуальність та застосовність у їхніх майбутніх кар'єрах.

Ключові слова: комп'ютерні технології; міждисциплінарні зв'язки; інтеграція; педагогічна підготовка; освітній процес.