

Article

Research on digital resources for organizing STEM education in elective courses with integrated content in Ukrainian schools

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CITATION

Nazarenko T. Research on digital resources for organizing STEM education in elective courses with integrated content in Ukrainian schools. *Forum for Education Studies*. 2025; 3(1): 2005. <https://doi.org/10.59400/fes2005>

ARTICLE INFO

Received: 8 November 2024
Accepted: 20 December 2024
Available online: 12 February 2025

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Abstract: Every year, various changes occur on planet Earth. Robotics appears, both in production and in everyday life, 3D printers, driverless cars, drones, the development of augmented reality and artificial intelligence, etc. Various innovations have also affected the education system of Ukraine. Forms, methods, teaching aids, the role of teachers and students, curricula and assessment systems are changing. With the modernization of the educational process, new directions in education are emerging. For example, today you can hear about blended, inverted, mobile, social learning, video scribing, cloud technologies, flipped classroom, storytelling, start-up challenge, etc. In connection with the spread of coronavirus infection and active military operations in the territory of Ukraine, distance learning has been introduced, which requires certain skills from both teachers and students. It is worth being able to use various gadgets to complete educational tasks, communicate with parents, students, colleagues, etc. Today, another educational reform is underway in Ukraine, which is supported by state educational documents, in particular, the approved concept of STEM education, which involves the integration of natural sciences and emphasizes the development of new technologies, mathematical calculations, and innovative thinking. In this context, the educational process is reoriented to the development of the individual, and such a reorientation involves improving the entire education system, and therefore, the methods of teaching individual disciplines, including natural sciences. To do this, it is necessary to calculate various aspects of implementing STEM education in the educational process of general secondary education institutions in Ukraine, which in the future should satisfy the country's needs for qualitatively trained STEM education specialists. Therefore, scientists from the Institute of Pedagogy of the National Academy of Sciences of Ukraine are conducting relevant research, including on the topic of implementing the Concept of STEM education and educational STEM technologies in the educational process of general secondary education institutions. As a result of the study, it was found that the most acceptable is the use of integrated content of various elective courses that are of an extracurricular nature. Thus, using various gadgets that are used in the educational process in elective courses, we came to the conclusion that digital technologies of augmented reality are the most effective. The purpose of the scientific work of scientists of the National Academy of Pedagogical Sciences of Ukraine is to analyze the implementation of STEM education in the educational process of Ukrainian schools and its impact on the formation of key and subject competencies in students, in our case—geographical ones. The pedagogical experiment was supposed to last three years from September 2020 to June 2023, but the military actions that began on the territory of our state suspended it in February 2022. It was attended by 923 teachers and 4750 students who chose STEM teaching through elective courses.

Keywords: STEM education; STEM training; elective courses with an integrated component; integrated learning; digital resources; competency-based learning

1. Introduction

The authors of the Ukrainian educational reform emphasize interactive content and innovative teaching methods that develop students' critical thinking. It is believed that, first of all, it is necessary to introduce STEM education in Ukrainian schools. In this context, the European Parliament and the Council of the European Union in 2006 selected eight key competences for lifelong learning, "fundamental for every person, necessary for life in a knowledge-based society" [1]. It should be noted that this document defines competence as a set of knowledge, skills and abilities in an appropriate context.

STEM education (S—science, T—technology, E—engineering, M—mathematics) [2] is a new direction in the global education system, and Ukraine has not been left out, actively implementing this direction in its own education system. The abbreviation STEM explains the peculiarities of didactics through the implementation of interdisciplinary teaching methods focused on the study of natural and mathematical disciplines.

International studies conducted in Ukraine by the Center for Educational Monitoring of the Quality of Science and Mathematics Education—TIMSS [3], PISA [4] etc., indicate that Ukrainian schoolchildren perform reproductive tasks quite adequately, but demonstrate a low level of formation of general educational skills to work with coded information presented in texts, tables, diagrams, pictures, schemes, geographical maps, etc., this is precisely what is stated in the State Standard of Basic Secondary Education [5].

A significant part of students does not perform those tasks in which it is necessary to give an answer in a free form, which indicates the insufficient formation of communication skills among adolescents necessary for forming their own opinion, which must be expressed in a coherent form and in verbal presentation [6].

Scientists from the Department of Geography and Economics of the Institute of Pedagogy of the National Academy of Sciences of Ukraine, led by the author of the article, conducted a study to study the level of geographical preparation of schoolchildren and their involvement in STEM education through elective courses. Geography is a complex educational subject that has a dualistic structure: Physical geography belongs to the natural educational branch, and economic geography to the social one.

The identified shortcomings of the geographical training of schoolchildren can be largely eliminated if the educational process is dominated by an activity approach, which is not based on the transfer of ready-made knowledge to students, but forms the ability to independently acquire knowledge while working with any educational information. To do this, it is necessary to form skills in students that will be useful in any situation. For this, elective courses have been created, which are unfairly suppressed by the main subjects, but their content-applied orientation interest's students much more than being in lessons, in addition, as a rule, the content of elective courses contains information of an interdisciplinary even STEM nature, as evidenced by the curricula created by scientists of the department [7].

It is worth noting that in Ukraine, before the war in 2022, STEM centers were created and successfully operated. The first of them began to operate in Kyiv and

Dnipro in general secondary and higher education institutions. A survey conducted by the Department teaching of Geography and Economics of the Institute of Pedagogy of the National Academy of Sciences of Ukraine in early 2020 showed that there are more than 150 STEM centers and STEM laboratories operating in Ukraine. The work of these centers was especially active during quarantine and active hostilities in conditions of distance learning [8].

One of the components of the New Ukrainian School is the creation of an innovative educational environment, a STEM space, which will contribute to the organization of various forms of work of educators, the development of students' sustained interest in STEM professions, the need for knowledge and professional self-determination of young people. The organization of an innovative space involves not only equipping them with modern equipment and material and technical base, but also creating conditions for the formation of the emotional intelligence of young people. Important components for the formation of a STEM environment are the development of integrated programs, elective courses; emphasis on project, team and group work of students; conducting non-standard lessons and various organizational forms (competitions, quests, excursions, hackathons, scientific picnics, thematic days and weeks, scientific exhibitions, etc.); creating activity zones in the classroom; cooperation with parents, higher education institutions, public organizations, museums, scientific laboratories, business structures, etc.; systematic monitoring of results [9].

2. Theoretical background

The scientists of the department provide scientific and methodological support and advocacy for the implementation of STEM education in Ukraine, and also research educational innovation processes in this area. Over the past five years, STEM has maintained its position among educational brands; attracts the attention of teachers, scientists, methodologists and other interested parties; allows integrating different branches of science and educational subjects. STEM education is a category that defines the appropriate pedagogical process (technology) of forming and developing the intellectual, cognitive and creative qualities of young people. STEM education is based on interdisciplinary approaches to building multi-level curricula, individual didactic elements, studying phenomena and processes of the surrounding world, solving problem-oriented tasks. Using the leading principle of STEM education—integration—makes it possible to modernize the methodological principles, content and volume of educational material in the subjects of the natural and mathematical cycle, technologize the learning process and form the educational competencies of students. student. qualitatively new level. An important aspect in the implementation of STEM education is the use of modern digital resources. The digitalization of education leads to the emergence of new teaching tools: Multimedia projectors, digital science laboratories, measuring complexes, mobile devices (smartphones, tablets, iPads), blogs, wikis, social networks, cloud services, virtual and augmented systems, augmented reality devices and artificial intelligence. And the task of scientists is to provide methodological recommendations to teachers on the use of various digital applications in mastering subject competencies.

3. Literature reviews

In 2020, the Concept of Science and Mathematics (STEM) Education was approved in Ukraine [10]. The development of the Concept was an important step towards the modernization of education to meet society's demands for science-intensive education and the formation of competencies relevant to the labour market.

Over the past five years, Ukrainian scientists have conducted a number of studies that define the essence of STEM education, namely: Researcher Valeriy Bykov [11] developed the process of forming a STEM educational environment. Natalia Morse [12] explained the formation of key and subject competencies of students using robotic STEM education tools. Vasylashko et al. [13] developed methodological recommendations for the development of STEM education in general secondary and extracurricular education institutions. Polikhun et al. [14] created methodological recommendations for the implementation of STEM education in the context of integrating formal and informal education of gifted students. Sipyi [15] considers STEM as modern polytechnic education. Nazarenko [16] deals with the integration of natural sciences on the basis of STEM education through the introduction of elective courses. Scientist Honcharova [17] proposes to include elements of STEM education in the training of future teachers.

Scientists of the National Academy of Pedagogical Sciences of Ukraine [18] conduct various studies on the transformation of education for the STEM era. Their research aims to ensure the implementation of STEM education through the development of curricula for courses with a selection of appropriate integrated content, which are focused on the formation of the necessary competencies for further professional activity, since the definition of a specialist is of particular importance.

In particular, the program of training, retraining and advanced training of a teacher who teaches a certain subject is proposed to include the following issues: General concepts of STEM education, application of STEM education elements in teaching students, creation of other STEM projects, use of STEM technologies, etc. Issues of professional training of future teachers of natural sciences are closely related to issues of postgraduate education and advanced training. Scientists of the Department of Teaching Natural Sciences of the Institute of Pedagogy of the National Academy of Sciences of Ukraine have repeatedly participated in conducting field classes at advanced training courses, web conferences, training seminars dedicated to improving the skills of teachers of natural sciences in the context of implementing the Concept of STEM education and an integrative approach in school natural sciences, as was repeatedly noted on the department's Facebook page [19]. Data analysis shows that teacher training should be aimed at mastering integrative forms and methods of teaching, digital technologies, the task of which is the formation of integrated natural knowledge in the field of natural sciences, engineering and technology.

As we can see, there is a sufficient scientific and practical-methodological basis for the implementation of STEM education in educational institutions of Ukraine.

4. Research methodology

The study that we conducted in Kyiv schools using theoretical and empirical research methods: Synthesis and analysis, aimed to demonstrate a comparative analysis of STEM teaching categories with augmented reality using digital resources and traditional educational approaches without using the specified categories in teaching.

When conducting pedagogical research through the method of observing the educational process of elective courses through quantitative analysis and surveys, we made certain conclusions regarding the level of knowledge of students, who were divided into groups: Those who studied elective courses of integrated content and those who did not attend these classes.

As a result of the analysis, it turned out that students who attended elective courses with an integrated component demonstrated high results in geographical competence, unlike those who did not study elective courses with integrated content.

A special form of cross-curricular STEM education is integrated classes, which are aimed at establishing interdisciplinary connections that contribute to the formation of a holistic, systemic worldview in students, and the actualization of personal attitudes to issues considered in the lessons. Integrated classes can be conducted in two ways: By combining similar subjects through integrated approaches, or by forming integrated courses of a subject nature, where there is no link to the subject, working towards career guidance work for the student's choice of a future profession.

In general, secondary education institutions of Ukraine, an event such as STEM education week has been launched. The goal of the week is to develop and offer accessible educational solutions that would help teachers' interest and immerse students in the world of science and technology, give impetus to the development of their own potential, motivate teachers and continue to experiment with educational tools, looking for interesting opportunities to learn about the world. The results of the "STEM week" indicate an increased interest of students in science. Participants proposed educational models that can be used in lessons, during breaks, and after-school hours to make the format of subject weeks interesting. In addition, courses in various formats help in the implementation of STEM education

Through integrated elective courses in STEM education, students begin to think globally without being tied to a subject and thus form an idea of intersubjectivity and suprasubjectivity, which ensures complex thinking, including about the geographical picture of the world. Elective courses provide motivation, interest in studying geography, will contribute to the formation of appropriate value orientations, as well as the ability to apply geographical knowledge and skills in real-life situations.

Design and research activities contribute to the formation of social competencies, allow you to go through the technological algorithm from the emergence of an innovative idea to creating a commercial product—a start-up, and also learn how to present it to potential investors.

5. Results

The analysis of observations of the educational process in schools in Kyiv (Ukraine) showed that in the process of studying natural sciences, including geography, not enough time is allocated to tasks that encourage students to use the studied theoretical material, that is, to apply the knowledge gained. These factors cause a rapid loss of interest in learning, interfere with the process of full and effective assimilation of knowledge. In order to change this situation, it is necessary to strengthen the practical orientation of learning; increase the share of creative forms of work by reducing reproductive activity; improve the system of monitoring students' academic achievements through the systematic use of tests (educational, for self-control and control); increase the number of tasks to test various types of activities, tasks that test the use of surrounding natural phenomena in their explanation, and also organize students' research activities in STEM areas.

Since digital resources are involved in STEM learning, we conducted a survey among all participants about what and how different digital devices are used in the learning process and what their benefits are.

Using the pedagogical experiment shown in **Figure 1**, a study was conducted on the topic: Using digital resources in STEM-learning of elective courses. 4750 11th grade students and 923 teachers participated in the study.

Scheme 1.

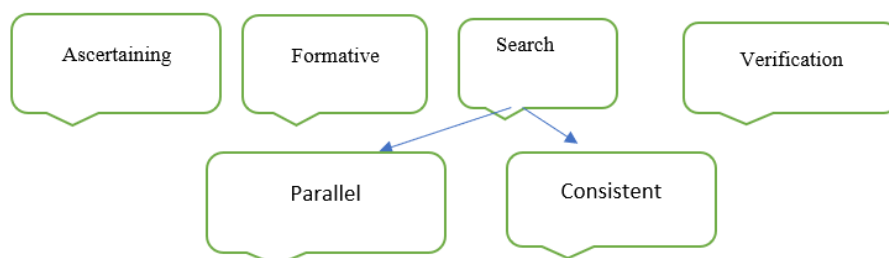


Figure 1. Type of pedagogical experiment [11].

How do you use digital resources in the learning process? Indicator 100%. The indicator is calculated for 100% of the learning time.

Teachers' answers:

Constant access to the Internet 73.80%.

Virtual/augmented reality 32.50%.

Interactivity and speed of information retrieval 56.30%.

QR code reading 42.50%.

Digital laboratories (sensors, pedometers, blood sugar, calculator, blood pressure, etc.) 26.30%.

Organizer (schedule storage, notes, reminders) 50%.

Students' answers:

Constant access to the Internet 83.80%.

Virtual/augmented reality 52.50%.

Interactivity and speed of information retrieval 76.30%.

QR code reading 82.50%.

Digital laboratories (sensors, pedometers, blood sugar, calculator, blood pressure, etc.) 56.30%.

Organizer (schedule storage, notes, reminders) 50%.

Almost half of the surveyed teachers (48.8%) indicated that they use augmented reality applications in the educational process (we showed this indicator using **Figure 2**).

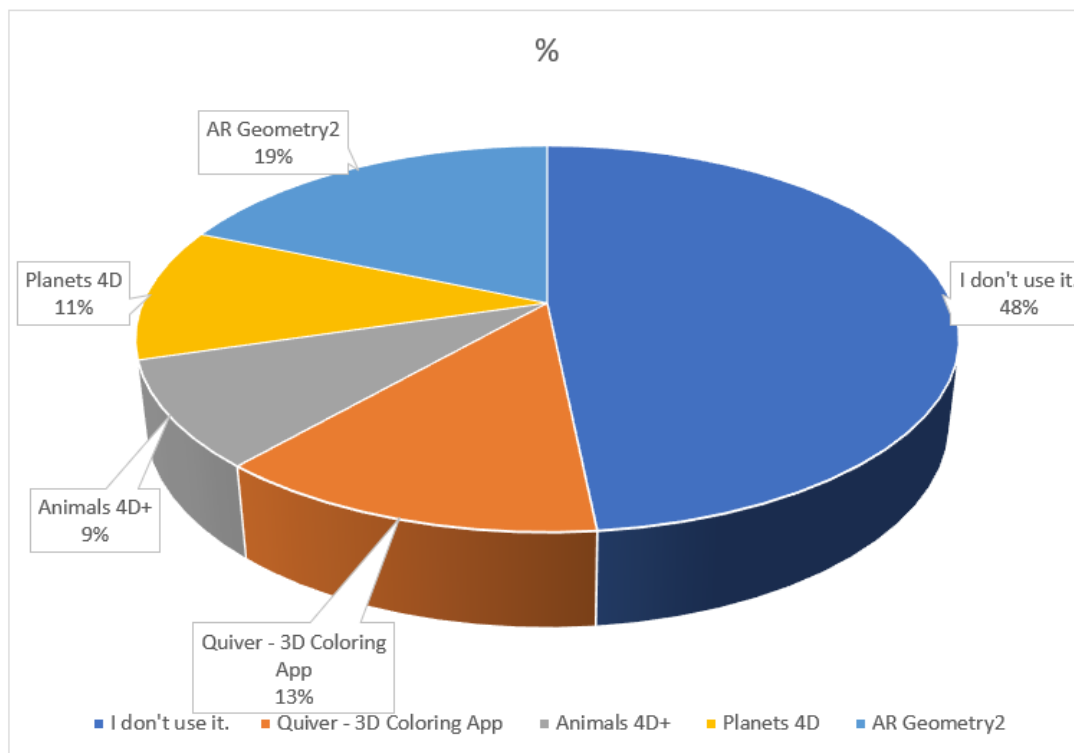


Figure 2. Using augmented reality applications in the educational process.

Ukrainian scientists-developers have also become interested in using augmented reality technology in the educational process, and today, thanks to their developments, domestic applications can be used in student education, such as “LiCo.SolarSystem”, “LiCo.Organic”, (Vasyl Stefanyk Precarpathian National University, Ivano-Frankivsk); “AR Skyscrapers”, “AR Electricity”, “AR Crystal”, “AR Bridges”, “Da Vinci Machines AR” (V. N. Karazin Kharkiv National University, Kharkiv), etc.

As a result of the research, we found that elective courses with an integrated component and the involvement of digital resources are more informative, and their content forms subject competence, which subsequently affects the choice of profession, but it is worth noting that some digital applications, especially virtual/augmented reality technologies, have different effects on the physiological and psychological state of adolescents, and this effect is still quite unstudied and requires our further scientific research.

6. Discussion

One of the components of the Concept of the New Ukrainian School [20] is the creation of an innovative educational environment, a STEM space, which contributes

to the organization of various forms of work of educators, the development of students' sustainable interest in STEM professions, the need for knowledge and professional self-determination of young people. Important components for the formation of a STEM environment are the development of integrated programs for elective courses.

Geography teachers participating in the pedagogical experiment, together with scientists from the Department of Geography and Economics of the Institute of Pedagogy of the National Academy of Sciences of Ukraine, enrich their methodological arsenal by actively implementing research and augmented reality technologies. The development of science and mathematics education (STEM education) according to the Concept [10] involves, first of all, the practical application of scientific, mathematical and technical knowledge to solve practical problems. The expected result for students is critical thinking, creativity, digital literacy and communication skills. Therefore, the use of geography workbooks from the "I am a researcher" series of the Educational Service "Education" [21] provides an opportunity to consider, discuss and solve real geographical problems with students. At the same time, the tasks can be applied both holistically to the entire research topic and fragmentarily, without reference to it. There are enough research topics in the curricula.

Unfortunately, the pandemic and military operations in Ukraine have suspended the active implementation of STEM education in educational institutions, but despite this, work in this direction continues. In the Department of Geography and Economics of the Institute of Pedagogy of the National Academy of Sciences of Ukraine, headed by the author of the article, there was a researcher Natalia Honcharova, who was engaged in studying the implementation of STEM technologies in the educational process. Unfortunately, with the beginning of hostilities, she was evacuated from Ukraine. The people who participated in this project remained in the occupied territories and there is no contact with them; others were captured, some died or went missing, so today this direction in the department is suspended. We hope that politicians will come to an agreement, peace will reign in Ukraine and we will be able to fully continue the relevant research.

7. Conclusion

For Ukraine, the development of STEM education, which is supported and implemented through all types of education: Formal, non-formal, informal—based on online platforms, media products, STEM centres/laboratories, virtual STEM centres, through non-standard methodological STEM technologies: Excursions, quests, contests/competitions, festivals, hackathons, master classes, etc. For the effective development of STEM educational areas, the primary task is: Development of scientific and methodological support and special teaching aids; training and advanced training of scientific and pedagogical workers; expansion of the network of regional STEM centres/laboratories; creation of an information base for the development of STEM education in Ukraine using IT technologies, etc. This is the creative activity that we will engage in scientifically and it is in this that the applied nature of the research will manifest itself.

Conflict of interest: The author declares no conflict of interest.

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