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Didactic Opportunities for Developing Students' Algorithmic Culture and Educational Competencies Based on Steam Technologies

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Abstract: This article examines the didactic potential of STEAM (Science, Technology, Engineering, Arts, and Mathematics) technologies in developing students' algorithmic culture and educational competencies from a scientific and pedagogical perspective. The relevance of the study is determined by the growing need to foster algorithmic thinking, problem-solving skills, critical and logical reasoning, and digital literacy in the context of educational digitalization. The research explores the integration of mathematics and geometry through the STEAM approach to enhance students' algorithmic activities, creativity, collaboration skills, responsibility, communication, and reflective abilities. Based on theoretical analysis, pedagogical observation, and comparative methods, the findings demonstrate that STEAM technologies serve as an effective tool not only for developing algorithmic culture but also for fostering students' educational and value-oriented competencies. Furthermore, linking algorithmic activities with real-life problems was found to increase students' learning motivation, interest in academic subjects, and engagement in independent learning processes.

Keywords: STEAM education, algorithmic culture, educational competencies, mathematics education, geometry, digital literacy, algorithmic thinking, integration, creativity, reflection.

Introduction: In the 21st century, the rapid development of the digital economy, artificial intelligence, robotics, and information and communication technologies poses new challenges to the education system [1; 4]. Today, students are required not only to possess knowledge in specific subjects but also to have competencies in analyzing complex problems, algorithmic thinking, decision-making based on critical and creative approaches, working with information, and effectively using modern technologies [3]. Therefore, the issue of developing algorithmic culture is recognized as one of the priority directions in the world's education systems [3; 4].

The results of international assessment programs, including PISA, TIMSS, and ICILS studies, indicate the need to develop students' mathematical literacy, problem-solving abilities, and digital competencies [4]. These requirements necessitate updating the content of education, strengthening interdisciplinary integration, and developing students' competencies oriented toward practical activities [5]. In particular, developing algorithmic thinking in the teaching of mathematics and geometry plays an important role in forming students' logical reasoning, analytical approach, and independent decision-making skills [3].

At the same time, the main goal of modern education is not limited to imparting knowledge but also involves educating a comprehensively developed, socially active, and responsible individual [5]. Developing educational competencies such as responsibility, collaboration, communication, initiative, reflection, and creativity in students is one of the urgent pedagogical issues of today [6]. This is because the labor market and societal needs demand specialists who can independently organize their activities, work effectively in teams, and promote innovative ideas [1].

In solving these problems, the STEAM (Science, Technology, Engineering, Arts, Mathematics) educational approach holds particular importance [2]. STEAM technologies ensure interdisciplinary integration, connect students' theoretical knowledge with practical activities, and create opportunities for applying knowledge and skills in solving real-life problems [1; 2]. This approach not only develops students' algorithmic culture but also shapes their creative thinking, engineering approach, communication skills, and social activity [2].

The relevance of the study lies in the fact that methodological approaches aimed at developing algorithmic culture in general education schools have not been sufficiently developed, and the opportunities of STEAM technologies in forming educational competencies have not been fully explored [2; 6]. Therefore, identifying the didactic opportunities and providing scientific-methodological justification for the development of students' algorithmic culture and educational competencies through the use of STEAM technologies in mathematics and geometry education holds significant scientific and practical importance.

LITERATURE REVIEW AND METHODOLOGY

Algorithmic culture is interpreted as a set of knowledge, skills, and competencies related to students' ability to create, analyze, and apply algorithms in practice [3]. In international research, J. Wing recognized algorithmic thinking as one of the important competencies of the 21st century [3], and local scholars have also paid special attention to this issue. In particular, N.A. Muslimov emphasizes the need to develop students' independent thinking and problem-solving skills based on a competency-based approach in the educational process [6]. O. Tolipov and M. Usmonboyeva scientifically substantiated that innovative pedagogical technologies can activate students' creative and logical thinking activities [8]. R.J. Ishmuhamedov demonstrated the importance of modern educational technologies in forming competencies oriented toward practical activity in students [7].

Scientific studies on the STEAM approach have noted that interdisciplinary integration develops students' creative thinking, critical analysis, and teamwork skills [1; 2]. Innovative educational ideas proposed by local researchers are also consistent with the main principles of STEAM education [6; 7]. In particular, interdisciplinary integration, practical activity-oriented education, and a competency-based approach are considered important pedagogical conditions for developing students' algorithmic culture [6; 8].

The uniqueness of this study is that it applies competency-based and innovative approaches proposed by local scholars in an integrated manner with STEAM technologies to mathematics and geometry education [2; 6]. In the study, algorithmic culture is interpreted not only as the skill of creating algorithms but also as a factor that develops students' educational competencies such as responsibility, collaboration, independence, and reflective activity [6; 8]. In this regard, the study enriches the scientific views of local scholars in practical terms and contributes to their development within the context of STEAM education.

The study employed methods of theoretical analysis, pedagogical observation, comparison, and generalization. Additionally, the effectiveness of lessons organized based on STEAM elements in mathematics and geometry subjects was examined [2; 7].

RESULTS

During the study, practical tasks, problem situations, and project activities were organized aimed at integrating the content of mathematics and geometry subjects based on STEAM technologies [2]. Throughout the experimental work, students' learning activities were regularly observed, and their algorithmic thinking, problem-solving strategies, and collaborative activities were analyzed. The observation results showed that in lessons organized based on the STEAM

approach, students demonstrated higher activity compared to traditional lessons. In particular, they strived to propose various options for solving given problems, analyze the causes and consequences of problems, and defend their ideas with evidence. This indicates an increase in students' interest in learning and intrinsic motivation [4].

The research results showed a significant development in students' knowledge, skills, and competencies regarding creating algorithms, modeling algorithmic processes, and applying them in practical situations [3]. During the lessons, students successfully implemented algorithmic activity elements such as breaking down complex problems into smaller steps, selecting appropriate solutions for each step, and analyzing the results. Especially in modeling tasks related to geometry, students not only studied the properties of geometric shapes but also had the opportunity to connect them with real objects and apply them in practical projects. As a result, logical reasoning, systematic approach, and critical analysis competencies were formed in them [5].

During the experiment, the importance of group activities in developing students' social and communicative competencies was also identified. While working in small groups, students acquired skills in exchanging ideas, distributing tasks, jointly solving problems, and achieving common results [6]. Such activities contributed to the formation of teamwork culture, mutual respect, and a sense of responsibility in them. At the same time, skills in listening to the opinions expressed by group members and responding constructively to them were also developed.

The research results confirmed the opportunities of STEAM technologies in developing educational competencies. In particular, qualities such as completing tasks on time, planning one's own activities, evaluating results, and striving to eliminate shortcomings were formed in students [8]. During the lessons, students learned to approach their activities critically, conduct reflection on the work performed, and draw conclusions for improving their future activities. This had a positive impact on the development of independence, responsibility, and self-development competencies in them.

Furthermore, STEAM projects created a favorable pedagogical environment for students to demonstrate their creative potential. During project activities, students strived to propose new ideas, seek non-standard solutions, and apply existing knowledge in new situations [7]. The integration of mathematical and geometric knowledge with technology and engineering elements increased students' interest in subjects and contributed to the formation of their professional orientations.

Within the framework of STEAM projects, students created various constructions and models using geometric shapes, solved simple engineering problems, and presented their developments using digital tools [1; 2]. For example, tasks such as preparing models based on geometric figures, designing energy-efficient structure models, and calculating their mathematical parameters allowed students to connect theoretical knowledge with practical activities. As a result, the content of algorithmic activity deepened further, and students actively participated in processes of mathematical modeling, analysis, and result evaluation.

In general, the research results showed that the use of STEAM technologies is an effective pedagogical tool not only for developing students' algorithmic culture but also for forming their educational, communicative, and social competencies. The obtained results confirm that the application of the STEAM approach in mathematics and geometry education serves to develop not only students' knowledge levels but also their personal qualities and life competencies [2; 3; 6].

DISCUSSION

The research results showed that the use of STEAM technologies is an effective tool for developing students' algorithmic culture [2; 3]. In particular, practical and project-based activities increased students' interest in lessons and motivated them toward independent inquiry. Students made more efforts to analyze problems and find solutions themselves rather than passively accepting ready-made knowledge.

In addition, the STEAM approach had a positive impact not only on the development of knowledge and skills but also on the educational aspect [6; 8]. In group work, students gained experience in listening to each other, showing respect for opinions, sharing responsibility,

and working collaboratively. As a result, important competencies such as communication, responsibility, and teamwork were formed in them.

In general, integrating STEAM technologies into mathematics and geometry education serves to connect students' theoretical knowledge with practical activities, develop their algorithmic thinking, and form the competencies necessary for their future professional activities [1; 2].

Scientific Novelty

The scientific novelty of the study is determined by the development of a didactic model for the development of students' algorithmic culture and educational competencies based on the integration of STEAM technologies with mathematics and geometry subjects, in close connection with the digital transformation being implemented in the education system today, the widespread introduction of artificial intelligence technologies, and the need for 21st-century competencies [1; 2; 4]. This model is aimed at forming algorithmic thinking, problem-solving, critical and creative thinking skills in students, as well as developing important educational qualities such as responsibility, collaboration, communication, reflection, and digital culture [3; 6].

The analysis of scientific literature shows that J. Wing's "computational thinking" concept interprets algorithmic thinking as one of the main competencies of modern education and emphasizes that algorithmic thinking should be integrated not only into the informatics subject but also into the process of studying all subjects. From this perspective, in this study, algorithmic culture was harmonized with the content of mathematics and geometry subjects, and mechanisms for directing students' theoretical knowledge toward practical activities were developed. According to M. Resnick's creative education theory, students independently create knowledge and form new ideas through project activities; therefore, organizing algorithmic activities through STEAM projects in the study was scientifically justified as serving the development of students' creativity and innovative thinking abilities. Relying on S. Papert's constructionism theory, which considers students' personal experience and practical activity as important factors in the active creation of knowledge, the process of developing algorithmic culture in the study was interpreted not only as forming technical skills but also in connection with the development of students' social and moral qualities. As a result, the educational opportunities of algorithmic activity were identified, and its role in forming responsibility, discipline, teamwork, mutual respect, and decision-making culture in students was revealed.

Another important novelty of the study is that the structural components of algorithmic culture — motivational, cognitive, practical-activity, and reflective components — were systematized, and a model of their mutual integration with educational competencies was developed. On this basis, criteria and indicators for assessing students' algorithmic culture were proposed. In particular, indicators such as the ability to create and apply algorithms, analyze problem situations, participate in collective activities, evaluate and improve one's own activities were defined as the main criteria. Furthermore, the interrelationship between algorithmic activity and educational competencies was pedagogically justified from the perspective of modern education requirements and the competency-based approach, and effective mechanisms for their complex development in a STEAM environment were proposed. The research results showed that aligning the process of developing algorithmic culture with educational goals ensures not only students' academic achievements but also their personal and social development. In this regard, this study holds scientific and practical importance as it enriches the theory and methodology of STEAM education and proposes new pedagogical approaches to forming algorithmic culture in general education schools.

CONCLUSION AND RECOMMENDATIONS

The research results showed that the educational process organized on the basis of STEAM technologies is an effective didactic tool for developing students' algorithmic culture [2]. This approach forms important competencies in students such as algorithmic thinking, problem analysis, modeling, decision-making, and result evaluation by integrating the content of mathematics and geometry subjects with practical activities [3]. At the same time, in a STEAM environment based on project and research activities, students' educational competencies such as

collaboration, sense of responsibility, communicative activity, reflection, and creativity develop consistently [6; 8].

It was determined during the study that the development of algorithmic culture not only improves students' level of mathematical preparation but also strengthens their digital literacy, critical and systematic thinking abilities [3; 4]. The STEAM approach, while ensuring interdisciplinary integration, creates opportunities to connect theoretical knowledge with real-life situations, which significantly increases students' learning motivation and interest in knowledge [1; 2]. As a result, students gain the opportunity to acquire the foundational and professional competencies necessary for successful activity in a modern information society.

The scientific significance of the study lies in the fact that it provides theoretical and practical justification for the pedagogical opportunities of a STEAM-based didactic approach that serves the interconnected development of algorithmic culture and educational competencies. The obtained results can serve as an important scientific-methodological basis for improving the methodology of teaching mathematics and geometry in general education schools, as well as for introducing educational technologies aimed at forming 21st-century competencies [6; 7].

The results of this study correspond to the tasks defined in the Law of the Republic of Uzbekistan "On Education" adopted on September 23, 2020, regarding the continuity of education, innovative development, and the introduction of modern pedagogical technologies [5]. They also align with the Development Strategy of New Uzbekistan for 2022–2026 and decisions aimed at digitalizing the education system and developing it based on international standards. In particular, the President's initiatives to improve the quality of education, form modern competencies in students, and widely introduce digital technologies into the educational process further enhance the practical significance of this study. Therefore, integrating STEAM technologies into mathematics and geometry education serves as an effective tool for developing students' algorithmic culture, creative thinking, and educational competencies.

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