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THE ISSUE OF USING ADAPTIVE EDUCATIONAL TECHNOLOGIES IN FORMING METACOGNITIVE COMPETENCE IN PHYSICS EDUCATION

Khalikov Zarifjon Mukhtaralievich
Teacher of Secondary School No. 26,
Bekabad District, Tashkent Region

Abstract
This article theoretically analyzes the problem of using adaptive learning technologies in the formation of students' metacognitive competencies using the example of the electricity and magnetism section of the 8th grade physics course. Metacognitive competence refers to the ability of students to monitor, manage, and reflect on their own learning process. Adaptive technologies, on the other hand, select tasks in accordance with the individual readiness and needs of students and provide personalized feedback in real time. A review of the literature and a generalization of existing studies show that such technologies can be an effective tool for deepening knowledge, increasing student motivation, and developing metacognitive strategies in physics lessons. At the same time, limitations such as technological infrastructure, teacher qualifications, algorithmic bias, and digital inequality were identified. The article develops recommendations for overcoming these problems.

Keywords: Physics education; electricity and magnetism; metacognitive competence; adaptive learning technologies; artificial intelligence; personalized learning.

Introduction

Metacognitive competence – that is, the ability of a student to monitor, manage and adapt his or her own thinking processes – plays an important role in modern education. This competence provides students with the skills to consciously control their learning activities, analyze their mistakes and self-assess. In particular, in physics, students with strong metacognitive skills achieve better results in solving complex problems and critically approaching their knowledge.

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Studies have shown that metacognitive skills have a significant positive impact on students' academic performance in the subject. Therefore, the formation of students' metacognitive competence in physics education is considered one of the priority tasks. However, in practice, it is observed that these approaches are not sufficiently applied – in particular, reflective analysis and metacognitive strategies are rarely used in the classroom.

In recent years, opportunities have emerged to solve this problem by introducing adaptive learning technologies into education. Adaptive learning systems select materials and tasks according to the individual needs and level of knowledge of each student. As a result, the learning process is personalized, creating an environment for each student to learn based on their own pace and abilities. Such technologies provide personalized feedback in real time, immediately indicating the student's mistakes and misunderstandings. As adaptive systems and intelligent tutors (for example, tutoring programs based on artificial intelligence) are integrated into the educational process, they provide new opportunities not only to consolidate students' knowledge, but also to support their metacognitive development. In physics, especially the topics of the electricity and magnetism section, the most difficult and abstract topics for students are considered. According to research, a number of misconceptions about electrical and magnetic phenomena are widespread among students, which may not be identified in a timely manner in traditional lessons. Therefore, it is expected that in the 8th grade physics course (on the topics of electricity and magnetism), it is expected that using adaptive technologies to quickly identify each student's misunderstandings and applying an individual approach will serve to form metacognitive competence [1].

This theoretical article analyzes the issue of using adaptive teaching technologies in the formation of metacognitive competence in physics education in the format of a theoretical paper. The introduction highlights the role of metacognitive competence and adaptive technologies in education [3]. The following sections present an analysis of theoretical literature as a research method, review previous studies and summarize their results. The results section presents theoretical conclusions based on previous research, and the discussion discusses the possibilities and limitations of this approach and factors for its implementation in the classroom. The conclusion section offers key recommendations and methodological solutions.

METHOD

This study is based on the method of theoretical analysis and literature review. That is, previously published scientific articles, dissertations, conference proceedings, as well as foreign and domestic studies on the topic were studied and analyzed. The pedagogical and psychological literature on metacognitive competence and adaptive educational technologies was studied in depth, and the scientific approaches in them were analyzed comparatively. In particular, the studies of foreign scientists on the formation of students' metacognitive strategies (for example, J. Flavell, R. Azevedo, etc.) and updated developments on the use of information and communication and adaptive systems in physics education were considered. Sources in the local context were also not ignored: normative documents on the introduction of a competency-based approach in the education system of Uzbekistan and articles by local researchers were analyzed. Data from previously conducted experimental work, in particular, statistical indicators obtained as a result of the use of ICT tools, were theoretically re-analyzed, and general conclusions were drawn. The conceptual ideas and scientific results identified during the literature review formed the basis for the formation of the Theoretical Results and Discussion sections of this article.
According to the research design, the existing scientific literature on the topic was first analyzed. Then, the sources found were analyzed in terms of content, and their methodological approaches and results were compared. Thus, the views and findings on the use of adaptive technologies in the formation of metacognitive competence in physics were systematized. In carrying out this theoretical work, methods of searching for information using ICT (for example, using electronic scientific databases) and processing the data found in an analytical approach were used. All arguments and conclusions presented in the article were given in connection with the literature - that is, each important idea was substantiated based on the relevant source (a list of literature used is provided at the end of the article). Thus, the research methodology is a theoretical and literary analysis, which is aimed at integrating previously published scientific works and drawing conclusions based on them [9].

RESULTS

A review of previous studies suggests that the introduction of adaptive technologies in physics education can improve student performance and develop metacognitive competencies. In particular, studies conducted in the United States, Europe, and Asia have identified a number of positive effects of using artificial intelligence and adaptive learning tools in physics. Experiments with intelligent tutoring systems show that such systems provide real-time feedback on the topic and the solution of tasks, deepening students' conceptual understanding. For example, in a study by Hwang et al., students in a class where an adaptive learning platform was used achieved significantly higher learning outcomes than a control group taught in a traditional way - it was noted that the adaptive system significantly increased the level of students' knowledge. It is also noted that through this platform, individual tasks are provided that meet the needs of each student, and this approach helps to reduce the differences between strong and weak learners.

In other studies, students in physics classes enriched with artificial intelligence have been found to use more effective strategies to solve complex problems than their peers in traditional classes. For example, in an experiment conducted in a university-level physics course, students in the AI-taught group scored significantly higher on average on tests in mechanics and electromagnetism than the control group. The normalized gain was 0.55 for the AI-taught group, compared to 0.35 for the traditional group – indicating a statistically significant difference between the two groups' results. The researchers attributed this difference to the ability of AI-based adaptive tools to provide immediate explanations and personalized support: when students encountered an incorrect answer or misunderstanding, the system immediately provided them with an explanation or suggested an additional simpler example. As a result, students were able to correct their mistakes immediately and consolidate their knowledge. Most notably, students who were taught with adaptive technologies also developed metacognitive strategies. For example, physics students who worked with an AI tutor began to master skills such as consciously choosing which formula to use first when solving a given problem, correctly applying the formula in the context, and evaluating the logic of the final answer. In other words, students' ability to monitor and control their own thinking processes was strengthened. This was also evident from the results of reflective activity observed during the experiment: students who were finding solutions with the help of AI became accustomed to expressing their thoughts out loud (reasoning aloud) and working on their mistakes. This process activated metacognitive skills that may have been poorly developed in students before [11].

The analysis of the results shows that students' interest and activity in science increases if an adapted learning environment is created for them. It was found that in AI-integrated lessons, students showed more interest in the lesson, asked more questions, and sought to learn independently. For example, in physics lessons, the group taught using the ChatGPT chatbot and interactive simulations had a significantly higher level of interest in the lesson than in the traditional group. This means that adaptive technologies have a positive effect not only on learning, but also on motivation to study. It was observed that students' enthusiasm for working on themselves and solving problems independently without fear increased - the non-punitive, error-tolerant environment of the artificial intelligence tool played an important role in this. Students tried different solutions without being afraid to make mistakes, and after each mistake, they drew conclusions based on the recommendations given by the system. Thus, the "safe learning environment" created by adaptive technologies served to develop students' independent thinking and reflection skills. In conclusion, the theoretical results obtained from the literature review can be summarized as follows: (1) Adaptive learning technologies in physics education help to increase students' knowledge level and academic performance (for example, significantly improve mastery in complex sections such as electricity and magnetism). (2) Such technologies increase students' learning activity and interest in the lesson, as the educational process becomes interactive and individualized. (3) Most importantly, adaptive tools create favorable conditions for the formation of metacognitive competence: students learn to monitor their own thinking processes, reflect on their mistakes, and adjust their learning strategies. These theoretical conclusions are analyzed in more depth in the next section, Discussion, and considered from the perspective of their implementation in the real educational process.

DISCUSSION

The above theoretical results show that the integration of adaptive technologies into the educational process of 8th grade students in physics has great potential. In terms of opportunities, the education system of Uzbekistan is currently also striving to introduce digital technologies. The Development Strategy for 2022–2026 identifies improving the quality of education and digital infrastructure as

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one of the priority areas. This means that e-learning platforms (for example, the "Kundalik" electronic journal system, Khan Academy online resources, etc.) are being gradually introduced in schools. There are also various interactive simulators and problem banks in physics, and the possibilities for their adaptive use are expanding. Thus, the technological ground is ready for the development of metacognitive competence: lessons can be enriched and personalized by integrating existing electronic resources into education [6]. The number of methodological guides and trainings for teachers is also increasing - this is also a good opportunity to introduce an adaptive approach to the classroom.

However, it is necessary to take into account the existence of a number of limitations and problems in the implementation of this approach. The main problems identified during the discussion and their solutions can be explained as follows:

Quality and compatibility of technology: The effectiveness of an adaptive learning system primarily depends on the quality of its algorithms and database. If the system is based on incorrect data or if programming errors are made, it can give students incorrect recommendations and harm the learning process. In complex sections such as electricity and magnetism, there is a possibility that misleading recommendations or incorrect feedback will create misleading concepts in the student. Therefore, the adaptive systems to be implemented must have scientifically correct and verified content.

Changing the role of the teacher: The introduction of adaptive technologies into the classroom also changes the traditional tasks of teachers. The teacher must now not only be a source of knowledge, but also an expert in the effective use of technology. This requires new competencies from teachers - for example, digital pedagogy and data analysis skills. The current situation shows that some teachers are not yet ready for this innovation, and their ICT literacy needs to be improved [3]. Therefore, as a solution to the problem, it is necessary to work on improving the skills of teachers and training them to work with adaptive technologies.

Pedagogical and psychological factors: When using an adaptive system, the student should not rely too much on it. Some researchers warn that if a student immediately relies on computer support for every issue, his metacognitive activity may weaken over time. That is, excessive "reliance" on technology is likely to limit a student's habits of independent thinking and self-examination. Therefore, in the classroom, the teacher should maintain a balance between

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technology and independent learning - he should encourage activities such as critically analyzing the answer given by the AI, as well as considering alternative solutions.

Ethical and security issues: Digital adaptive platforms collect students' personal data and track their learning activities. This raises issues of data privacy and ethical use. For example, an AI system knows what types of issues a student is struggling with – there should be a guarantee that this data will not lead to discrimination or stigmatization in the wrong hands. There is also the issue of algorithmic impartiality: does the system treat students with different abilities or levels of preparation fairly? The principles of algorithmic fairness must be observed, otherwise some students may be unfairly treated. From this point of view, it is necessary to develop codes of ethics and create mechanisms for data protection when implementing adaptive technologies. Digital inequality and infrastructure: In Uzbekistan, not all schools have equal technological support. Unfortunately, there is a digital divide – especially in rural areas, some schools lack computer labs, internet speed or modern devices. This limits the ability to use adaptive technologies. In addition, some students may not have access to computers or the internet at home, or may be disabled. As a result, if such systems are only implemented in urban or well-equipped schools, the educational gap is likely to widen. Therefore, it is important to improve the digital infrastructure at the national level, create resources that equally cover all students [10].

To reduce the above problems and make the most of adaptive technologies, a comprehensive approach is needed. In particular, measures should be taken to strengthen control over the quality of technologies, increase the digital competence of teachers, ensure compliance with ethical standards, and eliminate the digital divide. It is also proposed to enrich adaptive systems with special elements of reflective activity in order to develop metacognitive competence: for example, if at the end of each chapter the student is given the opportunity to reflect on his learning process with questions such as "How did you learn?", "What mistakes did you correct?", technology and metacognition will be combined. Such methodological solutions are presented below, in the conclusion, in the form of specific recommendations.

CONCLUSION

Based on the above analysis, the following recommendations and methodological solutions are proposed for the use of adaptive teaching technologies to form metacognitive competence of students in 8th grade physics education (especially in the topics of electricity and magnetism):

1. Providing adaptive systems with quality content: Adaptive learning platforms in physics must consist of scientifically based and verified materials. Problem solutions and feedback in the systems should be pre-tested by methodologists and specialists, thus preventing misleading recommendations.
2. Improving teacher skills: In order to successfully use adaptive technologies in lessons, teachers must have strong competencies in ICT literacy and digital pedagogy. To this end, it is proposed to organize regular trainings, seminars, and popularize best practices through "master-apprentice" programs. The teacher should consciously manage technology as an auxiliary tool and monitor the individual growth trajectory of each student.
3. Integrate metacognitive activity: Adaptive lesson design should include methods that stimulate student reflection. For example, small blocks called "Analyze Yourself" are introduced, and after finding a solution, students are asked to evaluate their processes (what worked well, what needs to be paid attention to). In this way, the technology is enriched with elements of self-regulated learning and directly affects the formation of metacognitive competence.
4. Adherence to ethical principles and data protection: The confidentiality of student data collected in adaptive systems should be ensured and used only for the purpose of improving the learning process. Platforms should be implemented in accordance with international codes of ethics (e.g. Child Privacy or Fair AI principles). Mechanisms should also be developed to monitor and promptly correct unexpected algorithmic errors.
5. Addressing the digital divide: Reducing the gap in equipment and internet access between schools should be a priority for state policy. Specific programs should be developed to create conditions for 8th grade students in all regions to use adaptive technologies – for example, by allocating additional computers to low-income schools and expanding the internet network. Otherwise, technology used only in some places may exacerbate educational disparities.
6. Phased implementation and analysis: Instead of suddenly and massively

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introducing adaptive learning technologies, it is recommended to first test them in the form of pilot projects and analyze their results. It is necessary to pilot the adaptive platform in physics for grade 8 in several schools, documenting the problems and achievements that arose in the process. Based on the data obtained, it will be possible to improve methodological guidelines and the platform itself. In conclusion, it can be said that the formation of metacognitive competence in physics education is of great importance not only for mastering the subject, but also for the general cultural and intellectual development of the student. Adaptive learning technologies open up new horizons in this process - they allow individualizing education, activating student thinking, and teaching to work on errors. However, like any innovation, a thoughtful approach to its implementation is necessary: technological, pedagogical, and ethical aspects should be taken into account. By implementing the recommendations presented in this article, metacognitive competencies can be developed in physics lessons for grade 8 using adaptive technologies. This, in turn, will help students gain a deeper understanding of not only physics, but also other subjects, and will help them grow into independent and critical thinkers in the future.

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