Adaptive Learning in Improving Students' Physics Education

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Abstract.
Despite the numerous studies carried out in the context of the problem field of adaptive learning processes, the effectiveness of their practical realization remains debatable until now. The hypothesis of the study is the assumption of integrative effectiveness of combining adaptive learning strategy with available didactic technologies, each of which demonstrates a sustainable positive result in learning.

The aim of the study is theoretical substantiation and experimental verification of the effectiveness of didactic technologies in the formation of students' subcompetences in physics classes in the implementation of disciplinary courses on adaptive platforms of universities in Azerbaijan. The experience of university teachers in the use of adaptive learning tools, the level of teaching, knowledge assimilation and students' involvement were taken into account when assessing the effectiveness. The study used a mixed methodological approach of Quant data – Qual data with control and experimental groups. Within the framework of the study, students mastered the topic «Mathematical Modeling».

The results demonstrated the high efficiency of the implementation of adaptive learning in integration with didactic technologies on the results of learning, manifested in the self-improvement of students in mastering the knowledge of the discipline. The practical significance of the study lies in the possible application of our proposed model of implementation of adaptive learning in integration with didactic technologies in the educational process of professional training of physics teachers.

Keywords: Adaptive teaching, Personalized learning, Curriculum Development

Адаптивне навчання в удосконаленні освіти учнів з фізики

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Анотація.
Незважаючи на численні дослідження, проведені в контексті проблемного поля адаптивних процесів навчання, ефективність їх практичної реалізації залишається дискусійною до теперішнього часу. Гіпотеза дослідження полягає в припущенні інтегративної ефективності поєднання адаптивної стратегії навчання з доступними дидактичними технологіями, кожна з яких демонструє стійкий позитивний результат у навчанні.

Метою дослідження є теоретичне обґрунтування та експериментальна перевірка ефективності дидактичних технологій у формуванні субкомпетентностей студентів на заняттях з фізики при виконанні дисциплінарних курсів на адаптивних платформах університетів Азербайджану. При оцінці ефективності було враховано досвід викладачів університету щодо використання адаптивних інструментів навчання, рівень викладання, засвоєння знань та залучення студентів. У дослідженні використовувався змішаний методологічний підхід даних Quant data – Qual data з контрольною та експериментальною групами. В рамках дослідження студенти оволоділи темою «Математичне моделювання».

Отримані результати продемонстрували високу ефективність впровадження адаптивного навчання в інтеграції з дидактичними технологіями за результатами навчання, що проявляється у самовдосконаленні студентів у засвоєнні знань з дисципліни. Практична значущість дослідження полягає в можливому застосуванні запропонованої нами моделі реалізації адаптивного навчання в інтеграції з дидактичними технологіями в освітній процес професійної підготовки вчителів фізики.

Ключові слова: адаптивне викладання, персоналізоване навчання, розробка навчальних програм

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Introduction.

The rapid development of technology in the last decade provides a wide range of pedagogical tools that greatly facilitate the learning process. Adaptive learning has emerged as one of these tools, proposed to improve the learning process. According to P. Moskal et al. (2017), adaptive platforms based on a large body of knowledge offer a non-linear approach to learning and timely adjustments when needed.

They are able to dynamically adjust to learners and their level of preparedness in the learning process, providing content in the right sequence in conjunction with their individual characteristics at a given time to achieve progress in knowledge acquisition. These systems use algorithms, assessments, feedback, adjustments, and a variety of media files to deliver new knowledge to learners who are ready to improve.

However, despite the numerous studies carried out in the context of the problem field of adaptive learning processes, the effectiveness of their practical implementation remains debatable to date.

The aim of the study is theoretical substantiation and experimental verification of the effectiveness of didactic technologies in the formation of students' subcompetences in physics classes when implementing disciplinary courses on adaptive platforms of universities in Azerbaijan.

Analyzing previous studies and publications. One of the pillars of higher professional education is flexibility, capable of providing students with a large number of options in the context of spatial and temporal parameters of knowledge assimilation. Thus, the educational model allows the creation of an ecosystem of educational technologies that provide a personalized approach to students and teachers. This ecosystem of innovative educational technologies can improve the teaching and learning process by providing a personalized experience in mastering the program material. One of the components of this ecosystem is content and learning resources, whose effective realization depends on the technologies used, related to educational platforms and learning resource management tools. It is this condition that requires research to establish a search for technologies that provide personalization of adaptive platforms offered by numerous developers «in the educational marketplace». Some platforms offer adaptive content and do not require or allow editing of such content; others have features to create content and integrate adaptive learning with authored content.

In order to implement the research activity in the context of the formulated goal, most of the technologies that could be used in teaching students' physics with the creation of a personalized path of knowledge assimilation were evaluated. We took into account the following requirements:

Learner Experience. Diagnostic assessment results indicated that the learner should receive feedback and guidance on knowledge content through continuous assessment throughout the personalized learning pathway.

Instructor Experience. Instructors should be provided with the necessary information to monitor student progress and easily adjust the content offered or take corrective action.

Curriculum Development. The functionality should allow for the creation of a map of competencies or course objectives, their interrelationships, requirements, prerequisites, and expected learning.

Adaptability. Recommendations to students on how to choose the best content depending on their academic performance level using some algorithm (e.g. artificial intelligence - hereinafter AI).

Reports and analytics. The platform should independently create reports on students' knowledge needs and their progress in mastering learning material.

Content types. The platform should support multiple formats such as HTML, multimedia (images, audio and video), video games, scripts and links to external sites.

As a preliminary assessment, after analyzing numerous adaptive platforms offered on the educational market, we opted for Realizeit's technologies, as they meet the above requirements to a greater extent:

- Personalized learning pathways;
- artificial intelligence algorithm;
- formative and summative assessments;
- Real-time analytics for students and instructors to track progress in personalized learning trajectories;
- Different types and formats (HTML, multimedia, documents and open resources) are allowed;
- A high level of integration with the learning platform and the educational technology ecosystem, facilitating the transfer of assessments from the platform to the discipline's assessment system.

In the present study, the analysis based on the diagnostic data obtained from the student's interaction with the learning content offered to them and their actions identified their needs, strengths, weaknesses, and potentialities for developing the learning content of the class topics.

The didactic model we are developing using adaptive learning (hereafter referred to as DMAO) integrates actions before and after the lesson, as well as actions that occur during the lesson. The lower part of the model is represented by lower-order cognitive processes according to Bloom's taxonomy (Anderson, 2001), in which actions focus on using an adaptive platform to acquire information through digital resources such as videos, readings, podcasts, viewing designed examples, and performing exercises with automatic feedback.

Having previously studied the content of a particular topic of the academic discipline, the student is able to actively participate in activities that require a higher level of cognitive ability, such as solving problems, performing complex exercises and overcoming difficulties or problem situations.

Speaking about adaptive learning, it is necessary to point out the significance of the personalized approach, the provisions of which constitute an overall educational strategy akin to an «umbrella» that covers simultaneously several approaches and models, including competency-based learning, differentiated learning, etc. (Schmid, & Petko, 2019).

Theoretical analysis of the results of research activities of authors from different countries allowed us to state that personalized learning is a multilevel construct with numerous definitions and forms of implementation. Niknam, M. et al. (2020) argued that society is interested in creating a personalized learning system that adapts pedagogy, curriculum and learning environment for students according to their needs and learning preferences.

The author of the studies defines the term «personalized learning» as an educational approach in which each student's learning is tailored to his/her individual needs, strengths, abilities and interests, giving him/her the flexibility to choose what, when, how and where to learn within the curriculum of the discipline. Various strategies and technologies provide students with a degree of autonomy and choice in learning in this environment.

According to E. Smyrnova-Trybulska et al. (2022), adaptive learning is about adapting the learning process according to the needs, competencies and abilities of the student. Morze N. et al. (2021) indicate that adaptive learning technologies aim to provide students with the means to acquire information according to their learning needs and cognitive differences. Lagubeau G. et al. (2020) argue that such technologies promote active learning, while M. O. González Fernández et al. (2018) indicate that they also promote self-regulation. Students, thanks to the tools offered by adaptive technologies, take control of their learning process, accessing learning resources according to their needs and learning at their own pace.

Liu M. et al. (2017) argue that most educators recognize the benefits of adaptive technology, but evidence-based research is limited. Moskal P. et al. (2017) point out that adaptive technologies can level gaps in understanding of instructional material, guarantee student improvement by avoiding «teaching for the intermediate level» in which advanced or retarded students are not considered. In addition, the use of adaptive technologies makes it easier for teachers to carry out the process of tracking students in order to identify those who need help or accompaniment, thus maximizing learning outcomes.

Kara N. et al. (2020) states that adaptive technologies use algorithms, assessments, feedback, adjustments, and various means to provide new learning materials to students who have reached the desired level or for those who have not. As for teachers, according to Moskal P. et al. (2017), students are provided with additional opportunities to better understand the content of the program material of the discipline, especially the one in which the student has difficulties in mastering. Thus, the role of the instructor changes from content provider to facilitator of learning. However, in order to achieve this effectiveness, instructors must know how to use the systems correctly.

We propose to understand by adaptive learning an educational strategy that uses technologies based on data analytics to adapt education and create a personalized learning trajectory, whose content has been pre-designed by the instructor to be effective for each student, depending on their performance level, profile and learning needs. This allows the instructor to identify gaps in the group's understanding, develop actions for improvement, and adjust their educational practice, optimizing student performance. In addition, adaptive learning can coexist with other technologies, such as:

The flipped classroom. Bergmann J. (2012) indicate that the «flipped» classroom creates a structure that provides students with a personalized learning experience tailored to their needs. Lagubeau G. et al. (2020) indicate that «flipped» learning aims to optimize instructional time through active learning. Van Alten D. C. et al. (2019) say that some studies have shown that the use of «flipped» classroom technology improves learning compared to traditional teaching methods. However, these studies emphasize the importance of thoughtful classroom organization for success.

The application of the named technology takes into account the following aspects:

- creating flexible spaces allows students to choose when and where to study, and the facilitator to choose where and how to apply learning assessments;
- The flipped learning model intentionally shifts instruction to a learner-centered approach in which topics are explored in greater depth during class time and ample opportunities for learning are created;
- Instructors use targeted content to maximize class time and employ student-centered active learning strategies based on class and course level;
- during the lesson, the instructor should observe, give feedback and constantly evaluate students' work. Teachers analyze their practice, improve their teaching, accept constructive criticism, and allow controlled chaos in their classes.

Thus, the use of flipped classroom elements, allows students to complete exercises and review the content of their classes in advance, creating personalized pathways to discuss problematic issues and solutions with their instructors and classmates.

Self-regulation of learning. Another important element of adaptive technologies is self-regulation, which is the ability to control thoughts, emotions, and actions through personal strategies to achieve goals and avoid undesirable outcomes. It should be noted that self-regulation allows us to analyze the environment, respond to it and modulate the subsequent response to adapt to it. This ability has a significant impact on an individual's personal development, social adaptation, and overall well-being. It is important to distinguish three domains in which self-regulation is manifested: behavior, learning, and emotions (Castro, & Gallardo, 2021).

Self-regulated learning is a process of self-reflection and action in which students' structure, monitor and evaluate their learning. Self-regulated learning is associated with better learning, higher engagement in the learning process and improved academic performance (Ganda, & Boruchovitch, 2018).

There are various models of self-regulated learning, each addressing different stages and activities. However, Zimmerman B. J. (2013) and Pintrich P. R. (2000) identified commonalities between the different models:

- First, most models assume that students actively shape their meanings and goals and are influenced by a variety of environmental factors and their cognitive system;
- Second, students can track and monitor cognitive, motivational, behavioral, and contextual aspects of learning;
- Third, self-regulation can be conditioned or facilitated by intrapersonal factors (e.g., biological and developmental) and extrapersonal, contextual factors;
- Fourth, self-regulation models of learning emphasize an individual's ability to set learning goals and to monitor his or her learning against those goals through control processes influenced by assessment results.

Self-regulation is closely related to adaptive learning because it allows students to take control of their learning and tailor it to their needs. In turn, adaptive learning offers the opportunity to create a personalized and effective itinerary using technology to adapt the content and activities a student can perform, so both help to achieve academic success.

Microlearning. Microlearning is learning through small, well-planned modules and short-term learning activities (Allela, 2021). It is an activity-based approach capable of providing learning in small parts (Skalka et al., 2021), allowing regular alternation between microcontent and micromedia. Microcontent refers to short text, sometimes enriched with images, tables or diagrams. Among the main needs met by microlearning is the search for learning strategies that do not affect the cognitive load or attention threshold that a student may have. Similarly, it is related to strategies to develop learning processes in knowledge areas subject to constant change (Allela, 2021).

According to Göschlberger B. et al. (2019), when developing microcontent, it should be considered that it should be self-contained and self-explanatory, contain a single learning action, typically be completed in a few seconds, and provide immediate feedback.

Trabaldo S. et al. (2017) note that microlearning materials are brief, continuous, contextualized, incremental, informal and detailed. The microlearning approach is an alternative to creating didactic sequences on a specific topic with small blocks of content that can be quickly learned in a small-time frame.

Results.

The study utilized a quantitative experimental design approach at the preliminary - experimental level of research to achieve the objective, which is to establish the feasibility of applying adaptive learning in integration with didactic technologies in teaching physics to students in vocational education.

47 third-year students participated in the study. The experiment was conducted during the 2023/2024 academic year. Adaptive learning was integrated into the educational process using didactic microlearning technology.

The research tools included survey methodology; a questionnaire was used for the independent variable as a final assessment tool, and questionnaires were used for the dependent variable before and after the pedagogical experiment in order to identify changes – dynamics of values in the studied indicators. Cronbach's Alpha coefficient and expert judgment were used to measure the reliability of the instrument. The questionnaire contained 20 questions with a multiple-choice Likert scale.

All implemented lessons were created through the tools offered by Google Meet in accordance with the microlearning methodology. Testing results were recorded in protocols before and after the implementation of the lessons using microlearning to understand the effectiveness of its impact on the level of students' preparedness in physics.

The results of the study indicate a positive effect of microlearning on students' mastery of physics knowledge because, the Z (cal) value of -2.248 is lower than the Z value of 1.960 determined by (Z1- ∞/ 2) and a p-value of 0.012. Relying on the findings, it is possible to testify that the changes that occurred are significant enough to reject the null and alternative hypothesis. Consequently, when comparing the results of the pre-test and post-test of the learning variable showed that as a result of the pedagogical intervention, the students' scores were located on average between 8 and 15 points.

There was a significant change after applying the microlearning technique, as it was found that students' scores improved significantly from 11 to 19 points. These results signify a significant improvement in student learning, which allows us to state the effectiveness of applying microlearning in the context of adaptive physics mastery platforms.

Regarding the results of the questionnaire in relation to the variable of microlearning, it was found that 61.5% of the students strongly agree that the application of this methodology is suitable for learning and 76.9% of them strongly agree that the design of microlearning helps to improve their learning. From the result, it can be concluded that most of the students believe that the application of microlearning in the context of mastering the knowledge component of physics enhances learning through the use of extended content in small groups. About 46.2% of the students strongly agree that through the use of microlearning facilitates the process of understanding complex topics. Thus, about 84.6% of the students, believe that effective use of microlearning helps to improve the understanding of physics topics. About 46.2% of the students believe that microlearning enables them to learn anytime and anywhere.

Regarding the hypothesis testing, the results obtained from the analysis and based on the value of Wilcoxon coefficient indicate an increase in the quality of learning and learning level after the pedagogical intervention. The results obtained confirm the findings of Conopoima Moreno Y. et al. (2021) which indicates more than 93% of students were satisfied with the use of microlearning tools. Similarly, the study of Jomah O. (2016) et al. indicates that almost 81% of students believe that microlearning is the best learning personalized system. Also, Triana A. J. et al. (2021) in their study with higher education students indicates that 91.6% of the students were satisfied or very satisfied with the microlearning experience and 89.5% of the students believe that the classes built practical skills compared to traditional continuing education methods.

Similarly, Muñoz-Organero M. et al. et al. (2012) in a pilot study conducted among higher education students in Spain found that attendance rate increased up to 56% due to microlearning methodology. Thus, the results of our study are consistent with previous studies.

Conclusions.

Microlearning methodology is relevant in its application if it follows instructional design using didactic resources and adaptive learning. The use of microlearning influenced the process of learning physics in students who showed high results in the values of academic success and acquired competencies. The study demonstrated that microlearning integrated with adaptive platforms helped to improve students' academic performance, and significantly reduced learning time by making it available anytime and anywhere. Future research is planned to develop pedagogical innovations with applications in student learning in physics mediated by microlearning and synchronous and asynchronous environments.

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