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DEVELOPMENT OF STUDENTS' SELF-LEARNING AND SELF-ASSESSMENT SKILLS USING CHECKLISTS

Abstract

The relevance of this research stems from the growing need to develop adaptable learners who can quickly respond to the changing demands of the modern educational environment. However, current scientific literature offers a limited focus on fostering student independence across various subjects, including biology. This gap drives the search for innovative approaches to teaching academic disciplines. This study aimed to assess the effectiveness of using checklists to enhance independent learning skills in biology lessons. Descriptive statistics and one-way analysis of variance (ANOVA) were applied to analyze the data. During the formative experiment, the first experimental group, which used both checklists and defined success criteria for the «Fundamentals of Cytology» unit, demonstrated the highest levels of self-directed learning, significantly outperforming the control group. ANOVA confirmed that the differences in academic achievement across the three experimental groups and one control group were statistically significant at a high level of confidence. Overall, the experiment confirms the pedagogical value of checklists in promoting independent learning and self-assessment in biology. The practical significance of this research lies in the successful testing and implementation of checklists and success criteria in a modern school setting, offering a potential strategy for enhancing biology education.

Keywords: learning strategies; biology course; learning skills; pedagogical technologies; quality of teaching.

Introduction. Modern society poses challenges to the education system associated with the formation of a mobile personality, capable of expressing self-sufficiency skills and successfully applying them in practice (Karlen et al., 2024). Therefore, following Bremner et al., (2022), the approach in which the student is the main priority of the educational process has become increasingly important. Du Toit-Brits (2021) notes that autonomy is one of the main learning skills in the 21st century. Artino and Ioannou (2008) refer to it as an indispensable quality of the modern education system. It is worth noting that several scholars in their research have covered the issues of organizing students' independent work (Basilotta-Gómez-Pablos et al., 2022; Darby, 2007; Boelens et al., 2017; Aizu et al., 2018; Bosch et al., 2019; Dewan et al., 2019; Sosibo, 2019; Robinson and Persky, 2020). The main emphasis in these works is on the effectiveness of learning material through the organization of self-learning. But still, some aspects of this problem remain understudied. For example, little attention has been devoted to the formation of students' self-learning and self-assessment skills in most school subjects, including biology.

The development of information technology and the popularity of online education have led to the fact that most educators understand the need to develop such skills in students (Çakiroğlu et al., 2024). Therefore, the study of these issues is extremely relevant, especially concerning biology. For many students, the study of modern biology has certain difficulties. This is due to a large number of complex concepts, the lack of creative tasks in the textbook, and, most importantly, the lack of real

self-assessment of the student. Bremner et al. (2022), Geng et al. (2019), and Sabanov (2019) agree that students should not only be allowed to learn independently but also do everything possible to make them take responsibility for their results. Often, the students do not understand what aspects they are missing in learning the material. Therefore, the research on self-assessment skills development peculiarities is of great importance. In the modern system of education, the teacher's role is to motivate students to independently find issues in learning and eliminate them (van der Linden et al., 2023). For this purpose, the teacher builds a learning path and allocates outlined criteria for success. They represent the milestones that need to be overcome by the student to learn the material effectively. If learning the school curriculum encounters obstacles along the way, it is easier for the student to recognize at what point they are having problems. To minimize the possibility of missing important information in the study of school subjects, and to promote the development of students' self-learning and self-assessment skills, checklist technology is being actively implemented (Alimova & Raimova, 2023; Budaychiyev et al., 2024).

Scriven (2000) defines a checklist as a list of certain main knowledge points, which are organized in a certain way to achieve the goals set. Under this technology, the student, following the items on the checklist, marks the actions already accomplished and sees the tasks to be accomplished. This is a convenient and entertaining form of work, which allows students to independently assess the correctness of the completed task and not stray from it. By marking items on the list, it is possible to determine at what stage of studying the material the student is. Wingate (2002) points out that checklists first appeared in aviation, where they ensured that pilots did not forget the take-off order, and landing, among other things. Later, they were transferred to other industries: medicine, catering, and others. In education, checklists were used to solve auxiliary problems unrelated to the study of material, for example, they helped the student pack a backpack or prepare for the report. Over time, this technology was used in teaching school subjects. As seen in the recent publications of Dos Santos (2019) and Dorji et al., (2021), there is still an unresolved issue on the pedagogical effectiveness of checklists, especially within the study of certain school subjects. The research aims to evaluate the suitability and pedagogical effectiveness of using checklists in a school biology course to develop students' independence skills.

Materials and Methods. The experiment was carried out based on the Nazarbayev Intellectual School of Chemistry and Biology in Kyzylorda, Republic of Kazakhstan. The study involved 200 students aged from 15 to 18 years (100 people of each gender). Three experimental and one control group (50 people in each group) were chosen to conduct the formative experiment.

In the first experimental group (EG-1) students used checklists and success criteria when independently studying the topics from the «Fundamentals of Cytology» section of the biology course. The checklists were compiled based on a generally accepted set of requirements (Scriven, 2000). Each checklist was a table consisting of educational tasks, and the student during self-learning had the opportunity to make a mark on the results of their solutions, assessing the level of their knowledge. Criteria of success were clear, and understandable and represented the results of learning (what the pupil had to strive for when mastering the material).

In the second experimental group (EG-2) only success criteria were used, and in the third group (EG-3) checklists were used. In the control group (CG), instruction was conducted traditionally without the use of checklists and success criteria. In all groups, the educational process was based on the same biology curriculum and was held at the same time. The same teachers were involved.

Descriptive statistics and one-factor analysis of variance methods were used for static data analysis. The results of the academic knowledge evaluation were processed using the standard software package «PASW Statistics 17». The normality of the distribution was evaluated

using the Kolmogorov-Smirnov criterion. In all cases studied, the variables had a normal distribution. After each self-study of the topics «Cell division» and «Application of enzymes in the industry», an assessment was conducted and three levels of academic knowledge of students were identified within each of the 4 experimental groups: low, medium, and high.

To assess the degree of the statistical reliability of the differences in the level of academic knowledge between the studied groups, one-factor analysis of variance was applied. The statistical method allows evaluation of the influence of the independent variable (use of checklists and/or success criteria) on the dependent variable under study (level of academic knowledge) by variance. In the literature and «PASW Statistics 17», analysis of variance is referred to as ANOVA/MANOVA (Analysis of Variance/Multivariate Analysis of Variance).

The null hypothesis (H_0) was formulated as follows: differences in academic proficiency between groups are distinct no more than random differences within each group. It is also worth noting that in this research the authors rejected the null hypothesis at $p<0.05$, thus allowing no more than a 5% chance of error.

Results. In recent years, teachers started to actively introduce technologies into the educational process aimed at developing students' self-learning skills. For example, checklists are used when studying school subjects more often. The key point of checklists is not to make a mistake in a given plan of action. That is, they directly reduce the likelihood of making mistakes «due to not knowing». Although elements of checklist technology have long been used in pedagogical activities in the form of action plans, memos, and instructions designed to study or consolidate the material, there is every reason to consider checklists an innovative technology in education. Mostly due to the requirements for the content of checklists (Scriven, 2000):

– the checklist should fully cover the topic being studied;

– evaluation criteria must be verifiable, reliable, and delineated;

– the items on the checklist should cover only one area of knowledge;

– the checklist should be short.

Checklists were developed to study the section «Fundamentals of Cytology» in the course of school biology. Tables 1 and 2 show examples of checklists for «Cell division» and «Application of enzymes in the industry».

Table 1. *Checklist for «Cell division»*

№	Question	Answer (✓/X)
1	Define meiosis as a method of cell division.	
2	Describe the meiosis phases.	
3	Specify the main differences between anaphase I and anaphase II of meiosis.	
4	Find the similarities between the phases of meiosis II and mitosis.	
5	Define the following terms: «homologous chromosome», «crossover», «sister chromatids», «bivalent/tetrad», «and alleles».	
6	Name the stage of meiosis in which «crossingover» occurs.	
7	Define meiosis.	
8	Compare meiosis and mitosis.	

Table 2. *Checklist for «Application of enzymes in the industry»*

№	Question	Answer (✓/X)
1	Name the main enzymes used in the production of detergents.	
2	Compare enzymes of plant and bacterial origin. State the possibilities of their use in medicine.	
3	Provide examples of the use of enzyme preparations in industrial large-tonnage processes.	
4	What are the main applications of lipases in the industry?	

5	What are the main problems with using ferments in medicine?
6	Provide examples of how enzymes function in our bodies.
7	Categorize beta-lactam antibiotics.
8	Provide examples of the use of enzymes in the food industry.
9	Name the main industries that use protease and amylase.
10	Define glucose isomerase and characterize its role in syrup production.
11	Define the role of lactase in milk production.
11	Name the enzyme used as the basis for the glucometer.

Tables 1 and 2 show that the checklists consist of three columns: the first column contains the number, and the second column contains the formulation of the task. The third column is for the mark, which the student puts as he or she learns the material, independently assessing their knowledge. It is especially important that students feel responsible for identifying and defining gaps in knowledge and forming learning goals following these gaps. The checklists contain a significant amount of specific knowledge. In other words, they represent data presented in the best possible way to achieve learning objectives. The use of checklists contributes to the improvement of the student's knowledge. The main goal of the experiment was to test the introduction of checklists in the self-study of the topics from the section «Fundamentals of Cytology». Their pedagogical effectiveness and suitability for the formation of students' independence skills were evaluated.

The checklists were offered to EG-1 and EG-3 during self-study of the educational material. Aside from the checklists, students in EG-1 were also provided with success criteria – statements allowing participants in the educational process to determine whether the learning goal was achieved. In EG-2 only success criteria were used. In addition, it is worth noting that the checklists were used after self-study of the material, and students were familiarized with the success criteria in advance. Tables 3 and 4 show the success criteria formulated for the topics «Cell division» and «Application of enzymes in the industry», respectively.

Table 3. *Success criteria for «Cell division»*

№	Criteria
1	I can describe and explain the phases of the cell life cycle and DNA (deoxyribonucleic acid) replication.
2	I can identify and describe the phases of mitosis on medical micrographs.
3	I can explain the characteristics of gamete formation in plants and animals.
4	I can identify the process of meiosis in plants on ready-made micro preparations.
5	I can explain the stages of meiosis.
6	I understand the process of tumour formation as the result of uncontrolled cell division.
7	I know the basic ways of dividing eukaryotic cells.

Table 4. *Success criteria for «Application of enzymes in the industry»*

№	Criteria
1	I know the classification of enzymes.
2	I can provide examples of how enzymes function in our bodies.
3	Provide examples of the use of enzymes in the food and cosmetics industry.
4	I can name the reactions catalysed by lipases, and I know the products that result.
5	I understand how the latest scientific advances in enzymology are applied in the treatment of cardiovascular, cancer, neurodegenerative, and other serious diseases.
6	I know the role of enzymes in chocolate production.
7	I can name at least 3 industries in which protease and amylase are actively used.

8	I understand the process of making high fructose syrups.
9	I understand how lactose-free milk is produced.
10	I know how a glucometer works.

The success criteria help the student to independently assess whether the goal set in mastering the material is achieved. During the formative experiment, the level of academic knowledge in the experimental and control groups after self-study of the topics from the school course biology was evaluated. The results of the control are shown in Figures 1 and 2. It was determined that the best results of self-study of the «Cell division» topic were noted in the experimental group of EG-1, where the percentage of students with a high level of knowledge was the highest – 40% (Figure 1). In comparison with the control group, this indicator is better by 30% (in CG it was 10%). Also, EG-1 recorded the smallest percentage of students with a low level of knowledge – 10% (compared to 25%, 18%, and 60% in EG-2, EG-3, and CG respectively). Figure 1 shows that the use of checklists in EG-3 led to higher academic proficiency scores than the use of success criteria alone in EG-2. In the first case, the percentage of students with a low level of knowledge was 18%, and in the second case, it was 25%. It is also worth noting that the highest percentage of students with an average level of knowledge was observed in EG-3 (60% compared to 50%, 55%, and 30% in EG-1, EG-2, and CG, respectively).

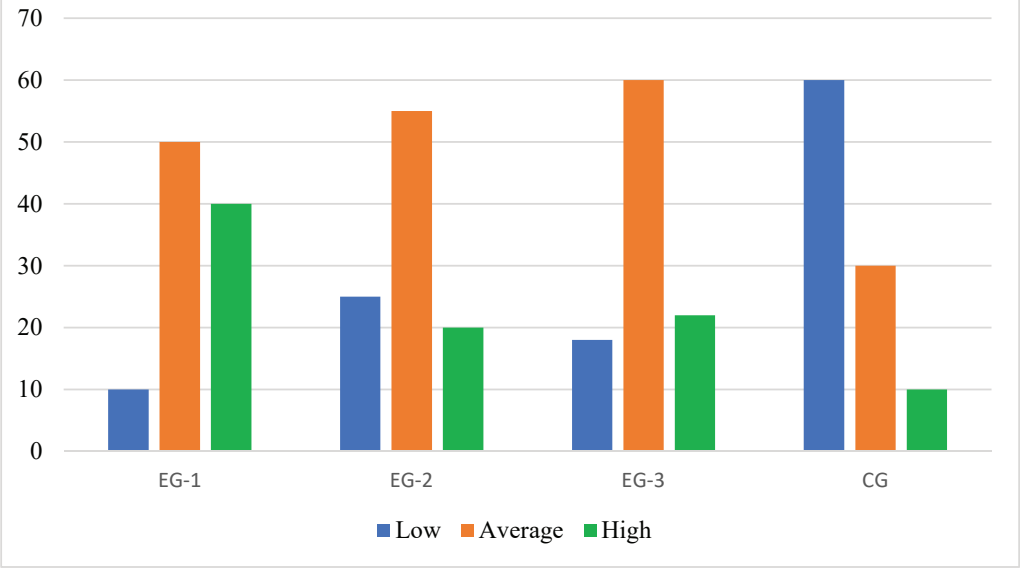

Figure 1: The level of academic knowledge in the experimental and control groups after self-study of the «Cell division» topic

Figure 2 demonstrates the level of students' knowledge after self-study of the «Application of enzymes in the industry» topic. The three experimental groups show a distinct difference in the level of academic knowledge, especially in comparison with the control group. A high level of knowledge in EG-1 had 45% of students, in EG-2 – 21%, in EG-3 – 26%, and in the control group, this indicator was the lowest – only 15%.

In the EG-3 experimental group, a higher level of academic knowledge was noted than in EG-2. A low level of knowledge was noted in 14% of students who used checklists during self-study of the «Application of enzymes in the industry» topic, which is 4% less than in students from EG-2 who used only success criteria for the same purpose. The lowest level of academic knowledge was noted in the CG group (Figure 2), where the biology studies were conducted with traditional conditions. As such, in the experimental groups where checklists and/or success criteria were introduced into the learning process during

self-study of topics from the school biology course, the student's level of knowledge was significantly higher than in the CG. To assess the degree of the statistical reliability of the differences in the level of academic knowledge between the studied groups, one-factor analysis of variance was applied to examine the influence of the independent variable (use of checklists or success criteria) on the dependent variable under study (level of academic knowledge).

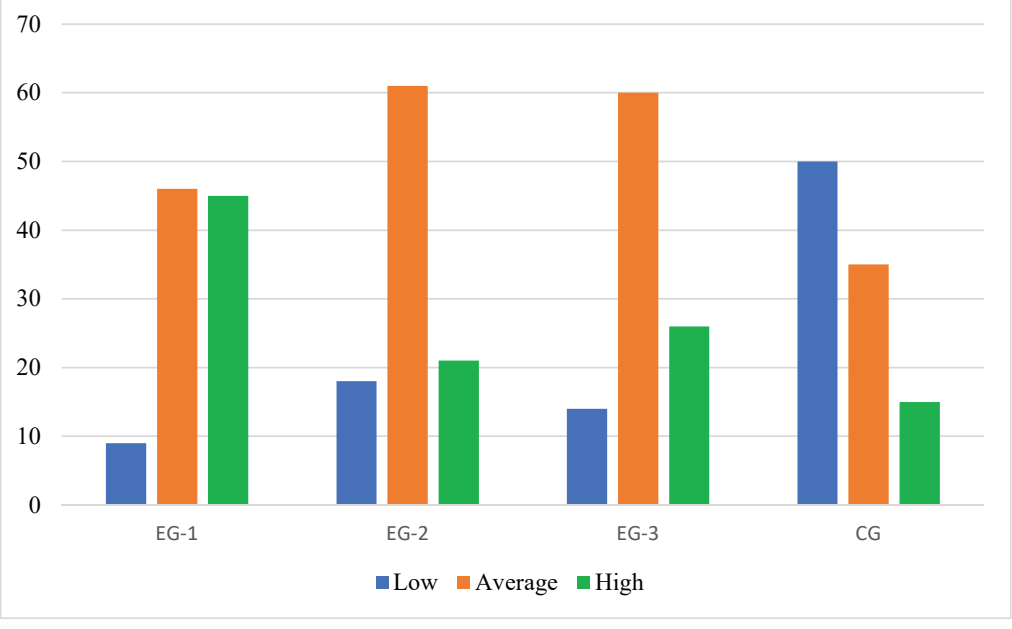

Figure 2: The level of knowledge in the experimental and control groups after self-study of the «Application of enzymes in the industry» topic

It is necessary to note that the popularity and usefulness of variance analysis as a popular technique for handling empirical data is caused by at least one significant reason. First, this analysis method allows the assessment of differences between average samples, similar to the student's test, but unlike it, in the variance analysis, there are no restrictions on the number of averages to be compared. This is especially relevant in this research since the results of self-learning in three experimental and one control group were analyzed. The null hypothesis H_0 was tested twice. In the first case, a significant difference in the level of knowledge of students from the experimental and control groups was verified after studying the «Cell division» topic, and in the second case, after studying the theme «Application of enzymes in the industry».

In the first case, $F_{emp} = 7.83$, and in the second case, $F_{emp} = 6.44$. For the significance level $p = 0.05$, F_{cr} was determined by the Fisher-Snedekor distribution table: $f_{cr} = 1.96$. In both cases, the empirical value of the criterion is greater than the critical value. Therefore, the differences in the level of academic knowledge between all experimental groups of students and the control group in the two studied cases are statistically reliable at a high level of significance. In other words, with a 95% probability, it can be stated that the use of checklists and/or success criteria for students' self-learning has a significant impact on their level of knowledge. The results confirmed the hypothesis that the introduction of checklists expedites the development of self-learning skills and self-assessment in students in biology classes. This is especially important since nowadays there are educational requirements to develop an independent personality capable of quickly adapting to the changing conditions of the world.

Discussion. Modern society demands schools to prepare individuals to adapt to rapidly changing conditions. Today, there is tension in the education system between the need to build up academic knowledge at a fast pace and the

limited opportunities for students to acquire it. This situation poses a need for educators to develop students' self-learning skills as much as possible. In such a case, there is a demand for pedagogical approaches where the focus of learning is not on the teacher but on the student, his or her dispositions, and interests. Approaches to student learning are inextricably linked to teaching methods and strategies. Recently, educators have been focusing specifically on learning strategies (Oxford, 2016; Bremner et al., 2022). Oxford (2016) categorizes strategies into three main groups:

– the first group relies on the mechanisms of human memory: the development of logical relationships, the use of visual, sound, and other components;

– the second group includes mental operations: comparison, inference, deductive and inductive analysis;

– compensatory strategies based on assumptions, synonyms, and more.

The use of checklists can be attributed to strategies based on human memory mechanisms. Scriven (2000) refers to checklists as a «mnemonic tool« since they minimize the likelihood of missing important knowledge milestones and making mistakes due to important information not being learned. The use of checklists in aviation resulted in a noticeable drop in the number of mistakes made by pilots due to their forgetfulness. Later checklists were successfully used in medicine, management, and other fields. As for education, checklists in the educational process were used by teachers in the study of certain disciplines. For example, the checklists proved themselves well in geography classes. They were used with geographical maps, including filling out contour maps, etc. In the school literature course, they were effective in teaching the analysis of a poem, an episode (Yarygina and Yarygin, 2019).

At the beginning of the research, a lack of data on the pedagogical effectiveness of checklists in biology classes was present. The issue of their usefulness for the formation of students' self-learning and self-assessment skills remained unclear. For many of today's students, the biology course is considered difficult due to its complex and extensive conceptual apparatus. In addition, students often misunderstand what they have learned well and what they do not know. This problem can be solved through the organization of pedagogical activities aimed at the development of these skills in the teaching of biology. The main feature of students' self-learning is the awareness of each action that the student performs in the course of achieving the educational task. The checklists allow students to independently assess their acquired knowledge by marking items from the list of educational tasks. In the developed checklist, there was a column, that pupils filled in as they learned the material. At the same time, they acquired knowledge of their initiative and were interested in it. The use of checklists constantly reminded the students of their work, prevented distractions, and forced them to move forward in mastering the educational material.

It is worth noting that self-learning strives for more natural forms than traditional learning. However, much depends on several facts: the socio-demographic characteristics of the student, the peculiarities of their information consumption, among other things (Loeng, 2020). Educators are seeing the trend, in which traditional learning is no longer as effective, which means that some aspects of it need to be reconsidered. Learners should be able to self-regulate their cognition, motivation, and behavior. To develop the necessary skills, it is necessary not only to give the student autonomy in learning but also to do everything possible for the student to take responsibility for the results obtained. This is facilitated not only by the checklists but also by the success criteria developed for the two topics from the section «Fundamentals of Cytology» during school biology. The student's ability to self-assess depends on the success of their learning.

In the EG-3 experimental group, where only checklists were introduced in the learning process, the highest percentage of students with an average level of knowledge was noted. In the same group, the knowledge level indicators were higher than in EG-2 and CG. Thus, the use of checklists provided better learning outcomes

than the use of only success criteria and teaching in traditional settings. This can be explained by the fact that when using checklists, unlike success criteria, a student has an opportunity to mark items on the list and see the progress of learning the material, thereby avoiding making mistakes. Although success criteria showed greater pedagogical effectiveness compared to the traditional system of teaching in the control group, where the highest percentage of students who did not learn the material was noted. The best results of independent learning were noted in the EG-1 experimental group where not only checklists but also success criteria were involved in the educational process.

The research results indicate that the checklists and success criteria contribute to the development of students' independence skills and have a positive impact on the level of their knowledge. It can be assumed that this is due to the motivation of students to find problem areas in learning and solve them. Indeed, researchers have noted that one of the most important components of self-learning is motivation, which is the desire to engage in a particular activity and achieve goals (Morris, 2019; Boelens et al., 2017). A student will act independently if they believe that the activity contributes to an outcome that is important to them. Additionally, if motivation is not present, the learner will not have control over the learning process and will not achieve the learning goals. Artino and Ioannou (2008) articulate that when students' internal motivation is addressed, they are freed from the need to receive positive external cues and can focus on their needs rather than the opinions of others.

The use of modern pedagogical technologies increases students' motivation to learn and has a significant impact on the level of their knowledge. Using a single-factor variance analysis, the differences in the level of academic knowledge between all three experimental groups and one control group were found to be statistically reliable at a high level of significance. In other words, the use of checklists and/or success criteria for independent learning of topics from the school biology course has a significant impact on the level of student knowledge. The results show that the introduction of checklists promotes the development of student's independent learning skills and self-assessment in biology classes.

Conclusions. The use of checklists in biology lessons contributes to the development of students' self-learning skills and self-assessment. In all three experimental groups, the level of knowledge differed for the better in comparison with the control group. Although the use of checklists provided better learning results than the use of success criteria alone. The best results of self-learning were noted in the EG-1 experimental group, where checklists and success criteria were involved. It can be assumed that this is because to develop the necessary skills pupils need to be motivated to find problem areas in learning and to solve them. This is facilitated not only using checklists but also by the success criteria which allow the student to independently assess whether the goal set for them in mastering the material has been achieved.

The conducted research allows us to state with a 95% probability that the application of checklists and/or success criteria in the educational process has a significant impact on the level of student's knowledge. Thus, checklists are a suitable and effective tool for shaping students' self-learning and self-assessment skills. Therefore, the developed checklists and success criteria can be successfully applied when studying the section «Fundamentals of Cytology». The issue of forming students' independence skills is complex and diverse, especially within the study of school biology courses, a discipline with a complex and extensive conceptual apparatus. The conducted research creates prerequisites for a more comprehensive study of this issue. The main prospects for further research are related to the introduction of other teaching strategies to develop students' independence skills in biology classes. Also, the issues of the effective study of school disciplines in a distance learning environment, which has recently become more and more topical and popular, require more detailed consideration.

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THE CONCEPT OF DESIGNING A «SMART CLASSROOM» OF AN EDUCATIONAL INSTITUTION

Abstract

The creation of a smart classroom is one of the priorities of the digital transformation of higher education, which allows for an increase in the efficiency of the educational process creates comfortable conditions for learning using the latest technologies, and is carried out in several stages. Concept development is one of the first and most important steps in creating a smart classroom. It defines the main directions and goals of creation, the structure and content components of a smart classroom, and the requirements for its functionality to create the most efficient and convenient space. The purpose of this study was to develop a concept for designing a smart classroom for the training of future informatics teachers and ICT specialists for education, the further implementation of which will not only optimize resource management but also create more effective, comfortable, and modern conditions for learning. The research methodology included analysing literature on the creation and implementation of smart classrooms in the educational process, as well as surveying its potential users to determine the functionality requirements. Based on the analysis of literature and the survey results among informatics students and future ICT education specialists, the functionality for the «smart classroom» was constructed, and its key structural components for implementation were identified and substantiated. The developed concept defines the technological basis for creating a functional smart classroom that meets modern requirements.

Keywords: smart classroom, equipment management automation, control sensors, system integration, Likert scale, sensor equipment.

Introduction. The creation of a smart classroom is one of the priorities for the modernization of the educational process in universities in modern conditions of rapid development of intelligent technologies. The Smart Classroom, based on the Internet of Things concept, represents a high-tech learning space where all technical systems and devices work in coordination with minimal or no human intervention, ensuring maximum comfort and effectiveness of the educational process (Yağanoğlu et al., 2024).

Such classrooms contribute to the development of innovative approaches to learning and education, providing new opportunities for interactive learning, the use of virtual and augmented reality, video classes, and other innovative educational formats (Ma et al.,