AI-Supported Learning Methodologies: Theoretical Review and Empirical Research on the Educational Process Impact

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Abstract **– Contemporary education is undergoing significant transformations through the implementation of Artificial Intelligence (AI) in the learning process. This paper provides a comprehensive theoretical overview of AI-supported learning methodologies and presents empirical research on their impact on the educational process. The theoretical section explores six fundamental AI-supported approaches: personalized learning, gamification, virtual assistants, problem-based learning, AI-supported collaborative learning, and Virtual Reality/Augmented Reality (VR/AR) technologies. Empirical research on Information Technology students demonstrates that AI technologies complement traditional methods, creating synergy particularly pronounced in collaborative learning. The findings have significant implications for designing future educational programs and integrating technology in higher education.**

Keywords **– Artificial intelligence in education, collaborative learning, AI-supported methodologies, personalized learning, educational technologies.**

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1. Introduction

Contemporary concepts of artificial intelligence (AI) and its accompanying instances (generative artificial intelligence, natural language processing...) have become an integral part of concepts and elements that are used daily. These technologies generate diverse opinions; advocates recognize their potential, while critics emphasize their negative aspects. The essence is that they cannot be avoided. The primary goal is to use them in a way that maximizes their positive effects. Certainly, the education process has moved far from the concept of "blackboard and chalk". Information technologies and artificial intelligence have "revolutionized" the world, including the process of education and training [1]. Specifically, AI technologies in education (AIED) bring significant changes in the way knowledge is acquired, transmitted, and applied. The presence of these technologies not only changes the existing educational process but also creates new directions and paradigms within, which adapt and shape it according to the needs of the 21st century.

When observing the contribution of AIED in the educational process, one of the significant (if not the most significant) benefits they provide is the personalization of the educational process. This means that AIED can adapt teaching materials and learning approaches to each individual and their abilities, thereby achieving increased motivation and efficiency for each of them. Additionally, AIED contributes to increasing educational inclusivity by supporting students with developmental disabilities through various speech and text recognition systems that enable access to educational resources for people with visual or hearing impairments. The use of these technologies enables global connectivity of participants in the educational process, thus creating online learning platforms. The use of AIED in the educational process has become a trend [2].

On the other hand, AIED can also help teachers focus on creative and interactive aspects of teaching by automating some routine tasks such as, for example, administrative work. Besides the numerous advantages they provide, it is necessary to consider the challenges that accompany their implementation (teacher training, privacy protection, ethical issues...) [3]. This paper examines which contemporary AI methods can be used in the learning process as well as their impacts on it. Additionally, through empirical research, this study investigates the impact of these methodologies on the student learning process.

2. AI Technology-Supported Learning Methodologies (AIED)

Contemporary education imposes the imperative that the implementation of AIED systems serves as a guide in shaping innovative learning methods. Innovative learning methods are not fundamentally new and conceived from scratch. They represent an enhancement of contemporary methods through the use of modern algorithms and technologies that change the approach to the learning process. As such, they enable numerous advantages for all participants in the education and training process. These methods transcend the “one-size-fits-all” learning concept and thus create a dynamic and adaptive learning environment [4].

In addition to benefits for students, AIED methodologies provide assistance to teachers by enabling them to receive valuable feedback about the status of the learning process in a timely manner and thus improve their teaching strategies, all with the goal of achieving better effects in the learning process [5]. The following sections present the most commonly used AI-supported learning methodologies, describing their fundamental characteristics, advantages, and limitations.

2.1. Personalized Learning

Personalized learning represents a pedagogical approach that involves adapting instructional content, learning pace, and assessment methods to meet the needs of each individual in the learning process [4]. It represents one of the most significant advantages that the application of AIED brings compared to traditional approaches. In traditional learning, this approach requires a significant amount of time, effort, and energy from teachers, therefore, it is very rarely applied in practice. On the other hand, automated algorithms, processing of large amounts of available data, and other elements that are characteristic of AIED systems enable rapid and widespread application of this methodology. Figure 1 shows the flow of the personalized learning process.

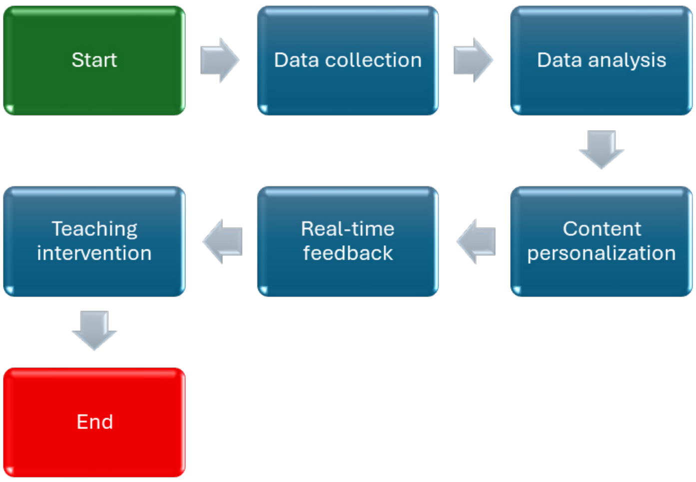


Figure 1. Personalized learning process

Within this process, AI algorithms perform continuous analysis of students’ previous work and progress, thereby enabling dynamic adaptation of the difficulty and format of instructional materials that are delivered to students. Through constant monitoring of individual progress, AIED technologies ensure that students receive appropriate content, thus preventing monotony and overload in the learning process, and creating optimal conditions for learning [6], [7], [8].

Numerous platforms that have been developed present content to each individual that is adapted to each student's knowledge level. The learning content found on these platforms is generally interactive and enriched with multimedia content based on AI.

Some of the most well-known platforms that offer a personalized approach to learning are:

- **Coursera** - Offers personalized course and material recommendations to learners from various fields based on their previous experience, interests, knowledge level.
- **Duolingo** - A language learning platform that adapts lessons to individual users based on assessment of their knowledge, mistakes they make in the learning process, learning speed.
- **DreamBox -** A mathematics learning platform that adapts lessons and tasks based on assessed abilities and student progress.
- **Century Tech -** Provides personalized lessons for students as well as analytics for teachers, and its operation is based on a combination of neural networks and AI.
- **Smart Sparrow -** A platform that enables teachers to create courses and learning materials that adapt to each individual.

The advantages of this methodology are numerous, because by adapting the learning process to the individual, specific segments that are characteristic of each person are activated, thereby increasing their motivation and engagement, which is a key element of success in the learning process. On the other hand, attention should also be paid to potential drawbacks of the individualized learning process such as: loss of social interaction, technology dependence, data privacy concerns, limitations of AIED algorithms.

2.2. Gamification and AI

A computer game can be defined as an interactive computer application that has a challenging goal, is fun to play and engaging, includes some scoring mechanism, and provides the user with knowledge, skills, and attitudes that can be useful in real life [9]. Unlike conventional games whose primary goal is entertainment, games that are used in the educational process aim for education and acquisition of new knowledge. Educational games enable participants in the educational process to acquire new knowledge and skills in an interesting and engaging way, which increases the effectiveness of the learning process itself.

The application of gamification in the educational process is not novel. People have long included games such as chess and other mind games in the education process, believing that they thereby stimulate critical thinking, logic, and cognitive processes in students [10].

The positive effects of applying this methodology in the educational process include [11]:

- Additional student engagement and motivation,
- Assistance in learning and memorizing material,
- Promotes visual and computer literacy,
- Encourages problem-solving abilities and rule-following,
- Promotes work and abilities of students with attention disorders,
- Encourages cooperation, sportsmanship, teamwork.

On the other hand, as negative effects of applying this methodology, the following can be stated:

- **Health problems** - Excessive computer use can lead to eye strain and other physical problems.
- **Cost of advanced technologies -** Technologies that enable education in this way are quite expensive, which can lead to discrimination against students who cannot afford them from this perspective.
- **Control of students using educational platforms -** When students begin to use these technologies en masse, the question arises of how successfully teachers can control all of this and prevent students from "incidentally" using other internet platforms that are not intended for education and training and that may be harmful to them.
- **Social isolation** - Students who use and rely solely on learning through games are isolated from real collaboration and interaction with other students in the real world and environment.

The emergence of AIED technologies has enabled the development of this discipline and brought it closer to participants in the learning process. As a result, a large number of platforms that provide the possibility of education and learning through the application of gamification as a learning methodology have been developed. Some of the most well-known platforms are: ***Kahoot*** **-** which provides the creation of quizzes and learning materials with gamified elements, ***Quizizz*** **-** provides a combination of games and learning, and gives participants feedback generated by artificial intelligence, ***Socratic by Google*** **-** uses AIED technologies to create interactive tasks to which students provide responses. What these platforms have in common is that they provide their users with constant feedback about their progress and success, reward them for success, and form leaderboards where they can always see where they stand in relation to other participants. In this way, they stimulate motivation and competitive spirit in students, and thus, the knowledge acquisition process is improved.

2.3. Virtual Assistants and Chatbots in the Educational Process

The expansion of AIED has also led to the emergence of chatbots and virtual assistants that are present in the learning and education process. The advantage of these tutors compared to traditional teachers is that they are always present and ready to help anytime and anywhere [12]. The only requirement is to have one of the smart devices (phone, tablet, computer...) nearby on which these technologies would be used. Chatbots and virtual assistants introduce some new principles into the educational process that serve as a complement and enhancement to traditional methodologies and principles in the learning process. They most often transmit educational content through multimedia content (text, images, presentations) and through speech. Content-wise, they cover a very large spectrum of lessons and areas because they are already “trained” and taught through large amounts of data from different fields. A characteristic of chatbots is that they are able to very faithfully simulate a human interlocutor and thus gain trust from students and increase the acceptability of AIED technologies. In addition to content transmission, they also enable very efficient material evaluation while obtaining feedback about the level of progress in students.

The implementation technologies for chatbots and virtual assistants are relatively inexpensive, positioning them as accessible tools that modernize contemporary learning processes and facilitate learning styles more aligned with student preferences. Simply put, the target group that can use them is very large. As such, the mentioned technologies have enormous potential for application in educational institutions.

These technologies can also provide enormous support and assistance to teachers in the learning process. Often, a large number of students in the classroom is a problem for the teacher, therefore, they cannot simultaneously provide equal help and attention to all students. By using virtual assistants as support in the learning and knowledge acquisition process, the teacher can devote themselves to students who are less autonomous in the learning process while virtual assistants work with more autonomous students who are more successful in mastering material and achieving goals [13]. Of course, the teacher is always there to guide and manage the learning process and to supervise and occasionally check students who have been working with virtual assistants.

Chatbots that can be successfully used in the teaching process are ***ChatGPT, IBM Watson Assistant, and Google Dialogflow***. They provide instant answers to all questions and tasks posed by students, simulating human interaction at all times.

On the other hand, virtual assistants like ***Siri*** and ***Alexa*** can be of significant help in conducting the education process. They enable the creation of personalized materials for each participant in the educational process as well as real-time monitoring of each participant.

2.4. AI Supported Problem-Based Learning (PBL)

Problem-based (project-based) learning - PBL is well recognized in contemporary education, especially within some engineering disciplines and sciences. PBL as a learning process should be collaborative, constructive, contextual, and self-directed [14]. The process itself involves building new knowledge that is based on some previous knowledge [15].

PBL enables students to integrate theory and practice, apply previously acquired knowledge in investigating problem-solving processes, thus create a sustainable plan for problem-solving [16]. In other words, this approach teaches students how to learn. During the learning process in this way, students take an active role as problem bearers, while the teacher's activity is reduced to mentoring work, monitoring the process flow, occasional advising, giving instructions.

Students discuss the posed learning problems among themselves and exchange previously acquired knowledge and experiences. Also, the collection of necessary information and resources needed for acquiring and applying new knowledge is performed. At the very end, ways and directions for solving the posed problems are determined, all through teamwork and collaborative learning.

The basic difference between PBL and other learning approaches is the *ill-structured problems* that are posed to participants (students) in the learning process [17]. Ill-structured problems are posed in such a way that they do not have one correct or predefined solution. They represent complex types of problems and usually occur in some real, everyday situations, so different approaches can be applied to solve them. Their essence is to encourage students to be creative and analytical and to make decisions in complex and complicated situations. In this way, students are prepared for real challenges in their later careers because in practice they will very rarely encounter situations that can be solved by simple application of previously learned rules and stereotypes.

Basic characteristics of ill-structured problems that characterize the PBL process are:

- ***Multiple possible solutions –*** There is no universal (unique) solution, but students are required to analyze the problem from multiple aspects and come up with several possible solutions.
- ***Incomplete information –*** Students are given basic directions and guidelines for problem-solving, and they must independently search for additional information and knowledge that enables better understanding of the problem.
- ***Require involvement of different knowledge areas*** – It is necessary for students to connect theoretical and practical knowledge from multiple areas in order to draw certain conclusions.
- ***Flexible for interpretation*** – How the understanding and approach to problem-solving will be carried out depends on students' previous knowledge and experiences.
- ***Closely related to real environment –*** These problems often represent real situations from the real environment for which solutions are sought, regardless of which field is involved (engineering, medicine, social sciences...).

Practical examples of ill-structured problems from different areas:

- **Medicine** – "How to reduce the obesity rate in children?" *(Problem-solving may include nutrition, psychology, physical activity...)*.
- **Engineering:** *"How to organize urban transportation in urban environments that is environmentally clean and energy efficient?"* (Various approaches to problem-solving are available (electric buses, metro, bicycle lanes), and economic, ecological, and technical aspects must also be analyzed).
- **Ecology:** *"How to reduce river pollution in your city?"* (Solving requires research of existing pollution sources, possible actions and interventions as well as their impact on the local community).

2.5. Collaborative Learning with AI

This educational approach involves a group of students working together on solving problems, creating a product, or completing a task [18]. Groups are organized with students of different levels of achievement so that groups are equal to each other and so that the more successful ones motivate and influence those students who achieve weaker performance. In such an environment, social as well as emotional reactions come to the fore because they must express and defend the views that they have presented regarding the solution of the posed problem.

Then unique solutions are created and concepts for solving a specific problem are formed that rely exclusively on the views and experiences of present peers, and not on some already established or written methods and procedures.

This methodology sets aside the traditional teaching environment - teacher lecturing in the classroom. In contrast, "collaborative classrooms" are created where the learning and working process is based on conversation and discussion between students who are assisted by teaching materials previously given to them by the teacher. Traditional teacher lecturing and recording facts that they present is not completely excluded in such an environment, but is reduced to a minimum, most often where the teacher gives guidelines and instructions for work and explains the teaching materials that have been distributed to them.

Work at the group level, within the collaborative classroom, must be directed and organized. This means that each student also has their individual tasks that they must perform. Collaborative learning does not mean that one or just a couple of students work at the group level (usually the more successful ones), while the others just observe and add their name to the work at the end [19].

Collaborative learning offers numerous advantages, which can be systematically organized into three categories [20]:

1. ***Social advantages:***

a) Develops learning communities,
b) Encourages social interaction between peers,
c) Establishes a positive work atmosphere and mutual cooperation,
d) Develops social support systems for students.

2. ***Psychological advantages:***

a) Increases student self-confidence,
b) Cooperation reduces anxiety,
c) Develops positive attitude toward teachers.

3. ***Academic advantages:***

a) Actively involves students in the learning process,
b) Encourages critical thinking,
c) Shapes problem-solving techniques in students,
d) Contributes to improvement of learning outcome.

One of the most significant innovations for improving this learning methodology is the introduction of information and communication technologies as assistance to this form of learning [21]. This process is known as *Computer-Supported Collaborative Learning (CSCL)*. The foundation for developing this way of working is certainly the existence of computer networks and communication technologies that would support this process.

Specifically in practice, CSCL uses various digital platforms that enable collaborative learning. One of the most well-known is ***Google Classroom*** which enables interaction between students and teachers, sharing of teaching materials and assignment of tasks. Also, ***Microsoft Teams*** is another popular platform that supports video conferences, chat options, and document sharing, which motivates teamwork and active participation in online discussions among students. Another significant platform is ***Moodle*** - A learning management system that offers numerous tools for collaborative learning (forums, wiki pages, group projects...). Connecting students, teachers, and parents is possible on the ***Edmodo*** learning platform which enables constant communication among actors and exchange of teaching materials.

In addition to general-purpose platforms, specialized platforms exist for implementing specific tasks such as ***Google Colab*** which enables collaborative work on learning programming code and programming for groups of students and ***Jamboard*** which is also a Google product and represents an interactive board on which multiple participants can work on the same task.

Regardless of which platform is in question, what they have in common is that they enable students to actively participate in the educational process, share resources, communicate with teachers, and support each other. CSCL, by adapting educational experiences to individual student needs and capabilities, also encourages personalized learning.

Computer-supported collaborative learning is considered very effective in the contemporary concept of education because it combines technology and pedagogy, creating a dynamic and interactive environment for all its participants. As expected, the application of this concept is expanding because contemporary digital technologies constantly evolve and provide better and more advanced conditions and possibilities for this type of learning.

2.6. VR/AR in Education

Virtual Reality (VR) represents technologies that create an environment that is completely generated (created) using computers. On the other hand, Augmented Reality (AR) represents technologies that add digital elements to the real world (most often combining a camera and screen of a mobile phone or some other device). Regarding education, these tools first appeared in the field of vocational education with the goal of improving it. The mentioned technologies enable new ways for developing practical skills and theoretical concepts in students as well as innovating teaching methods in this segment of education [22].

Although the technologies themselves emerged more than 2 decades ago, their application in teaching practice is still in an early stage and their more widespread use is only expected.

It is indisputable that contemporary education often requires knowledge and understanding of specific concepts and processes that are difficult for students to understand only with their own imagination, without appropriate realistic animation, experiments, or concrete demonstration. On the other hand, conducting such experiments in real-world conditions is often limited by high costs of necessary equipment, lack of required materials, safety risks, or difficulties due to geographical distances [23].

The development of computer technologies has enabled these difficulties to be overcome to the greatest extent. The application of computer technologies not only enables students to be brought closer to and have concepts explained to them that previously have been unavailable through AR/VR concepts, but the application of these elements in the educational process has become an imperative in some form. This can be said considering that current and future students belong to the so-called "Generation Z". These are students who were born in the digital era and the way they process information requires their educators to apply not only basic technologies, but also to use the full potential of e-learning that is supported by contemporary computer technologies [24].

The advantages of VR/AR technologies are that they can simulate and portray conditions, phenomena, and concepts that are physically inaccessible to students (e.g., tourist destinations, planets, human organs...). Likewise, these technologies can vividly display the occurrence of phenomena or processes that are not visible to the naked eye (e.g., magnetic field and the action of magnetic forces) [25]. Students can, with their help, be participants in some dangerous processes and analyze the real results of the same without endangering themselves [26]. And as a special advantage, one should certainly not forget the richness of sensory experience that is significantly richer than pure narrative, text, or images [25].

On the other hand, it is necessary to consider the disadvantages of these technologies. One of the main ones is the high initial cost for equipment and software, which can significantly limit the number of educational institutions that can afford them. From a health perspective, one should be careful that excessive use of these technologies can cause dizziness, nausea, thus significantly reduce the efficiency of the learning process. And certainly, the use of these technologies requires specific technical skills, which can represent a challenge for both students and teachers.

Some of the concrete VR/AR tools and platforms that can be used in the educational process are: ***Google Expeditions*** (enables virtual trips to historical locations, museums, underwater world, space...), ***CoSpaces EDU*** (enables creation of VR/AR animations, interactive lesson models...), ***TiltBrush*** (enables creation of art in virtual space), ***Zspace*** (combines VR/AR technologies for 3D display and interaction with STEM (science, technology, engineering, and mathematics) content, and many others.

3. Research Methodology

This section outlines the methodological framework employed to investigate the impact of AI-supported collaborative learning on student performance and engagement. The research was designed as a comparative study, examining differences between traditional and AI-assisted learning approaches in a real educational setting. The following subsections describe the research design, participant sample, procedures, and formulated hypotheses that guided the empirical investigation.

3.1. Research Description

The idea for the research, which will be elaborated in the following sections of this study, is to examine the effects of applying one of the learning methods based on artificial intelligence on a specific sample of students. Specifically, to examine the ***collaborative method*** and its impact on learning effects.

The concept of the research was to divide students into several groups (4-5 students) and to independently conduct the learning process and mastering of new material within that group. Half of the groups mastered the material and solved assigned tasks with the help of contemporary technologies and artificial intelligence (assistance from ChatGPT, Copilot...) while the other group mastered the material in a traditional way (teaching materials) and also solved tasks in a traditional way by writing code without anyone's assistance. The teacher's role was to prepare materials, issue clear instructions at the beginning, and distribute learning materials. During the research itself, the teacher visited groups, gave guidelines and instructions when needed, and monitored and recorded the times that were planned for task completion.

The target group in the research were second-year students of the *Information Technology* program at the Academy of Vocational Studies Šumadija, department in Trstenik. The subject on which the research was conducted was *Object-Oriented Programming*, and the teaching unit that students independently worked on and mastered was *Classes in Python - Basic Concepts, Inheritance, and Working with Lists Using Classes*.

The number of students in the sample was 26 (4 groups of 4 students and 2 groups of 5 students, total of 6 groups). The time planned for the research was 90 minutes.

The flow of the research itself was as followed: Students first took a *pretest* to check knowledge in order to measure students' initial knowledge in this area. The test consisted of 10 short questions. The time for completing the test was 10 minutes. After that, tasks, necessary materials, and work instructions were distributed to the groups.

Groups were supposed to first acquire certain knowledge (some in a traditional way and others with the help of AI technologies), and then use that knowledge to solve practical tasks. Specifically, they had three tasks to write Python code that solves a specific problem related to working with classes. For this activity, they had 60 minutes.

After that, they took a *posttest* which had the same questions as the pretest. The goal and expectation from this test were to achieve better results than on the pretest, and that would be a proof that the learning cycle was successful. For this activity, they had 10 minutes. In the last 10 minutes, students filled out a survey in which they expressed their impressions about this way of working and learning.

3.2. Hypotheses

The research was guided by two main hypotheses designed to test the effectiveness of AI-supported learning methodologies. These hypotheses were formulated based on the theoretical framework presented in the previous sections and aimed to provide empirical evidence for the impact of AI tools on both learning outcomes and student motivation.

H1: *Students who use AI-supported learning methods achieve better results than those who use traditional methods.*

H2: *AI tools increase student motivation and engagement.*

4. Research Results

This section presents the comprehensive analysis of data collected during the empirical study. The results are organized into three main categories: pretest and posttest performance analysis, task completion efficiency, and student satisfaction survey outcomes. Both quantitative metrics and qualitative feedback are examined to provide a complete picture of the research findings.

As stated, 26 second-year Information Technology students participated in the research. They were divided into 6 groups (4 groups of 4 and 2 groups of 5 students).

Three groups (13 students) acquired knowledge and solved tasks in a traditional way while 3 groups (also 13 students) acquired knowledge and solved tasks with the help of contemporary technologies supported by artificial intelligence.

Analysis of the results obtained in the first activity (pretest), which served to measure students' initial knowledge regarding the assigned topic, revealed the following.

The pretest consisted of 10 questions that assessed basic understanding of classes, objects, and other key concepts of object-oriented programming (OOP) in Python.

When entering results, each correct answer was marked with a value of 1, while incorrect answers were marked with 0 (Figure 2). Groups were marked with colors - students who learned in a traditional way are in blue, and students who learned using contemporary technologies supported by artificial intelligence are in green.

The average accuracy of 46.15% suggests that students faced significant challenges with the test material, demonstrating the need for additional training on class concepts in object-oriented programming.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Correct	Incorrect	%	method
Student 1	0	1	1	1	1	0	0	0	1	0	5	5	50%	Tradicional Group
Student 2	1	0	0	0	0	1	0	1	0	0	3	7	30%	
Student 3	1	1	1	0	1	1	0	1	0	1	7	3	70%	
Student 4	1	1	1	1	1	1	0	0	0	0	6	4	60%	
Student 5	1	0	0	0	0	0	0	0	1	0	2	8	20%	
Student 7	1	0	0	1	1	1	0	1	0	0	5	5	50%	
Student 8	0	1	1	1	0	0	0	0	1	0	4	6	40%	
Student 9	0	1	1	0	1	1	0	0	0	0	4	6	40%	
Student 10	0	0	1	1	1	0	1	1	1	1	7	3	70%	
Student 11	0	0	0	0	1	0	0	0	1	1	3	7	30%	
Student 12	1	0	0	0	1	0	1	1	0	0	4	6	40%	
Student 12	0	1	0	1	1	1	0	1	1	0	6	4	60%	
Student 13	0	1	1	1	1	1	0	1	1	0	7	3	70%	48%
Student 14	1	0	1	0	1	1	0	0	1	1	6	4	60%	AI group
Student 15	0	1	0	0	0	0	0	1	1	0	3	7	30%	
Student 16	0	1	1	0	0	0	0	0	1	0	3	7	30%	
Student 17	0	1	1	0	1	1	0	0	0	0	4	6	40%	
Student 18	1	1	1	1	1	1	0	0	0	0	6	4	60%	
Student 19	1	1	1	1	1	1	0	0	0	0	6	4	60%	
Student 20	1	1	1	1	1	1	0	0	0	0	6	4	60%	
Student 21	0	1	0	0	0	0	0	0	0	0	1	9	10%	
Student 22	0	0	0	0	1	0	0	0	1	1	3	7	30%	
Student 23	1	0	0	1	1	0	0	1	0	0	4	6	40%	
Student 24	0	0	0	1	0	0	1	1	0	0	3	7	30%	
Student 25	1	1	1	1	0	1	1	1	1	0	8	2	80%	
Student 26	1	0	1	1	0	1	0	0	0	0	4	6	40%	44%
Correct	13	15	15	14	17	14	4	11	12	5				
Incorrect	13	11	11	12	9	12	22	15	14	21		Total average		
%	50,00%	57,69%	57,69%	53,85%	65,38%	53,85%	15,38%	42,31%	46,15%	19,23%			46,15%	

a)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Correct	Incorrect	%	method
Student 1	1	1	1	1	1	1	0	1	1	0	8	2	80%	Tradicional Group
Student 2	0	1	1	0	0	0	1	1	1	0	5	5	50%	
Student 3	1	1	0	1	1	0	1	0	1	1	7	3	70%	
Student 4	1	0	1	1	1	0	1	1	1	1	8	2	80%	
Student 5	0	0	1	1	0	0	1	0	1	0	4	6	40%	
Student 6	1	1	1	0	0	0	0	1	1	0	5	5	50%	
Student 7	1	0	1	1	1	0	1	0	0	0	5	5	50%	
Student 8	1	1	1	1	0	1	0	1	0	1	7	3	70%	
Student 9	1	0	1	0	1	0	1	1	0	0	5	5	50%	
Student 10	0	1	1	1	0	1	0	0	1	0	5	5	50%	
Student 11	0	0	1	0	1	1	0	0	1	0	4	6	40%	
Student 12	0	1	1	1	1	1	0	1	1	0	7	3	70%	
Student 13	1	1	1	1	1	1	1	1	0	0	8	2	80%	60%
Student 14	1	1	0	0	0	1	0	0	0	1	4	6	40%	AI group
Student 15	0	0	1	1	1	0	0	0	0	1	4	6	40%	
Student 16	0	0	1	1	1	1	1	0	0	1	6	4	60%	
Student 17	1	1	0	1	1	1	0	0	0	1	6	4	60%	
Student 18	0	0	1	1	1	1	1	0	1	0	6	4	60%	
Student 19	1	1	1	1	1	1	0	1	1	0	8	2	80%	
Student 20	0	1	1	1	0	1	1	1	1	1	8	2	80%	
Student 21	1	0	1	1	1	1	0	1	1	0	7	3	70%	
Student 22	0	1	0	0	1	1	0	0	1	1	5	5	50%	
Student 23	1	0	1	1	1	1	0	1	1	0	7	3	70%	
Student 24	0	1	1	0	1	0	1	1	1	0	6	4	60%	
Student 25	1	1	1	1	1	0	1	1	0	0	7	3	70%	
Student 26	0	1	1	1	1	1	0	1	1	0	7	3	70%	62%
Correct	14	16	22	19	19	16	12	15	17	9				
Incorrect	12	10	4	7	7	10	14	11	9	17		Total average		
%	53,85%	61,54%	84,62%	73,08%	73,08%	61,54%	46,15%	57,69%	65,38%	34,62%			61,15%	

b)

Figure 2. Tabular presentation of pretest (a) and posttest (b) results

The largest number of students (13 of them) correctly answered 4 to 6 questions, 4 students correctly answered 7 and 8 questions. There were no students who correctly answered 9 and 10 questions. On the other hand, the smallest number of questions that students answered was 1, and that was one student. There were no students who did not have a single correct answer.

Detailed analysis of correct and incorrect answers provided insight into the following:

The questions with the most correct answers were:

- Question number 5 (*What is a constructor* ***(init*** *method)*) - 17 correct answers or 65.38%, and
- Questions number 2 and 3 (*How to create a new class in Python? What is the basic unit in OOP?*) - with 15 correct answers or 57.69%.

These questions showed that students have solid prior knowledge regarding some concepts related to object-oriented programming. This result suggested that students possessed some preliminary knowledge of object-oriented programming concepts, presumably acquired through previous coursework.

The questions with the fewest correct answers were:

- Question number 7 (*Which keyword enables inheritance in Python?*) - 4 correct answers or 15.38% and
- Question number 10 (*How to access a class attribute?*) - 5 correct answers or 19.23%.

These questions showed that, although they relate to basic concepts of working with classes in Python, students could not manage and had difficulties with them.

After completing the training and task completion, students took the posttest. By summarizing the answers and analyzing them, the following facts were established.

The average accuracy of answers after the test was 61.15%. Most students correctly answered 5-7 questions (15 of them). Four students correctly answered 8 questions, which was also the best result because there were no students who correctly answered 9 and 10 questions. On the other hand, no student had fewer than 4 correct answers.

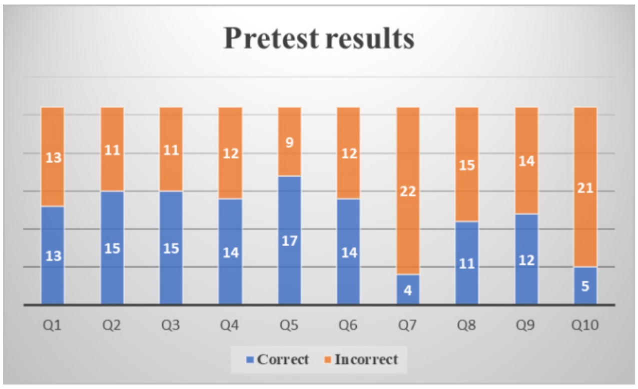
In this situation, the highest number of correct answers was recorded for the following questions:

- Question 3 (*What is the basic unit in OOP?*) - 22 correct answers or 84.62%, and
- Questions 5 and 6 (*What is a constructor* ***(init*** *method?), How is a class attribute defined?*) - 19 correct answers or 73.08%.

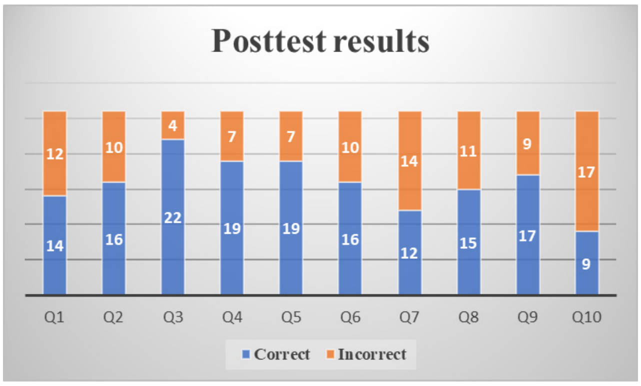
The lowest number of correct answers was recorded for the following questions:

- Question 10 (*How to access a class attribute?*) - 9 correct answers or 34.62%, and
- Question 7 (*Which keyword enables inheritance in Python?*) - 12 correct answers or 46.15%.

A comparative analysis of the pretest and posttest results (Figure 3) demonstrates an overall progress of 15% in mastering the material. The greatest progress is achieved on question 7 (30.77%) and question 3 (26.93%). This indicates that students directed most of their attention toward understanding concepts that had not been sufficiently mastered previously, and achieved significant progress in this domain.



a)



b)

Figure 3. Graphic presentation of pretest (a) and posttest (b) results

The smallest progress (Figure 4) is achieved on questions 1 and 2 (both 3.85%), which may indicate that students had already achieved relatively good results on the pretest (slightly below 60%) or that the implemented teaching method did not yield significant results in improving understanding of these questions. Notably, all questions have demonstrated improvement on the posttest, with no instances of performance decline compared to the pretest. The average student progress per question is 15.39%, which is consistent with the overall student progress.

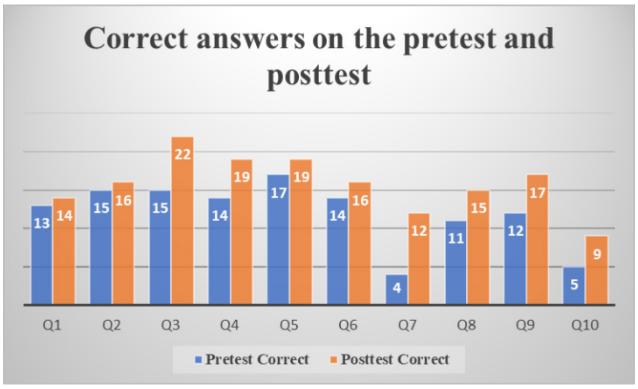


Figure 4. Review of the relationship between correct answers on the pretest and posttest

When examining progress by groups, greater progress was achieved by the group that learned using modern AI methods. They achieved 44% accuracy on the pretest (compared to 48% for the group that learned using traditional methods), while on the posttest they had 62% accuracy (compared to 60% for the group that learned traditionally). This would represent a progress of 16%, while the group that learned using traditional methods achieved a success rate of 12% (Figure 5).

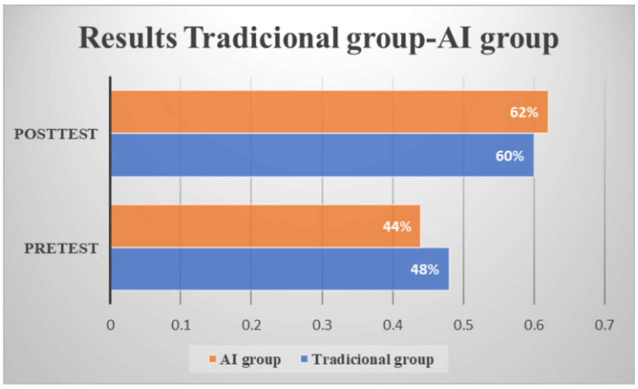


Figure 5. Comparison of the results of the group that learned using the traditional method and the AI group

After creating the pretest, the teacher provided instructions for further work to the groups and distributed the materials they needed to complete the tasks. In this part of the research, students had the task of first acquiring certain knowledge (some using traditional methods and others with the help of AI technologies), and then using that knowledge to solve practical tasks (3 tasks in Python). They had 60 minutes for this activity (20 minutes for learning + 40 minutes for solving tasks).

For each group, a student was selected to serve as a coordinator - reading materials, leading the group's work, and directing the activities of its members. The teacher conducted quantitative and qualitative monitoring of the groups' work - measuring the time required by the groups to complete the tasks and evaluating the accuracy of the tasks.

After completing this part of the research, the following data were obtained:

- All groups completed the assigned tasks and correctly solved all tasks
- Task completion times were as follows:
  - AI group 1- 28 minutes,
  - AI group 2- 32 minutes,
  - AI group 3- 35 minutes,
  - Traditional group 1- 43 minutes,
  - Traditional group 2- 49 minutes,
  - Traditional group 3- 51 minutes.

As it can be seen, the AI groups were the first to complete their tasks, while the groups that learned traditionally finished their tasks somewhat later, within the allocated time (Figure 6). This was expected, as the AI groups had assistance from chatbots that helped them write code, while the "traditional groups" wrote all the code for the tasks manually using only the instructional materials they had available.

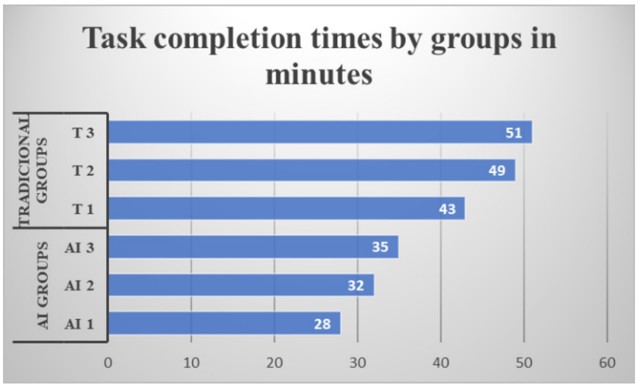


Figure 6. Comparison of task completion times by groups

The average task completion time for the AI group was 31.6 minutes, while for the "traditional group" it was 47.6 minutes. In other words, the AI group completed their tasks 33.5% faster, i.e., they required approximately one-third less time (Figure 7).

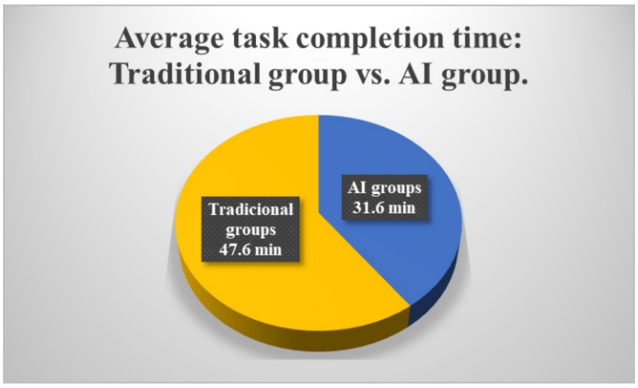


Figure 7. Comparison of average task completion times by groups

4.1. Results of the Student Satisfaction Survey

After completing the practical part of the research and solving the posttest, all research participants completed an anonymous survey lasting 10 minutes. The aim of the survey was to examine students' individual opinions about the applied learning methods, their satisfaction with this mode of work, as well as to identify potential challenges and difficulties they encountered during collaborative learning.

The survey consisted of 10 questions and had the following structure:

- ***Likert scale questions (1-5)*** - Used to measure the level of understanding of the material before and after the experiment, evaluate the effectiveness of AI tools, and assess student engagement and motivation (*questions 1, 2, 4, 5, 8*).
- ***Closed-ended questions (YES/NO)*** - Used to examine the usefulness of collaborative work and desire for future use of AI tools (*questions 3, 6*).
- ***Multiple-choice questions*** - For identifying the most effective learning methods and preferences in working approaches (questions 7, 9).
- ***Open-ended questions*** - For obtaining more detailed explanations regarding previously given answers (parts of questions 6 and 10).

The survey questions, as well as additional explanations related to it, are provided within Table 1.

Table 1. Survey questions with explanations

Q1: How would you rate your level of understanding of Python classes before participating in this experiment? (1-5 scale)
Q2: How would you rate your level of understanding of Python classes after participating in this experiment? (1-5 scale)
Q3: Did you benefit from collaborative group work? (Yes/No)
Q4: How do you rate the impact of AI assistance on your understanding of the material? (1-5 scale)
Q5: How would you rate the effectiveness of using AI tools (if you used them) in learning? (1-5 scale)
Q6: Would you like to use AI tools for learning in future subjects? (Yes/No)
Q7: Was it easier for you to learn the material through collaborative group tasks or working independently?
Q8: How would you rate your engagement and motivation during the experiment? (1-5 scale)
Q9: Which method was most effective for your learning?
Q10: What are, in your opinion, the biggest challenges (difficulties) you encountered during this experiment?
Group Types: **AI** = AI-assisted learning group, **TR** = Traditional learning group
Color coding: Green = AI groups, Orange = Traditional groups

The Likert scale from 1 to 5 was used as a standard instrument for measuring attitudes where:

- 1 represented the lowest level (very poor, no engagement).
- 5 represented the highest level (very good, very motivated).

Special attention during the survey was devoted to comparing responses between groups that used AI tools and groups that learned traditionally in order to quantify differences in subjective perception of the effectiveness of different learning methods.

The survey also enabled students to express their opinion about which methodology was most useful to them, as well as what major difficulties they encountered during the learning process.

After collecting and processing the survey data, the results were analyzed, revealing significant differences between the groups. Detailed results are presented in the following figures that illustrate the key findings of the research.

AI group students reported 79% greater learning progress than traditional learners (+1.38 vs +0.77 points) in their self-evaluations (Figure 8).

Category	AI Group	Trad. Group	Total
Average progress	**1.38**	**0.77**	**1.08**
Average progress %	**48.40%**	**26.40%**	**37.50%**
Students with progress ≥2	6 (46.2%)	2 (15.4%)	8 (30.8%)
Progress range	+1 to +3	0 to +2	0 to +3

Figure 8. Self-reported progress in understanding (Q1-Q2) - tabular presentation

Based on student self-evaluations, the AI group consistently outperformed the traditional group in perceived understanding (4.23 vs 3.69) and motivation (4.15 vs 3.38). AI tool users gave high effectiveness ratings (4.23/5) to these technologies (Figure 9).

Question	AI Group - Mean	AI Group - SD	Trad. Group - Mean	Trad. Group - SD	Overall - Mean	Overall - SD	Difference
Q1 (Understanding before)	2.85	0.69	2.92	0.76	2.88	0.71	-0.07
Q2 (Understanding after)	**4.23**	**0.6**	**3.69**	**0.48**	**3.96**	**0.6**	**0.54**
Q4 (AI assistance impact)	4.15	0.69	-	-	4.15*	0.69	-
Q5 (AI tools efficiency)	4.23	0.73	-	-	4.23*	0.73	-
Q8 (Engagement/motivation)	**4.15**	**0.69**	**3.38**	**0.51**	**3.77**	**0.71**	**0.77**

Figure 9. Summary results by questions (Likert scale) [1] - tabular presentation

AI students identified AI assistance as most effective (53.8%), while traditional students favored collaborative work (76.9%).

Both groups valued collaborative approaches, indicating synergy between AI and group learning (Figure 10).

Method	AI Group - Count	AI Group - %	Trad. Group - Count	Trad. Group %	Total - Count	Total %
AI assistance	**7**	**53.80%**	**0**	**0%**	**7**	**26.90%**
Collaborative work	5	38.50%	10	76.90%	15	57.70%
Independent research	1	7.70%	3	23.10%	4	15.40%

Figure 10. Most effective methods (Q9)- tabular presentation

4.2. Analysis of Survey Results

The survey results provide significant insights into student perceptions of AI-supported learning methodologies and indicate their potential advantages. **H1** is supported by data showing that the AI group reports 79% higher perception of progress in understanding the material (+1.38 vs +0.77 points based on self-assessment) compared to the traditional group. **H2** is also supported by data on motivation and engagement, where the AI group expresses 22.8% higher levels of motivation (4.15 vs 3.38 on a 1-5 scale). It should be noted that these results are based on student self-assessment, which represents a subjective measure of the learning experience.

The effectiveness of AI tools was rated highly (4.23/5), with 53.8% of AI group students considering AI assistance the most effective learning method. Collaborative work showed high acceptability among all students (84.6%), but was particularly pronounced in the AI group (92.3%), indicating synergy between AI technology and group work. The AI group also demonstrated greater efficiency in problem-solving, completing tasks 33.5% faster than the traditional group.

The main challenges identified by students include technical issues (4 mentions in the AI group), coordination of group work (7 total mentions), and time constraints (4 mentions). The traditional group particularly highlighted the problem of lacking immediate answers to questions and limited learning resources.

The analysis shows that AI technologies do not replace traditional learning methods, but rather complement and enhance their effects. The combination of AI assistance with collaborative learning represents the most promising approach, enabling students to achieve better results with greater motivation and engagement. However, successful implementation requires appropriate training, a balanced approach, and careful monitoring of effects to avoid excessive dependence on technology.

5. Discussion

Analysis of the experimental results reveals solid and objective evidence for confirming both research hypotheses. **H1** (assumes that students using AI-supported learning methods achieve better results) was confirmed through actual progress measurement results where the AI group achieved a 16% improvement on the posttest compared to a 12% improvement by the traditional group.

Additionally, the AI group achieved final results of 62% accuracy compared to 60% for the traditional group. This difference, although modest, testifies to the positive effects of AI technologies.

H2 (relates to increased student motivation and engagement through the use of AI tools) was confirmed through actual efficiency indicators, as the AI group completed tasks 33.5% faster (31.6 vs 47.6 minutes), indicating greater engagement and focus during work. Survey results further support these findings through high satisfaction ratings for AI tools (4.23/5) and students expressed preference for combining AI assistance tools with collaborative learning.

[1] Only AI group answered questions 4 and 5.

A significant conclusion of the conducted research represents the synergy between AI technologies and collaborative work, which manifested through the fact that 92.3% of the AI group preferred collaborative tasks. This result indicates that AI tools do not replace the social component of learning, but rather enhance it and make it more efficient. The main challenges identified by students include technical issues related to using AI tools and the need for better coordination of group work, which points to the importance of adequate training before implementation.

The research has certain limitations that should be considered when interpreting the results. The small sample of 26 students and short-term measurement of effects (90 minutes) limit the generalization of findings, while the focus on the specific area of object-oriented programming may differ from effects and results that would be obtained in other disciplines. Also, subjective assessment of progress through the survey may be influenced by students' enthusiasm toward new technology. Despite these limitations, the combination of objective measures (execution time, solution accuracy) with subjective assessments provides valuable insight into the potential of AI-supported learning methodologies and represents a solid foundation for future research in this area.

6. Conclusion

This study integrates a comprehensive theoretical review of AI-supported learning methodologies with empirical research, examining their practical application and impact on the educational process. A comprehensive analysis of six fundamental approaches (personalized learning, gamification, virtual assistants, PBL, collaborative learning, and VR/AR technologies) provides a clear picture of the current state and possibilities of these technologies in modern education.

The empirical research confirmed the established hypotheses through demonstration of AI-supported groups' performance in terms of task execution speed, knowledge progress, and subjective student satisfaction.

A significant contribution of this work represents the discovery of the complementary nature of AI technologies and traditional educational methods, particularly in the context of collaborative learning.

The practical effects of the work indicate the need for a strategic approach to the implementation process of AI in education. Also, attention should be devoted to adequate staff training and careful creation of instructional activities that maximize the advantages of technology. Research limitations, including sample size and short-term monitoring of effects, open directions for future research that should focus on long-term studies and application in various academic disciplines. This work represents a significant step toward a deeper understanding of the role of artificial intelligence in transforming educational processes.

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