Educational Methods for Enhancing Students' Critical Thinking Skills

Yuliia Saienko [1], Hanna Poberezhets [2], Olena Isakova [3], Maya Bondarenko [4], Rostyslav Liashenko [5]

[1] Bohdan Khmelnytsky Melitopol State Pedagogical University, Zaporizhzhia, Ukraine.
[2] Mykolayiv National Agricultural University, Mykolayiv, Ukraine.
[3] Dmytro Motornyi Tavria State Agrotechnological University, Zaporizhzhia, Ukraine.
[4] Ivano-Frankivsk National Medical University, Ivano-Frankivsk, Ukraine.
[5] Volodymyr Vynnychenko Central Ukrainian State University, Kropyvnytskyi, Ukraine.
[1] Corresponding author: saienkoyuliia@mspu.edu.ua

Abstract: The globalisation of the modern information environment and the challenges of professional development make it crucial to develop students' critical thinking skills, including data analysis skills, the argumentation of points of view, and decision-making based on the information received. The study aims to analyse pedagogical strategies for developing critical thinking in students and identify the most effective ways to develop this skill in higher education students. The key components of this work are the identification of the most effective pedagogical strategies for developing critical thinking in students, their implementation in the educational process and the evaluation of learning outcomes for higher education students who used the selected strategies and for students who studied according to the requirements of the established educational programme. The methods of questioning teachers, analysing learning outcomes and conducting a pedagogical experiment were used to achieve this goal. Identification of the most effective pedagogical strategies for the development of critical thinking was carried out by forming a questionnaire based on the developed evaluation criteria, which included: the level of involvement of higher education students, the quality of argumentation, the practical application of the selected strategies and the development of reflection and self-assessment skills. In this part of the study, the most effective strategies for developing critical thinking were selected, including problem-based learning, discussions and debates, case analysis, and work with contradictory sources. The next stage is the implementation of these strategies in the educational process. A control and an experimental group of students were formed; their indicators before the study did not have significant differences, while after the experiment, the experimental group that used the outlined strategies for developing critical thinking increased the number of students with high levels of learning. It is determined that identifying the most effective strategies for developing critical thinking positively impacts its development and learning outcomes and forms a high level of professional training for higher education students.

Keywords: critical thinking, pedagogical strategies, higher education students, case analysis, problem-based learning.

Introduction

One of the important tasks of the modern educational process is to develop critical thinking in higher education students. Critical thinking is the basis for the successful formation of professional competences and is aimed at analysing controversial situations, questioning certain statements, and making effective decisions in professional activities. Given the rapid growth of information and the challenges of analysing it, there is a need to develop critical thinking in future professionals and apply critical thinking strategies in practice.

The necessary professional skills of higher education students include extracting the central point from the information flow and checking the correctness and reliability of this data. Today's educational standards are based on the formation of competences based on the principles of analysis, evaluation, and synthesis of information, and

critical thinking is a key component of this process. Developing critical thinking is an important aspect of adapting to the challenges of the information society and professional fulfilment.

Despite the impact of critical thinking development on learning outcomes and further professional development, this aspect remains insufficiently addressed in pedagogical practice. Higher education institutions usually rely on the traditional knowledge transfer model, which is mainly focused on reproducing information with minimal opportunities for training critical thinking skills. Teachers often struggle to choose appropriate methods and strategies for developing critical thinking. Therefore, the analysis and implementation of pedagogical strategies in developing critical thinking is an urgent problem that needs research and implementation.

The study is devoted to identifying the most effective pedagogical strategies for teaching critical thinking to students and assessing their impact on learning outcomes.

Literature review

The development of critical thinking in today's context presents it as a key competence that forms the ability to analyse information and solve problems. Debates and discussions contribute to developing reflection and analysis skills as students analyse different points of view during this strategy [1], [2]. Debates stimulate cognitive conflict, which develops skills of argumentation, critical thinking and collaboration [3].

However, it should be noted that discussions can be ineffective due to the low level of students' knowledge [4], [5]. Case studies are popularised as a way of teaching students through the analysis of real-life situations. Case analysis teaches higher education students to use an interdisciplinary approach to solve today's challenges [6]. Case methods link theory to practice, which is especially important in the context of professional training [7]. However, the problem with using case studies is the difficulty of preparing cases.

Working with contradictory sources allows for identifying false information for manipulation [8]. This strategy develops media literacy and critical thinking in information overload [9], [3]. There is a need to prepare higher education students to perform a thorough analysis [10]. In addition to developing critical thinking skills, problem-based learning allows for creative competence and conscious learning [11], [12]. However, this strategy requires human, professional and time resources and is ineffective when applied to students with low motivation [13], [14]. A common feature of the author's points of view on developing critical thinking is the development of active learning by students, analysis of information and application of knowledge in practice [15]. Important aspects of the study of this topic are the interdisciplinarity of these approaches and the analysis of the conditions for adapting these strategies to the conditions of the educational programme.

The study outlines how to apply critical pedagogy in a university context that should mobilise academic dynamics [16]. The study aimed to expand and strengthen teachers' knowledge of active pedagogy as an opportunity to generate educational innovation processes through various strategies. The results show a dynamisation of learning processes and teacher satisfaction with topics that allow them to transform their teaching practice [17].

The application of critical pedagogy methods in graduate courses in security and control has revealed opportunities, challenges, and outcomes that provide key action strategies and commitments for both students and teachers [18]. Modern pedagogies are needed, and the implementation of a critical thinking approach to learning for engineering graduates is discussed [19].

Research has shown that introducing critical thinking strategies into the learning process changes the learning environment, leading to increased positive effects on learning outcomes, increased enthusiasm for learning, and higher levels of motivation [20].

The author shares some thoughts on the current state of affairs in engineering undergraduate education and invites the reader to reflect on universities' role in promoting critical thinking [21]. The organisation, structure and implementation of the course "Approaches to Active Pedagogy" are analysed. The course aimed to expand and strengthen teachers' knowledge on issues related to active pedagogy as an opportunity to generate educational innovation processes through various strategies [17].

The study identifies discussions as a strategy for developing critical thinking in the context of modern pedagogical practice. It provides recommendations on how to use critical learning strategies in engineering classrooms [22]. It has been determined that joint reflection on specific problematic issues leads to developing critical thinking and analytical skills [23]. Numerous studies have also focused on the challenges of developing critical thinking in the era

of artificial intelligence [24]. A combination of different methods of critical thinking development provides a diverse learning process and a better level of student adaptation.

Research methods

1. *Questionnaire survey of teachers.* The study outlined the criteria for the effectiveness of using pedagogical strategies for developing critical thinking in students. Based on these criteria, a questionnaire for teachers was developed. The questionnaire allows data on which strategies for developing students' critical thinking are the most effective for further implementation in the educational process. The survey was conducted among 22 lecturers who provided the educational programme. The study was conducted at Bogdan Khmelnitsky Melitopol State Pedagogical University (Zaporizhzhia), Mykolayiv National Agrarian University and Dmytro Motornyi Tavria State Agrotechnological University.

2. *Analysing learning outcomes* before implementing the outlined pedagogical strategies for developing critical thinking in higher education students allowed us to conclude the results of the entrance control. The control group included 102 higher education students, and the experimental group included 101.

3. *The experimental study* compared the learning outcomes of the control and experimental groups to assess the impact of the selected pedagogical strategies on the development of critical thinking and mastering the curriculum by higher education students. The experimental study covered two semesters of the academic year 2023-2024 to conclude the impact of pedagogical strategies for developing critical thinking on student learning outcomes.

Research results

Critical thinking is characterised by the ability to analyse information and master the skills to question assumptions, analyse cause-and-effect relationships, and make informed decisions. Table 1 analyses pedagogical strategies for developing students' critical thinking.

Table 1. Analysis of pedagogical strategies for the development of critical thinking in students

Pedagogical strategy	Characteristics	Skills that the strategy develops
Discussions and debates	Participating in discussions, justifying own position and analysing other points of view.	Argumentation of opinions, identification of weaknesses in the opponent's arguments, and critical attitude to the information received.
Case analysis	Research of hypothetical or actual cases (cases)	The goal is to develop analytical and problem-solving skills, decision-making strategies, the identification of contradictions, and the selection of key factors.
Socratic dialogue	The presentation of a sequence of questions forces a deeper exploration of the topic and helps identify problematic aspects.	Developing the ability to find logical errors and the correct formulation of questions.
Reflection	Post-assignment analysis, discussion of how to apply the knowledge gained.	Formation of a conscious attitude to learning.
Analysing contradictory sources	Researching materials containing different points of view	Assessing the bias of points of view, drawing independent conclusions.
Critical reading	Analysing texts, identifying arguments, checking facts and assessing credibility.	Skills in working with information.
Problem-based learning	Application of analysis, synthesis, and evaluation.	Use of the acquired knowledge in real-life situations.
Project-based learning	Development of projects based on data analysis and planning, presentation of results.	Applying an integrated approach.
Brainstorming	Putting forward proposals, discussing, criticising and selecting the best ways forward.	Creativity and group interaction skills.
Roleplay	Exploring the problem as participants in the process	Analysing from a critical perspective and understanding different points of view

Source: compiled by the author

A questionnaire was conducted among teachers to study the effectiveness of pedagogical strategies for developing critical thinking in students. Out of the 10 strategies outlined, it was proposed to choose the 4 most effective ones and then evaluate them according to the criteria outlined. Appendix 1 contains a questionnaire for determining the effectiveness of pedagogical strategies for developing students' critical thinking.

The questionnaire was formed based on the criteria developed to determine the effectiveness of applying pedagogical strategies for developing critical thinking in students. The first criterion is the level of student engagement, i.e. it assesses how actively higher education students participate in the learning process involving critical thinking. The second criterion is the quality of analysis and argumentation, i. e., the quality of forming conclusions and arguments from the point of view and the depth of analysis of the information received. Another important criterion for assessing the development of critical thinking is the ability to apply knowledge in practice, which characterises the successful use of the acquired knowledge and critical thinking skills in simulated or real situations. Moreover, the last criterion for studying this issue is mastering the skills of reflection and self-assessment, which indicate students' self-awareness of skills and evaluation of their work. The questionnaire was developed according to the four criteria outlined above. The first part of the questionnaire proposes selecting the four most effective strategies for developing higher education students' critical thinking and then evaluating them from 0 to 100 according to the questions asked.

The experiment lasted for two semesters of the 2023–2024 academic year. At the ascertaining stage of the experiment, a survey was conducted among 22 teachers, during which the most effective pedagogical strategies were selected. During the formative stage of the experiment, a control and experimental group of 102 and 101 were formed for higher education, during which the initial levels of knowledge of higher education students were identified, and the implementation of the proposed strategies in teaching disciplines was initiated. The control stage of the pedagogical experiment was aimed at comparing the level of knowledge of the control and experimental groups after the implementation of the proposed strategies and identifying their effectiveness. The study was conducted for higher education students of medical, socio-humanitarian and natural sciences at Bogdan Khmelnitsky Melitopol State Pedagogical University (Zaporizhzhia), Mykolayiv National Agrarian University and Dmytro Motornyi Tavria State Agrotechnological University.

Critical thinking positively impacts medical students' professional activities; it is a key factor in clinical decision-making in professional activities and improves diagnosis skills. Social sciences and humanities students develop the ability to argue and defend their point of view when developing critical thinking skills. Students of science and technology specialities learn to apply certain aspects of critical thinking when developing hypotheses and interpreting experimental data. Developing critical thinking skills in specialists is important to improving academic results, independent problem-solving skills, and cognitive skills. Figure 1 shows the evaluation of the effectiveness of pedagogical strategies during the ascertaining stage of the experiment.
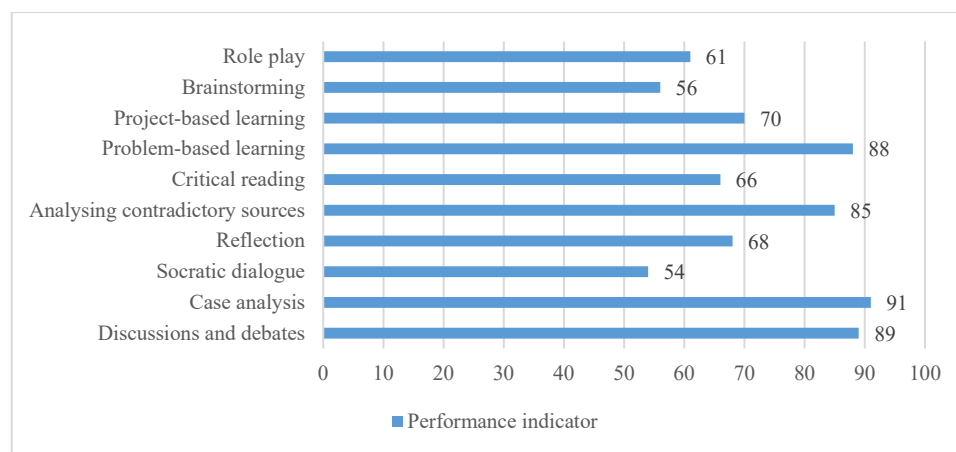

Figure 1. Evaluation of the effectiveness of pedagogical strategies in the course of the survey according to the developed criteria (on a 100-point scale)
Source: compiled by the author

The evaluation of the effectiveness of pedagogical strategies in the survey according to the developed criteria showed that the most effective strategies are discussions and debates, case analysis, analysis of contradictory sources and problem-based learning. Table 2 shows the effectiveness of the selected pedagogical strategies according to the criteria on a 100-point scale. These strategies were implemented in the course of the pedagogical experiment.

Table 2. Performance indicators of selected pedagogical strategies by the outlined criteria

Criterion Strategy	Level of engagement	Quality of argumentation	Ability to apply in practice	Reflection skills	Average indicator
Discussions and debates	88	90	90	88	89
Case analysis	90	92	88	92	91
Analysing contradictory sources	83	84	87	86	85
Problem-based learning	86	92	86	92	88

Source: compiled by the author

As Table 2 shows, the selected strategies scored high for each of the criteria, which allows us to assume the effectiveness of their implementation during the pedagogical experiment.

Table 3 presents the summarised results of higher education students' learning before implementing pedagogical strategies for developing critical thinking. For statistical testing, we used Pearson's χ^2 criterion, which answers whether different values of a feature occur with equal frequency in two or more empirical distributions.

Two hypotheses were put forward during the experiment:

H_0 - $\chi2_{(Emp)}$ is less than the critical value, the differences between the distributions are not statistically significant, the impact of the use of pedagogical technology on learning outcomes is insignificant;

H_1 - $\chi2_{Emp}$ is greater than the critical value, the differences between the distributions are statistically significant, and the impact of pedagogical technology on learning outcomes is significant.

Table 3. Learning outcomes of higher education students to implement pedagogical strategies for the development of critical thinking

Assessment	EG, %	EF $_{(EG)}$ of the number of higher education students	CG, %	EF $_{(CG)}$ of the number of higher education students	(EF $_{EG}$ − EF $_{CG}$)^2	(EF $_{EG}$ - EF $_{(CG)}$)^2/ EF $_{CG}$
A	7,92%	8	7,84%	8	0	0,00
B	12,87%	13	13,73%	14	1	0,07
C	17,82%	18	18,63%	19	1	0,05
D	25,74%	26	27,45%	28	4	0,14
E	25,74%	26	24,51%	25	1	0,04
FX	9,90%	10	7,84%	8	4	0,50
Total	100,00%	101	100,00%	102		0,81

Source: developed by the author

In Tables 3 and 4, the following conventions are used: EG, CG, % - the percentage of grades of a certain level on the ECTS scale for higher education students of the control and experimental groups; EF $_{(CG, EG)}$ of several higher education students - the empirical frequency of receiving grades for students of the control and experimental groups. The degree of freedom for this sample is v=5, critical values of χ^2 at v=5 ($\rho(0.05) \geq 11.07$; $\rho(0.01) \geq 15.086$)

The analysis of the results of higher education students' learning before introducing pedagogical strategies for developing critical thinking showed that the overall semester score of students in the control and experimental groups is practically the same. Levels C and D indicators predominate, and the share of level E is also significant. The value of $\chi^2 =$ is 0.81, which is less than $\rho(0.01)$ and $\rho(0.05)$. Therefore, we accept hypothesis H_0, the impact of pedagogical technology (before the experiment, both groups studied using traditional methods) on learning outcomes is insignificant.

Table 4 presents the summarised learning outcomes of higher education students after implementing the outlined pedagogical strategies for developing critical thinking.

Table 4. Learning outcomes of higher education students after the implementation of pedagogical strategies for the development of critical thinking

Assessment	EG, %	EF (EG) of the number of higher education students	CG, %	EF (CG) of the number of higher education students	(EF EG − EF CG)^2	(EF EG - EF CG)^2/ EF CG
A	17,82%	18	9,80%	10	64	6,40
B	25,74%	26	14,71%	15	121	8,07
C	27,72%	28	19,61%	20	64	3,20
D	13,86%	14	28,43%	29	225	7,76
E	11,88%	12	22,55%	23	121	5,26
FX	2,97%	3	4,90%	5	4	0,80
Total	100,00%	101	100,00%	102		31,49

Source: developed by the author

The analysis of the learning outcomes of higher education students after implementing pedagogical strategies for developing critical thinking showed that the overall semester grades of students in the control and experimental groups had significant differences. The number of students receiving A and B grades increased significantly, and the number of low-level grades decreased. The primary purpose of the pedagogical experiment was to identify the most effective pedagogical strategies for developing students' critical thinking and to study the impact of their application on learning outcomes. The value of $\chi^2 =$ is 31.49, it is more significant than $\rho(0.01)$ and $\rho(0.05)$, so we accept the hypothesis H_0, the impact of the use of pedagogical technology (before the experiment, both groups were taught using traditional methods) on learning outcomes is significant. Based on this, it can be argued that using the outlined pedagogical strategies for developing critical thinking positively impacts students' learning outcomes.

Figure 2 shows a general visualisation of the impact of pedagogical strategies for developing students' critical thinking on learning outcomes.
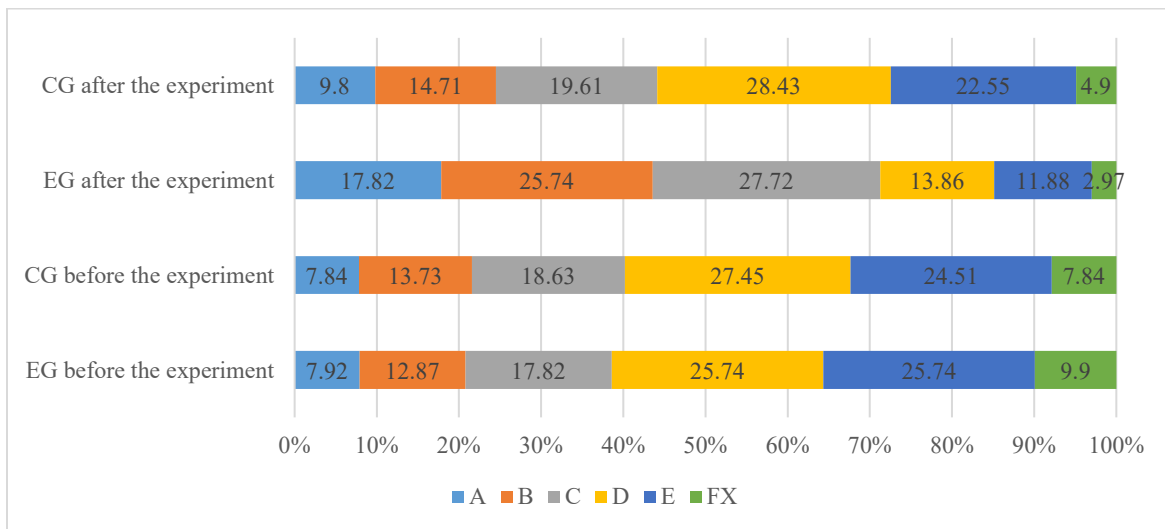

Figure 2. General visualisation of the impact of applying pedagogical strategies for developing students' critical thinking on learning outcomes.
Source: compiled by the author

The analysis of Figure 2 shows an increase in the percentage of higher education students with high levels of learning outcomes in the experimental group, which is an indicator of the effective selection and application of pedagogical strategies for the development of critical thinking and has a positive impact on the professional training of higher education students.

In order to develop critical thinking, various pedagogical strategies are used, each of which has its advantages and peculiarities of application. The paper investigates the creative thinking abilities of bioengineering graduates in the context of traditional and competence-based educational models. By comparing the convergent thinking scores of graduates of these different educational models, this study aims to identify the potential impact on problem-solving and innovation capabilities. The results reveal an understanding of the impact of educational models on critical thinking abilities. The analysis of the indicators indicates the possible impact of educational models on graduates' logical reasoning and analytical skills. The importance of this study lies in its contribution to the current discourse on innovative pedagogical strategies. Testing critical thinking abilities highlights the impact of educational models on graduates' cognitive skills [25]. Although problem-based learning shows high-performance indicators and develops teamwork and communication skills, it can be difficult for students with low levels of preparation and requires a significant time commitment from the teacher. This teaching strategy is usually effective in practical disciplines.

Information and communication technologies in medical education revolutionise learning by providing personalised learning and simulations, improving students' diagnostic and decision-making skills. It also offers access to vast databases for research and interactive learning, improving overall medical knowledge and practice. However, attention should be paid to effective pedagogical strategies to address critical thinking [26]. The ability to think critically is essential for medical students engaged in basic research, clinical diagnosis and treatment in the future. However, medical students currently lack this problem-solving strategy. The study outlines methods that positively impact improving students' computational thinking [27]. Case analysis develops decision-making skills and helps to integrate theory into practice. An important aspect of implementing this strategy is carefully preparing cases, which is important when teaching applied disciplines.

 An important skill for engineering and medical students is the implementation of electives related to health technologies in an interdisciplinary context; engineering and medical programmes should work closely together. Through these innovative projects, students discover new ways to co-design and interact with each other and

develop critical thinking skills [28]. The paper aims to study, analyse and synthesise the characteristics of medical students along with digital competences. A convincing visual model identifies the characteristics of medical students needed to develop digital literacy [13]. Processing contradictory sources provides an opportunity to assess the reliability of information critically. However, it should be noted that this method works well for high-level students and requires additional explanation of the methodology for lower-intermediate students.

The article investigates the use of intelligent equipment and the mode of online teaching of physiology in the practical activities of medical students. Based on the experience of the teaching process, the advantages of online teaching are summarised: high integration of learning resources, anytime, anywhere re-learning mode, network and data on the supervision of the learning process; teacher's assessment of critical thinking skills based on the use of problem-based learning techniques [4]. Discussions and debates require the teacher's moderating skills and can be ineffective for unmotivated students. They are effective if clear rules and structure are followed. A high level of teacher training, moderation skills, and the ability to create conditions for active learning are the leading professional qualities of academic staff to successfully overcome the challenges of developing students' critical thinking and implementing pedagogical strategies in this regard.

Conclusion

Thinking critically is one of the key skills that students must master during their studies at higher education institutions. The article analyses pedagogical strategies for developing critical thinking in students. A teacher questionnaire survey identified the most effective strategies for developing critical thinking, including problem-based learning, case analysis, discussions, and work with contradictory sources. Case analysis and problem-based learning tools are based on the interaction of higher education students with actual or hypothetical situations, contributing to the practice-oriented nature of learning and the development of argumentative skills. In the era of information overload, the use of analysis of controversial sources is relevant; it is aimed at developing the identification of unreliable data and argumentation of the point of view of higher education students. Debates and discussions contribute to developing communicative competence, comprehension and critical evaluation of one's own experience.

The most effective pedagogical strategies for developing students' critical thinking were identified based on an assessment based on four criteria: level of engagement, quality of argumentation, ability to apply knowledge in practice, and ability to reflect. After identifying the most effective strategies for developing critical thinking, their impact on learning outcomes was assessed. The overall results show that the learning outcomes of the experimental group that applied the identified strategies improved. Introducing critical thinking development strategies into the educational process contributes to forming competences that are important for the professional development of higher education students and is a priority area in pedagogical science.

References

[1]   Alkhatib, O. J. (2022). An effective assessment method of higher-order thinking skills (problem-solving, critical thinking, creative thinking, and decision-making) in engineering and humanities. *2022 Advances in Science and Engineering Technology International Conferences (ASET)*, Dubai, United Arab Emirates, 1-6. https://doi.org/10.1109/ASET53988.2022.9734856

[2]   Chuang, T.-Y., Lu, Y.-H., Tsai, S.-K., & Chen, W.-F. (2024). Examining critical thinking skills in game-based learning: A behavioural analysis approach. *2024 16th IIAI International Congress on Advanced Applied Informatics (IIAI-AAI)*, Takamatsu, Japan, 148-151. https://doi.org/10.1109/IIAI-AAI63651.2024.00037

[3]   Mujtaba, S. J., Kigobe, J., & Van Leeuwen, K. (2024). Parental involvement in primary schools in Tanzania: Effects of a pre- and in-service teacher training. *Teaching and Teacher Education* 140, 104459. https://doi.org/10.1016/j.tate.2023.104459

[4]   Liu, Y. (2022). Application of intelligent equipment and physiology online system mode in practice of medical students. *2022 4th International Conference on Smart Systems and Inventive Technology (ICSSIT)*, Tirunelveli, India, 1297-1300. https://doi.org/10.1109/ICSSIT53264.2022.9716289

[5]   Mazur, I., Hasiuk, N., Drohomyretska, M., Popovych, I., & Radchuk, V. (2023). Discussion on individual educational trajectory as an integral component of continuous professional development. *Advanced Education* 11(23), 144-156. https://doi.org/10.20535/2410-8286.295529

[6]   Muschkin, C., Ladd, H., & Sauval, M. (2024). Pre-K enrolments and teaching environments in North Carolina elementary schools. *Children and Youth Services Review* 164, 107832. https://doi.org/10.1016/j.childyouth.2024.107832

[7]   Khambuo, S., Tep, P., & Tanprasertkul, S. (2024). Implementing a constructionist project-based learning approach to enhance chemistry learning achievement in eleventh grade students. *2024 9th International STEM Education Conference (iSTEM-Ed)*, Cha-am, Hua Hin, Thailand, 1-5. https://doi.org/10.1109/iSTEM-Ed62750.2024.10663104

[8]   Deroncele-Acosta, A., et al. (2021). E-learning for the development of critical thinking: A systematic literature review. *2021 XVI Latin American Conference on Learning Technologies (LACLO)*, Arequipa, Peru, 173-180. https://doi.org/10.1109/LACLO54177.2021.00072

[9]   Farooqi, S., & Naeem, F. (2023). Antecedents and impact of flipped classroom on student engagement: A mediating study using SEM-PLS. *Advanced Education* 11(23), 52-68. https://doi.org/10.20535/2410-8286.272234

[10]   Batsurovska, I., Dotsenko, N., Gorbenko, O., Haleeva, A. & Kurepin, V. (2024). Online control of educational results of the unit "Electricity" in the conditions of blended learning. *Journal of Physics: Conference Series* 2871, 012013. https://doi.org/10.1088/1742-6596/2871/1/012013

[11]   Dotsenko, N. (2023). Interactive posters as a learning tool for practical tasks in the context of electrical engineering education. *2023 IEEE 5th International Conference on Modern Electrical and Energy System (MEES),* Kremenchuk, Ukraine, 1-5. https://doi.org/10.1109/MEES61502.2023.10402463

[12]   Gou, T., Guo, D., & Fan, M. (2024). Design and empirical research of critical thinking training model based on digital science argument mapping. *2024 International Symposium on Educational Technology (ISET)*, Macau, Macao, 324-328. https://doi.org/10.1109/ISET61814.2024.00070

[13]   Srikong, M., Wannapiroon, P., & Nilsook, P. (2021). Synthesis of digital medical student characteristics. *2021 6th International STEM Education Conference (iSTEM-Ed)*, Pattaya, Thailand, 1-4. https://doi.org/10.1109/iSTEM-Ed52129.2021.9625123

[14]   Van Veggel, N., Engward, H., & Howlett, P. (2023). Investigating higher education course leadership practice - An argument for using grounded theory. *Advanced Education* 11(23), 104-117. https://doi.org/10.20535/2410-8286.288558

[15]   Barkovska, O., Ivashchenko, H., Rosinskiy, D., & Zakharov, D. (2024). Educational training simulator for monitoring reading technique and speed based on speech-to-text (STT) methods. *Information Technologies and Learning Tools* 103(5), 21-38. https://doi.org/10.33407/itlt.v103i5.5647

[16]   Palomino-Flores, P., & Cristi-López, R. (2021). Emancipatory action of teaching practice in critical pedagogy. *2021 IEEE Sciences and Humanities International Research Conference (SHIRCON)*, Lima, Peru, 1-4. https://doi.org/10.1109/SHIRCON53068.2021.9652246

[17]   Garcés Chiriboga, M. V., Flores Chuquimarca, D. K., & Cajamarca Illescas, C. M. (2023). Active pedagogy as a tool for innovation: Perspectives from professional development in teacher education. *2023 XIII International Conference on Virtual Campus (JICV)*, Porto, Portugal, 1-4. https://doi.org/10.1109/JICV59748.2023.10565693

[18]   Jeimy, J. & Cano, M. (2023). Diflexive pedagogy: An educational proposal to create learning hubs in the classroom. *2023 IEEE World Engineering Education Conference (EDUNINE)*, Bogota, Colombia, 1-5. https://doi.org/10.1109/EDUNINE57531.2023.10102875

[19]   Chandarana, F., & Shukla, M. (2023). Smart way of learning graph theory with outcome-based educational model: Transformational pedagogy for engineering graduates in mathematics courses. *2023 IEEE 11th Region 10 Humanitarian Technology Conference (R10-HTC)*, Rajkot, India, 248-253. https://doi.org/10.1109/R10-HTC57504.2023.10461762

[20]   Efe, F., et al. (2023). Examining the impact of experiment-centric pedagogy on students' critical thinking, test anxiety, and motivation while using hands-on technology through pre- and post-activity questionnaires. *2023 IEEE Integrated STEM Education Conference (ISEC)*, Laurel, MD, USA, 162-166. https://doi.org/10.1109/ISEC57711.2023.10402320

[21] Ortega-Sanchez, C. (2023). From pedagogy to andragogy to heutagogy: Students becoming engineers. *2023 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, Auckland, New Zealand, 1-4. https://doi.org/10.1109/TALE56641.2023.10398316

[22] Murzi, H. (2024). Workshop proposal: Culturally relevant pedagogy in engineering: Examining how who we are informs how we teach. *2024 IEEE World Engineering Education Conference (EDUNINE)*, Guatemala City, Guatemala, 1-2. https://doi.org/10.1109/EDUNINE60625.2024.10500561

[23] Mei, A., Li, X., & Long, T. (2023). Does the blue hat work? The impact of using six-thinking hats in online collective reflection on pre-service teachers team cohesion, critical thinking, and creativity. *2023 International Symposium on Educational Technology (ISET)*, Ho Man Tin, Hong Kong, 28-33. https://doi.org/10.1109/ISET58841.2023.00015

[24] Ouyang, W., & Feng, H. (2022). Critical thinking on the Turing test as a standard for testing artificial intelligence. *2022 International Conference on Artificial Intelligence in Everything (AIE)*, Lefkosa, Cyprus, 297-300. https://doi.org/10.1109/AIE57029.2022.00064

[25] Martínez-Ávila, M., & Guajardo-Flores, D. (2023). A comparative study of creative thinking abilities among bioengineering graduates: Assessing the impact of traditional and competency-based educational models. *2023 World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC)*, Monterrey, Mexico, 1-6. https://doi.org/10.1109/WEEF-GEDC59520.2023.10343829

[26] Hind, B., Barkouk, A., Belayachi, N., Jallal, M., Serhier, Z., & Othmani, M. B. (2024). Empowering future healthcare professionals: Enhancing medical education through the integration of artificial intelligence. *2024 International Conference on Circuits, Systems and Communication (ICCSC)*, Fes, Morocco, 1-4. https://doi.org/10.1109/ICCSC62074.2024.10616755

[27] Si, J., Feng, H., Niu, Z., Bian, Yi., Fu, Yu, & Guo, H. (2021). Teaching methods of computational thinking for medical students in the big data age. *2021 16th International Conference on Computer Science & Education (ICCSE)*, Lancaster, United Kingdom, 13-20. https://doi.org/10.1109/ICCSE51940.2021.9569311

[28] Toma, M., Syed, F., & McCoy, L. (2023). Integrating multi-professional principles and practices into the medical education curriculum. *2023 IEEE Integrated STEM Education Conference (ISEC)*, Laurel, MD, USA, 89-95. https://doi.org/10.1109/ISEC57711.2023.10402190

Refer Next page for Appendix: Questionnaire

Appendix 1
A questionnaire for determining the effectiveness of pedagogical strategies for developing critical thinking in students

1.   The list below identifies the 4 most effective strategies for developing students' critical thinking.
o   Discussions and debates
o   Case analysis
o   Socratic dialogue
o   Reflection
o   Analysing contradictory sources
o   Critical reading
o   Problem-based learning
o   Project-based learning
o   Brainstorming
o   Roleplay

2. Evaluate **the level of** student **engagement** when using the four selected strategies. Each indicator (Items 1–5) is scored from 1 to 20 points.
L1. Students actively participate in discussions or assignments.
L2. Students ask questions during the discussion.
L3. Students give reasons for their answers or proposals.
L4. Students show interest in the topic under discussion.
L5. Students are ready to spend time independently and additionally study the topic.

Name of the strategy	S1	S2	S3	S4	S5	Amount
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	

2. Evaluate **the quality of** students' **analysis and aggregation** when using the four selected strategies. Each indicator (Items 1–5) is scored from 1 to 20 points.
Q1. Students provide unique arguments to support a point of view.
Q2. Students provide facts and evidence to support a point of view.
Q3. Students can find weaknesses in the statements of their opponents
Q4. Students interpret data accurately and correctly.
Q5. Students draw logical conclusions.

Name of the strategy	S1	S2	S3	S4	S5	Amount
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	

3. Assess **the ability to apply** students' **knowledge in practice** when using the four selected strategies. Each indicator (Items 1–5) is rated from 1 to 20 points.
A1. Students have a high level of task performance
A2. Students provide suggestions for improving educational processes
A3. Students explain complex ideas using the materials they have studied.
A4. Students can transfer knowledge from one area to another
A5. Students can perform tasks that involve solving real-world problems.

Name of the strategy	S1	S2	S3	S4	S5	Amount
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	

3. Assess **the** students' **self-assessment and reflection skills** using the four selected strategies. Each indicator (Items 1-5) is scored from 1 to 20 points.

S1. Students can critically evaluate their results and approaches.

S2. Students identify strengths and weaknesses in their work.

S3. Students provide suggestions for improving their learning activities.

S4. Students take reflective notes.

S5. Students provide insightful conclusions from the self-assessment process.

Name of the strategy	S1	S2	S3	S4	S5	Amount
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	
Enter the name	0-20	0-20	0-20	0-20	0-20	