The impact of AI integration on the formation of students' critical thinking in the modern educational process

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Abstract

This article examines the implications of using Artificial Intelligence (AI) technologies to develop students' critical thinking skills in the educational process. The paper considers both the positive aspects of using AI – such as opportunities for personalised learning, effective information analysis and stimulation of creative thinking – and the potential risks associated with over-reliance on technology and a reduced ability to independently and critically interpret data. The study's methodology uses a survey with Likert scale questions, the analysis of descriptive statistical indicators and the classification of students using the Support Vector Machine (SVM) method. Using permutation importance analysis, the study identified which aspects of AI use had the greatest impact on developing critical thinking. The results showed the high effectiveness of the SVM model in classifying students. Also, they revealed that ethical issues – especially those related to data confidentiality and verification of information reliability – are key factors in forming critical thinking. The data obtained indicate the need to develop adaptive educational strategies that consider modern technological trends and promote the development of a high level of analytical and critical skills in students.

Keywords

artificial intelligence, critical thinking, education, SVM, permutation meaning, data analysis, ethical aspects

1. Introduction

In the 21st century, artificial intelligence (AI) technologies have gained incredible popularity and have become an integral part of many fields, including education. Its application is changing how students and teachers interact and bringing about significant adjustments to educational processes and practices. In particular, thanks to AI's ability to analyse large data sets, generate new content and predict outcomes, it has considerable potential to transform education – a transformation that requires rethinking the roles of teachers, students and the educational process itself. Generative AI technologies, in particular tools such as ChatGPT, Gemini and others, enrich the learning process by providing personalised support to students, assisting with information retrieval, fact checking and problem solving. However, alongside these positive opportunities, AI in education presents new challenges, particularly in developing students' critical thinking skills. How can we balance the automation of learning and the ability of students to analyse and critically interpret information independently?

According to the UNESCO report "Recommendation on the Ethics of Artificial Intelligence" (2021) [1], the implementation of AI in the educational process should be accompanied by the development of ethical standards that ensure accountability for both students and educators in the use of these technologies, as well as helping to cultivate the ability to critically evaluate the information they receive through these tools – which, if used properly, can become a powerful tool for developing cognitive strategies.

Recent research highlights that the use of AI can positively impact students' development of critical thinking skills, particularly in the context of fact-checking, data analysis and complex problem solving. However, as noted by UNESCO in its "Competency Framework for Students" (2024) [2], achieving

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these goals requires that learners not only acquire knowledge about how to use AI, but also have the opportunity to develop skills in critically evaluating and analysing the information generated by these tools [3], [4]. AI can foster critical thinking by enabling students to quickly obtain necessary information, verify its accuracy, and evaluate different perspectives. At the same time, reliance on technology can reduce interest in thinking independently and interpreting information. According to the World Economic Forum's "Future of Jobs Report 2025" [5], technologies – particularly AI – are becoming key to developing the skills needed for future work, such as analytical thinking and technological literacy [2].

These technologies can also pose risks if students do not learn to effectively verify and analyse the information they receive, thereby reducing their level of critical evaluation.

Despite the significant potential of AI, only a few countries – such as Estonia, Korea, China, the United Kingdom, Canada and Australia – have national policies and frameworks for training educators to use AI in the educational process. These countries are actively integrating technology into their education systems, while also providing professional development for teachers to effectively use AI to foster the development of critical thinking skills in students [3].

In addition, new technologies are attracting investment in the education sector, and forecasts for the global market are very optimistic: the global market for AI in education is expected to grow by 36% per year until 2030 [6]. As noted in research by Wang et al. [7], the field of education is particularly well suited for AI technologies because the learning process – including knowledge acquisition and teaching – is a cognitively demanding scientific activity, and AI programs designed for problem solving and understanding based on algorithms and knowledge bases can effectively support and enhance both educators' and learners' abilities in teaching and learning. However, in addition to the many benefits, AI poses several challenges for educational institutions, particularly concerning ethics, privacy and ensuring the development of critical thinking skills in students.

Our research aims to investigate the impact of the use of AI technologies on the development of critical thinking in students during the learning process. Specifically, we are investigating how various factors – such as the frequency of AI use, attitudes towards fact-checking, and students' emotional state – influence their ability to interpret educational material critically. The results of this study will help determine whether integrating AI into the educational process promotes the development of critical thinking skills in students or creates the risk of technology dependency, thereby reducing their ability to analyse and evaluate information independently.

2. Literature review

In the current era of digitalisation of education, AI technologies are gaining significant importance in shaping innovative approaches to learning. From the emergence of the first experimental models to the implementation of modern generative systems, AI is continuously expanding its capabilities, contributing to enhancing the educational process and raising challenges related to ensuring the ethics and autonomy of students' thinking. Much attention has been paid to scientific research to analyse the impact of AI integration on the development of critical thinking, which is one of the key indicators of educational quality. The present literature review aims to systematise modern approaches to the use of AI in education, identify both the positive and negative consequences of this process, and outline possible directions for further research in developing students' cognitive skills.

Artificial intelligence emerged in the mid-twentieth century and, as noted by Perrotta and Selwyn [8], its tools are actively used in education for the study of different subjects (including languages and STEM) and to support teaching activities in interactions with students, assessments, etc. A bibliometric analysis presented by Wang et al. [7] shows a growing interest in AI in education since 2017, explained both by the expansion of technological capabilities [9] and by the massive shift to online learning during the COVID-19 pandemic [10].

In parallel with conceptual studies, applied algorithmic approaches are actively being developed to improve the efficiency of educational resources. For instance, in a study [11] conducted within the

methodological framework of design science, the support vector machine (SVM) algorithm was applied to optimise the classification of online educational materials. The research aimed to overcome the limited accuracy of traditional classification methods to provide students with more convenient and precise access to learning resources. The proposed SVM-based classifier was compared with neural networks and deep learning methods: the results showed an increase in precision by 3.26% and in recall by 2.01% compared to traditional approaches, as well as a better performance balance according to the F-measure. This demonstrates that the application of SVM has practical value in online education, particularly for tasks related to searching and organising large volumes of resources. Similarly, research in Educational Data Mining (EDM) highlights the potential of SVM for predictive analytics in higher education [12]. With the rapid expansion of educational institutions and the resulting accumulation of unstructured data, there is a growing need for effective tools to transform raw data into meaningful insights. One study applied an SVM-based classification approach to student placement data, successfully predicting placement outcomes and showing that such methods can improve institutional decision-making. Beyond supporting more effective student placement strategies, SVM was shown to enhance the competitive advantage of educational institutions by enabling more informed planning and resource allocation. As a supervised learning technique, SVM thus represents a robust and efficient tool for pattern recognition and predictive modelling within the educational domain. These contributions illustrate that beyond its theoretical appeal, SVM provides a strong methodological foundation for addressing classification and prediction tasks in education. This underlines its relevance as a machine learning technique and a practical means of improving educational quality and institutional effectiveness.

Regarding ethical considerations in the application of AI in education, Williamson [13] notes that in the initial stages of implementation, developers focused primarily on technological and pedagogical aspects – namely, on creating the system and evaluating its effectiveness in an educational context. The researcher also emphasises that modern ethical issues are becoming more pronounced due to the growing integration of technologies at all levels of education, the increased collection of data in the learning environment, and the active use of digital platforms to analyse and commercialise information about user behaviour. Similar observations are supported by studies by Akgün and Greenhow [14], Boulay [15] and Glover [16]. In particular, Boulay [15] points out the risk that the use of ChatGPT may lead to information being obtained that does not meet objective standards, and that educators may make decisions about student support based solely on analytical data.

Lim et al. [17] define the role of generative AI as a transformative resource for the future of education, while Yatigammana and Sampath [18] found in their systematic review that about half of the studies confirm the positive impact of generative AI on the development of students' critical thinking.

However, some studies warn of a potential threat to critical thinking associated with excessive reliance on GenAI tools. For example, Bhosale [19] emphasises that excessive use of such technologies can negatively affect researchers' ability to conduct independent analysis. Benard [20] notes that despite the increasing integration of GenAI into productivity-enhancing tools, these tools may limit users' ability to reflect on their own research. Over time, excessive reliance may lead to declining creativity and analytical skills. Research by Farrokhnia et al. [21] showed that although the use of GenAI by students facilitates faster decision-making, it simultaneously reduces their motivation to conduct independent research and form their own conclusions. In addition, the ease with which teachers can generate lesson plans and assessments can potentially affect their mastery of the subject matter, affecting high-level cognitive skills – particularly the ability to think critically and analytically. Szmyd and Mitera [22] found that although students find AI-based tools useful for developing information analysis and argumentation skills, many express concern that over-reliance on these technologies could weaken their ability to think independently and make well-considered decisions. According to their conclusions, students value the opportunity to critically assess their own beliefs, while recognising that while AI can support this process, it cannot completely replace traditional teaching methods, which are key to developing autonomous thinking.

Research by Thiga [23] has shown that the use of GenAI has a dual nature: on the one hand, it can stimulate the development of critical thinking through systematic analysis of the results of the use of these tools; on the other hand, it poses a danger, as the data obtained are often inaccurate, biased and

prone to hallucinations, thus complicating the process of making informed decisions.

Given the multiple impacts of AI technologies on the educational process and the development of critical thinking, there is a need for further research to elucidate these relationships better and to develop effective strategies for integrating AI into education to support the development of students' analytical and critical skills.

While prior research has demonstrated the utility of SVM for improving the classification of educational resources and predicting student placements, little attention has been paid to using SVM to model students' critical thinking directly. Our research addresses this gap by applying SVM to survey data on students' interaction with AI, thereby bridging the methodological advances of machine learning with the theoretical challenge of assessing cognitive and ethical skills.

3. Methodology

The research methodology aims to analyse the impact of AI technologies on the development of students' critical thinking in the learning process. To this end, a survey was conducted among students of the faculties of "Economics and Management" and "Finance and Accounting". The choice of humanities faculties is justified by the hypothesis that students of technical faculties have a higher level of critical thinking due to the greater number of mathematical disciplines in their curricula [24], [25], [26]. The study, therefore, focuses on determining how the use of AI affects the development of critical thinking, specifically in humanities students.

In addition to general information about age, gender and frequency of AI use during learning, the data collection survey included 15 questions covering different aspects of AI use in the learning process and reflecting students' attitudes towards critical thinking. For example, the question on the importance of privacy ('Rate how important privacy is to you when using AI') allows an assessment of how much students value ethical aspects when working with GenAI. Another question ('How confident do you consider yourself to be as an AI tool user?') measures the students' level of confidence in using AI tools, while the question on the frequency of verifying information from additional sources ('How often do you verify information provided by AI from other sources?') and statements indicating a tendency to seek alternative explanations allow for an assessment of their ability to conduct in-depth analysis and critically evaluate the information received. The survey also includes items designed to determine the impact of AI on students' emotional state when solving academic tasks, which helps to reveal how these technologies affect their levels of stress and self-esteem.

All questions were rated using a Likert scale from 1 to 5, where 1 means 'strongly disagree' / 'don't feel', and 5 means 'strongly agree' / 'strongly feel'. This approach allowed the collection of quantitative data reflecting the intensity of certain aspects of interaction with AI and the level of critical thinking.

The results obtained were used as input features for building a model to classify students based on their level of critical thinking using the Support Vector Machine (SVM) method. The method's main idea is to find a hyperplane that maximises the distance between the closest points of different classes, called support vectors. SVM can be used for both linear and non-linear classification by using different kernel functions. In this study, the RBF (Radial Basis Function) kernel was used for classification, which allows the model to work with non-linearly separable data. The RBF kernel transforms the data into a higher-dimensional space where it becomes linearly separable, allowing the model to determine the boundaries between classes in complex cases accurately. Model parameters such as C = 10 and gamma = 0.01 were chosen to optimise the balance between maximising the margin and minimising errors on the training data. Using this kernel helped to achieve high accuracy in classifying students into groups with and without critical thinking, indicating the model's effectiveness for this task. The model was trained on 80% of the data and its performance was evaluated on the remaining 20% by calculating accuracy, precision, recall and F1 score metrics, and by analysing the confusion matrix and the classification report.

Feature importance was assessed using the permutation method, which can be used to determine which survey questions have the most significant impact on classification results. Permutation importance is

a technique for assessing feature importance in machine learning models that measures the change in model accuracy after randomly shuffling the values of a given feature.

Thus, the methods applied allowed for a comprehensive assessment of various aspects of AI application in the learning process, and the built SVM model provided an effective classification of students based on their level of critical thinking. This contributes to a deeper understanding of the relationships between technological innovations and cognitive skills, which is important for further improving educational practices. Our design operationalises critical thinking through ethically and cognitively anchored items (verification, contradiction analysis, privacy salience, affect), enabling a direct, model-based assessment rather than proxy outcomes (e.g., grades or placements).

4. Results

The results of the study showed that most students use AI for learning, but the frequency of use varies: some use it regularly, others only occasionally (figure 1). The most common answer was 'several times a week', chosen by 117 respondents. This suggests that a significant proportion of respondents actively use AI tools in the learning process. Only 2 students stated that they never use AI in the learning process.

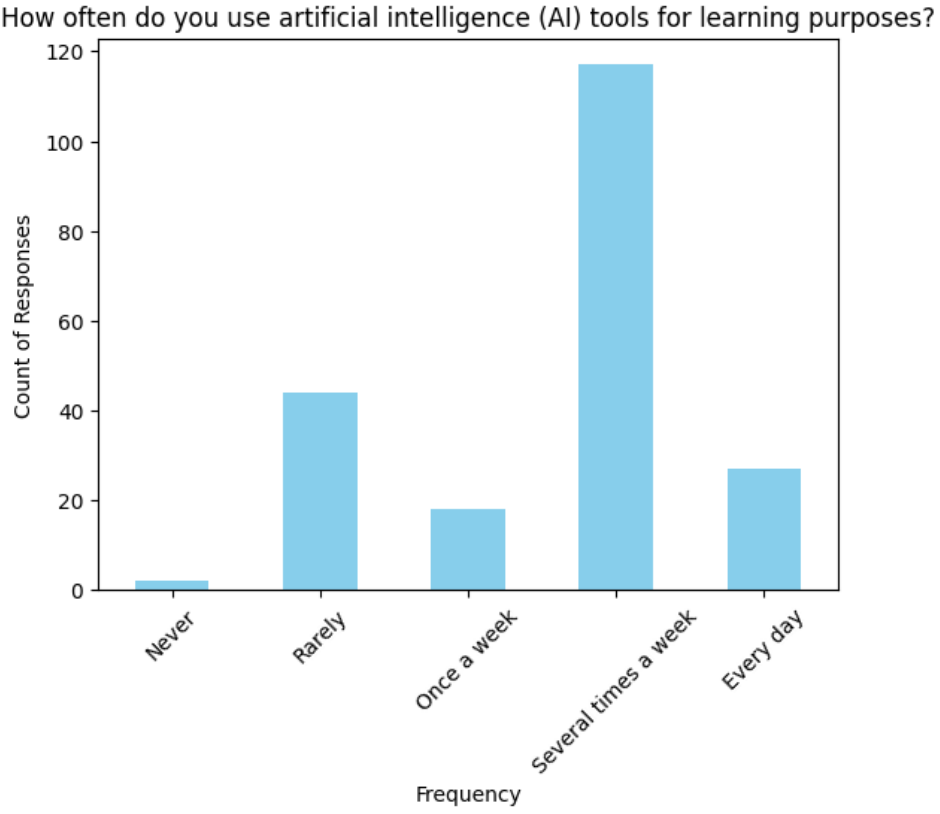

Figure 1: Frequency of AI use in the educational process.

Students generally demonstrate a high level of critical thinking by reviewing information from other sources, indicating their ability to analyse the data provided by AI (table 1).

The study results indicate that students generally tend to think critically, especially when they need to verify or analyse the information provided by AI. For example, most respondents indicated that they try to find confirmation of the information they receive from other sources, which is reflected by a mean of 3.25 and a standard deviation of 1.05. This indicates moderate variability in responses. Students also actively analyse information when it contradicts their knowledge (mean 3.66, standard deviation 1.09), indicating their ability to evaluate data from different perspectives thoroughly.

Table 1
Descriptive analysis of Likert scale responses.

№	Question	1 – 'strongly disagree' 5 – 'strongly agree'					Mean	Std. Dev.
		1	2	3	4	5		
Q1	Rate how important data privacy is to you when using AI.	10	12	74	55	57	3.66	1.09
Q2	How confident do you consider yourself as an AI tool user?	7	24	102	58	17	3.26	0.89
Q3	How often do you verify AI-provided information from other sources (e.g., refer to textbooks, websites, etc., for confirmation)?	13	33	78	62	22	3.23	1.04
Q4	When I receive information from AI, no matter how convincing it is, I always try to find confirmation in other sources.	8	38	87	43	32	3.25	1.05
Q5	If the information received contradicts my prior knowledge, I tend to thoroughly analyze it from different perspectives.	9	18	62	65	54	3.66	1.09
Q6	When I encounter unusual or ambiguous information, I usually make an effort to search for alternative explanations, even if the first one seems logical.	5	24	77	64	38	3.50	0.99
Q7	When using AI, I sometimes have doubts about the accuracy of the provided information and look for additional arguments to confirm or disprove it.	5	24	56	75	48	3.66	1.03
Q8	I like it when discussions about AI raise issues regarding data privacy – it encourages me to reconsider my views.	21	30	74	56	27	3.18	1.14
Q9	When the AI system provides me with an answer, I usually do not accept it immediately but analyze possible alternatives before using it in my work.	9	36	72	55	36	3.35	1.09
Q10	When the information received from AI about academic subjects raises doubts, I feel the need to consult with teachers or discuss it with classmates.	20	47	74	37	30	3.05	1.17
Q11	Using AI helps me find solutions quickly, but sometimes I feel that it reduces my need to think independently.	11	24	59	61	53	3.58	1.14
Q12	Using AI positively affects my ability to fact-check and search for alternative viewpoints.	7	28	76	61	36	3.44	1.03
Q13	I feel that discussions about AI ethics stimulate my interest in deeper material analysis.	11	34	88	47	28	3.23	1.05
Q14	How would you rate your ability to track hallucinations produced by AI?	31	40	81	47	9	2.82	1.08
Q15	How do you think the use of AI affects your emotional state (e.g., stress level, self-confidence) when solving academic tasks?	19	21	89	47	32	3.25	1.12

Furthermore, the majority try to find alternative explanations even when the initial one seems logical (mean 3.5, standard deviation 0.99), which underlines their cognitive flexibility. Respondents also expressed doubts about the accuracy of the information provided by AI, often seeking additional arguments to confirm or refute the given data (mean 3.66, standard deviation 1.03).

Regarding ethical issues, discussions- especially about data privacy- encourage students to reconsider their views (mean 3.18, standard deviation 1.14). In addition, most tend to analyse alternatives before using AI-provided answers in their work (mean 3.35, standard deviation 1.09).

Many respondents agreed that AI helps to find solutions quickly, although this sometimes reduces the need for independent thinking (mean 3.58, standard deviation 1.14). The use of AI also positively

impacts students' ability to check facts and seek alternative viewpoints (mean 3.44, standard deviation 1.03).

However, students experience some difficulty following AI 'hallucinations' (mean 2.82, standard deviation 1.08), suggesting additional training in this area. The assessment of the impact of AI on students' emotional state showed a mean of 3.25 and a standard deviation of 1.12, suggesting that they generally experience some impact on their stress levels and self-esteem as they solve tasks in the learning process.

Overall, the study suggests that students tend to analyse and evaluate the information provided by AI critically. However, certain aspects, such as tracking AI errors, require further development of their skills.

After analysing the responses, the next step is to divide the students into two groups: those with more developed critical thinking (class 1) and those with less developed critical thinking (class 0). For this purpose, the Support Vector Machine (SVM) method was used, which effectively partitions the respondents based on their responses to the survey. The input data for building the model are the students' answers to questions that assess different aspects of critical thinking, such as checking information, analysing conflicting data, searching for alternative explanations, and considering the ethical aspects of AI use. Students who demonstrate a high level of information verification and analysis, who can question the data received, seek alternatives and consider ethical implications, are assigned to the critical thinking group. The support vector machine method uses these characteristics as features for classification. After training, each student is classified based on their responses, allowing an automatic determination of whether they have developed critical thinking. The model is evaluated using classification accuracy, which helps to understand how effectively it classifies students into the appropriate categories. This approach provides an objective assessment of students' level of critical thinking, which is important for further research into the impact of the use of AI on the development of these skills in the learning process.

The study's results demonstrate the model's high effectiveness in classifying students according to their level of critical thinking, with an accuracy of 92.9%. This means the model correctly classified 93% of the students, indicating its high reliability (table 2).

Table 2
SVM classification report.

	Precision	Recall	F1-score	Support
Class 0	0.86	1.00	0.93	19
Class 1	1.00	0.87	0.93	23
Accuracy			0.93	42
Macro avg	0.93	0.93	0.93	42
Weighted avg	0.94	0.93	0.93	42

According to the classification report, the model achieved a precision of 86% and an excellent recall of 100% for students assigned to class 0, which means that all students in this class were correctly identified. However, for students with a high level of critical thinking (referred to as class 1), the model has a precision of 100%, although the recall for this class is slightly lower (87%), meaning that there is a small percentage of errors in identifying students in this group.

The F1 score for both classes (0.93) indicates that the model achieves a harmonious balance between precision and recall for both categories. The results show that the model performs uniformly across the two classes, providing a balanced classification not prone to excessive preference for one class over the other.

Notably, the macro and weighted averages (macro avg and weighted avg) show almost identical values for precision, recall and F1 score (0.93), indicating that the classification is consistent and the model does not show a significant bias towards any class.

Thus, these results demonstrate the high efficiency and accuracy of the model in classifying students according to their level of critical thinking (figure 2), particularly in the context of the impact of AI use on the learning process.

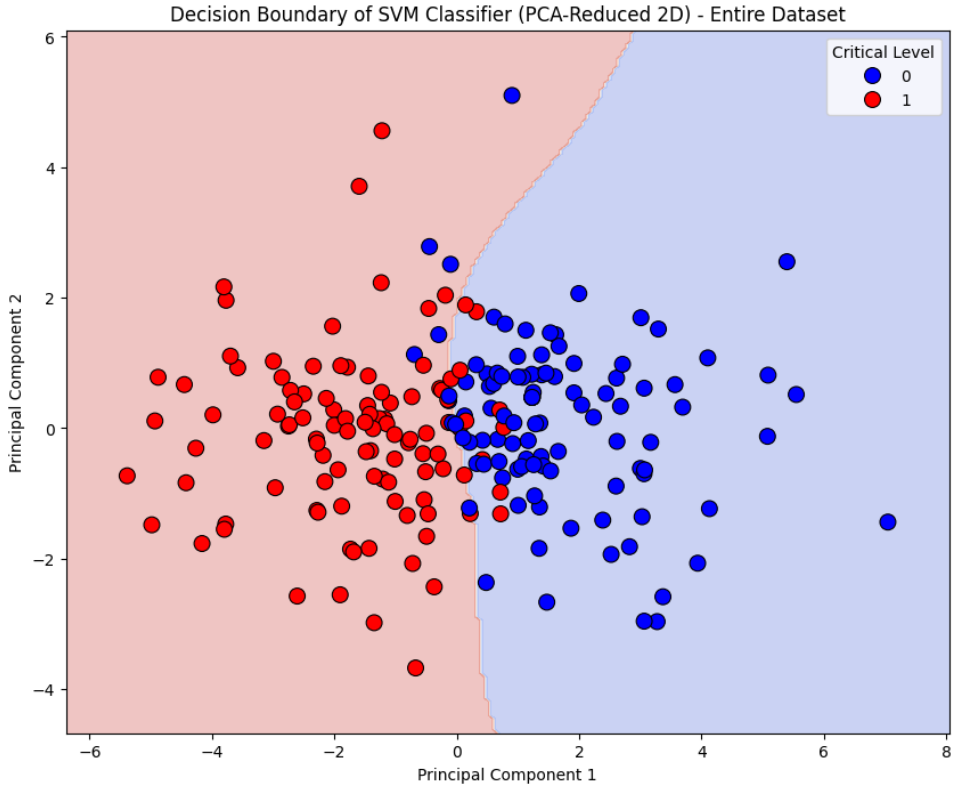

Figure 2: Decision boundary of SVM classifier.

By analysing the importance of the features using the permutation method, we were able to determine which responses had the greatest impact on the classification results (figure 3).

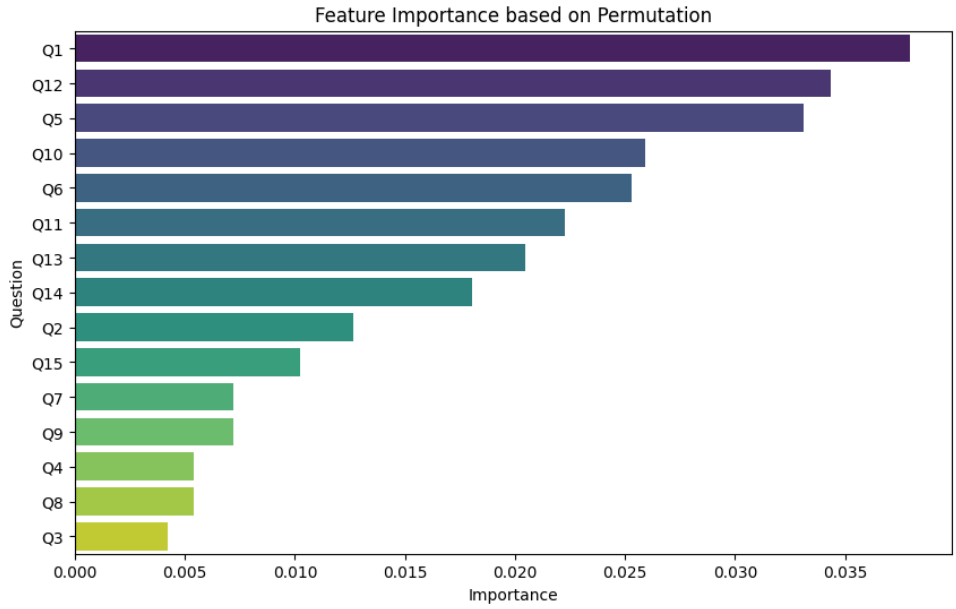

Figure 3: Feature importance based on permutation.

The feature with the highest importance is Q1 'Rate how important data privacy is to you when using AI' (0.037952), which indicates the importance of ethical aspects in using AI for assessing critical thinking. Other significant features include Q12 'Using AI positively affects my ability to check facts and seek alternative viewpoints' (0.034337) and Q5 'When information I receive contradicts my prior knowledge, I tend to analyse it thoroughly from different perspectives' (0.033133). These factors suggest that students who actively check information and pay attention to ethical considerations tend to have a higher level of critical thinking.

At the same time, the question with the lowest importance indicator – Q3 ('How often do you check information provided by AI from other sources (e.g. textbooks, websites, etc. for confirmation)?'), which refers to the frequency of checking information from other sources, suggests that not all aspects of AI use have the same impact on the development of critical thinking. The differences in scores allow us to conclude that some regions of interaction with AI, such as the emphasis on privacy and the thorough analysis of conflicting information, are more critical to developing students' critical thinking.

Thus, the study confirms that the impact of AI technologies on critical thinking is not homogeneous, but depends on the specific aspects of AI use and how students perceive them. These results can serve as a basis for further refining educational strategies aimed at developing analytical and critical skills by integrating modern technologies into the learning process.

5. Conclusions

The study results show that students are primarily inclined to critically analyse the information provided by AI, indicating the presence of well-developed critical thinking skills. Using the SVM model allowed effective classification of respondents according to their level of critical thinking, ensuring high accuracy and balanced classification. This confirms the reliability of the data obtained and its potential for further application. These results confirm that the ability to verify information, analyse conflicting data, seek alternative explanations and consider ethical aspects are important indicators of critical thinking that can positively influence the quality of the learning process.

Furthermore, the analysis of the importance of the features indicates that ethical issues – especially those related to data confidentiality – and the ability to verify the reliability of information play a key role in determining students' level of critical thinking. This opens up new opportunities for developing targeted educational programmes to foster these skills, considering modern technological innovations.

It is also worth noting that the high level of classification accuracy allows this approach to be used as a diagnostic tool for monitoring and evaluating the development of critical thinking in educational institutions. The data obtained can serve as a basis for further research aimed at improving methods of integrating AI into the learning process, as well as for developing interventions that will help to improve the level of critical thinking among students.

However, as with any study, the results obtained have certain limitations, particularly those related to the sample size and the specifics of the survey. Therefore, future work should extend the sample and consider additional parameters that influence the development of critical thinking. In this way, applying the SVM model not only allows an objective assessment of the level of critical thinking but also stimulates the development of more effective educational strategies that incorporate modern technological trends and contribute to improving the quality of the educational process in higher education institutions.

Author contributions

Conceptualization, Nataliia Dziubanovska; methodology, Nataliia Dziubanovska; software, Nataliia Dziubanovska; validation, Nataliia Dziubanovska and Vadym Maslii; formal analysis, Vadym Maslii; investigation, Vadym Maslii; data curation, Vadym Maslii.; writing – original draft preparation, Nataliia Dziubanovska; writing – review and editing, Nataliia Dziubanovska and Vadym Maslii; visualization, Nataliia Dziubanovska; supervision, Nataliia Dziubanovska; project administration, Nataliia Dziubanovska.

All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare no conflict of interest.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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