

Conceptions of AI among K-12 Students in Azerbaijan: A Topic Modeling Approach

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Abstract

This study explores the perceptions of artificial intelligence (AI) among Azerbaijani students by analyzing data collected from 73 participants. Using automatic topic modeling with the recent multilingual sentence transformer to generate word embeddings, along with manual semantic analysis, we identified 12 unique topics that reflect diverse aspects of students' understanding of AI. Key findings include students' recognition of AI's role in facilitating tasks, its applications in daily life, and its autonomous capabilities. However, there are significant knowledge gaps and misconceptions, with some students expressing concerns about AI's potential negative impacts. The analysis highlights the need for explainable AI (XAI) in K-12 education to address these misconceptions and provide a clearer understanding of AI technologies. These insights are crucial for designing educational interventions that prepare students for a future increasingly influenced by AI.

Keywords: AI Literacy, Computing Education, Topic Modeling, Conceptions, K-12

1. Introduction

Children today are growing up alongside constantly advancing AI systems, which are transforming daily life and future job markets. UNESCO has recognized the need for AI literacy, emphasizing the importance of equipping individuals with the knowledge, skills, and values essential for societal engagement in an AI-driven world (Miao & Shiohira, 2022). To adequately prepare young people, who are the future users and developers of AI, it is critical to understand their conceptions of AI and its implications for education.

AI literacy involves socio-technical competence, including knowledge about human-AI interaction, understanding the AI process (input, processing, and output), and experience in interacting with AI systems (Pinski & Benlian, 2023). As AI systems become increasingly accessible to younger children through gestures, touch, and speech (Williams, 2018), the need to introduce AI literacy at earlier educational stages is becoming more urgent.

Teachers play a crucial role in developing students' abilities to navigate and critically engage with AI (Karimov et al., 2024). However, expanding AI literacy in K-12 education remains a significant challenge, as it requires interdisciplinary research to explore effective integration methods. Existing efforts are still largely at the pilot stage. Studies in the USA, Finland, and Korea offer some initial insights (Table 1), but much more work is needed to fully understand and address this challenge (Ng et al., 2021; Van Mechelen et al., 2023).

Traditionally, computing education (CE) has focused on computational thinking and the content and methods of teaching computer science. However, the scope of CE has recently expanded to include AI literacy (Prather et al., 2023), which addresses data literacy—understanding how AI collects and processes data—and algorithm literacy, which involves understanding how AI algorithms analyze data for human-machine interactions, as well as the ethical aspects of these technologies (Miao & Shiohira, 2022).

Despite the growing recognition of AI literacy's importance, its integration into school curricula remains limited, particularly in developing countries like Azerbaijan. As AI adoption accelerates globally, it is forecasted to widen existing disparities between countries (McKinsey Global Institute, 2018). Therefore, it is crucial to include youth from historically

understudied countries and underrepresented languages in AI education initiatives to prevent further marginalization (Zhang et al., 2024).

Moreover, cultural differences significantly influence how AI is perceived and accepted (Dang & Liu, 2022). Research has shown that children's understanding of AI varies based on cultural, social, and personal factors, such as parental discussions about technology (Druga et al., 2019; Williams et al., 2019). This underscores the need for empirical research to better understand these preconceptions and develop effective teaching methods.

Our paper extends the dialogue on AI education to include perspectives from regions typically underrepresented in global AI discourse. Using authentic student responses, a multilingual topic modeling approach, and manual semantic analysis for verification and deeper insights, this research explores the conceptions of AI among K-12 students in Azerbaijan. By understanding students' conceptions of AI, we can create instructional strategies to better advance their understanding of AI technologies.

2. Study design

2.1. Study context and data collection

We asked teachers from various regions in Azerbaijan to administer a survey to their students. The participants (N=73) had an average age of 15 years ($\sigma = 3.34$). By the age of 15, most Azerbaijani students are in the final years of lower secondary education or the early years of upper secondary education. At this stage, students have already completed a curriculum that includes core subjects such as mathematics, science, history, and a foreign language. However, exposure to advanced topics in computing or AI is typically limited.

Even though Azerbaijan is considered a highly educated country from the perspective of schooling years and completed education level, student learning outcomes are underperforming, according to the World Bank (Karimov et al., 2023). This discrepancy suggests that while students may spend significant time in the education system, the depth of understanding and mastery of complex subjects, including AI, may not be as robust as expected.

AI initiatives in Azerbaijan mainly target university and high school students and focus on practical applications rather than exploring AI's educational role (Ministry of Science and Education of the Republic of Azerbaijan, 2024; Xalq Qazeti, 2023). To our knowledge, no similar study has been conducted with Azerbaijani students, underscoring the need to expand

research in this cultural and linguistic context.

For data collection, we employed a survey comprising demographic questions (age, gender, type of school attended, age at first phone) alongside inquiries into students' perceptions of AI. All respondents, except for one, reported studying at a public school. Among the participants, 58.9% identified as "female" and 41.1% identified as "male." While 12 students mentioned that they had never owned a smartphone, the average age at which the remaining participants first acquired a smartphone was 13 years ($\sigma = 2.55$).

To assess their AI perceptions, we adapted tasks used by Mertala and Fagerlund (2024) with Finnish 5th and 6th graders, which included the following five prompts: (i) Describe what you think AI means; (ii) Describe where you think AI is or what it is used for; (iii) Describe how you think AI works. (iv) Describe why you think AI is used; and (v) Name any words, things, or objects that you think are related to AI.

These prompts were designed to comprehensively assess students' knowledge, understanding, and perceptions of AI. They encouraged critical thinking, contextual understanding, and the ability to articulate and associate related concepts (Mertala & Fagerlund, 2024). To ensure we gathered sufficient data for analysis, students were instructed to write at least two sentences for each prompt.

2.2. Methods

To analyze the original Azerbaijani student responses, we employed a mixed-methods approach combining automatic topic modeling with *BERTopic* (Grootendorst, 2022) and manual semantic analysis. This combination allowed us to leverage the strengths of both methods, enhancing the robustness and depth of our analysis.

Automatic Topic Modeling To manage the complexity of analyzing a large collection of textual data in Azerbaijani, we utilized the *BERTopic* (v. 0.16.2) Python package, which offers several distinct advantages, particularly in multilingual contexts. *BERTopic* is highly versatile, automatically determines the optimal number of topics, and supports hierarchical topic reduction. These features make it an ideal tool for uncovering and categorizing themes in diverse and complex datasets like ours.

Our procedure for automatic topic modeling included several key steps as outlined in Figure 1: First, we compiled the original Azerbaijani responses into a single corpus of 365 individual responses (73 participants \times 5 answers, see Figure 1). Second, we eliminated Azerbaijani stop words using *advertools*

Table 1. Related work of studies with some kind of intervention (AI teaching) and testing AI literacy in children.

Authors	Country	N	Students	Data
Lin et al. (2020)	USA	14	8-11-year-olds	Pre-and post-assessments data, video data, log file data
K. Kim et al. (2023)	USA	14	6th-8th graders	Video and learning artifacts
Vartiainen et al. (2021)	Finland	34	6th graders	Students' artwork, design ideas, and co-designed applications data and structured group interviews
Vartiainen et al. (2020)	Finland	6	3–9 year olds	Video data and interview data
Kandlhofer et al. (2016)	Austria	57	24 kindergarten, 24 school and 9 high school students	Field notes, discussions, informal interviews
Park and Kwon (2024)	South Korea	23	12-13-year-olds	Data from two Likert-scale items: i) pupils' attitudes toward technology scale (Bame et al., 1993) and ii) AI competency scale (S.-W. Kim & Lee, 2020).

package, followed by the application of the multilingual sentence transformer (Wang et al., 2024) to generate word embeddings. This was followed using *UMAP* (McInnes et al., 2018) to reduce dimensionality.

Finally, to identify meaningful clusters within the data, we used Hierarchical Density-Based Spatial Clustering of Applications with Noise (*HDBSCAN*) (Campello et al., 2013). *HDBSCAN*'s ability to handle noise and automatically determine cluster sizes was crucial for ensuring that even smaller, less prominent topics were captured, with the smallest topic containing at least 10 responses.

One of *BERTopic*'s notable strengths is its support for hierarchical topic reduction, allowing us to refine the granularity of the topics as needed. After identifying the topics, the results were translated into English by a sworn translator, and one of the authors, a native Azerbaijani speaker, interpreted and named each topic, ensuring that the original meanings were accurately conveyed.

Manual Semantic Analysis While *BERTopic* provided a powerful framework for automatically discovering and categorizing topics, we complemented this with a manual semantic analysis to ensure a deep and nuanced understanding of the students' conceptions of AI. This manual analysis enabled us to capture contextual subtleties that automated methods might overlook.

However, we recognized that manual analysis introduces the possibility of researcher bias and can be highly time-consuming. To mitigate these issues, we relied on the objective baseline established by *BERTopic*. Additionally, we collaborated with a sworn translator to ensure that the linguistic and cultural

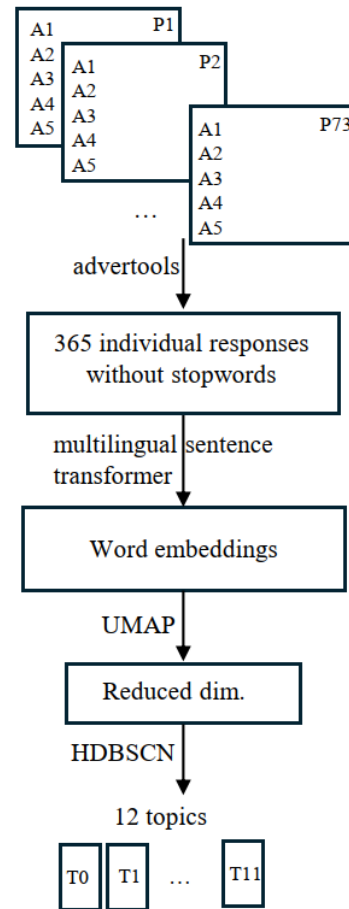


Figure 1. Flowchart depicting our methodology for automatic topic modeling using BERTopic.

nuances of the Azerbaijani responses were faithfully represented in the final analysis.

By integrating these automatic and manual methods, we aimed to achieve a balanced and comprehensive analysis, leveraging the advanced capabilities of *BERTopic*, including its multilingual support, automatic topic determination, and hierarchical reduction, alongside the depth and contextual sensitivity of manual semantic analysis. This approach allowed us to effectively categorize and interpret the diverse conceptions of AI among the students, leading to more reliable and insightful findings.

3. Results

Automatic Topic Modeling *BERTopic* modeling provided us with 12 unique topics. Figure 2 shows the top words for each topic and Figure 3 shows the closeness of these topics. Topic 0 *don't know* summarizes that students often did not know how to answer the tasks. Topic 1 *artificial* highlights the difference between unnatural (machine) in contrast to non-artificial (human or animal) intelligence while Topic 2 *social media* is about specific AI-powered apps, such as Instagram, Facebook, and YouTube.

Topic 3 centers around *robots*. Previous studies have indicated that both children and the general public often equalize AI with robots (Kerr et al., 2020; Kreinsen & Schulz, 2021; Long & Magerko, 2020). One of the most representative docs for this topic states that AI “is like a human being. We can talk.” This anthropomorphic view of AI, which likens AI to human emotions and cognition, is also a recurring theme in related literature (Kodama et al., 2017; Mertala et al., 2022).

Topic 4 emphasizes how AI *facilitates* things for people. Students described how AI simplifies and enhances daily life. Some respondents highlighted its ability to automate tasks and bring convenience. For instance, one document states that AI “makes things easier.” Conversely, another document discusses the negative aspects of this facilitation: “In an exam, an insecure student copies the answers to pass the exam so that he can pass the exam easily. Thus, he fakes high marks in any test.”

Topic 5, *knowledge*, indicates that students view AI as a tool for finding solutions and solving problems. One representative document notes “I use AI to gain new knowledge”. Topic 6, *applications*, emphasizes the various uses of AI in “scientific research, projects, and even in human social life”. As shown in Figure 3, the *applications* topic is closest to the *social media* topic, reflecting that students often associate AI applications with popular social media platforms.

Topic 7 highlights *modern technology*, including terms such as “current”, “modern”, “technical”, and “equipment”. Topic 8, *autonomy*, concerns the autonomy of AI. One document describes AI as “Human-made intelligence capable of thinking for itself, making its own decisions.” As visualized in Figure 3, the *autonomy* topic is closest to the *artificial* topic 1.

In contrast, Topic 9—while part of the same subcluster as topics 8, 1, and 3 (Figure 3)—focuses on the *training* needed for machines to become “independent” and “achieve” tasks. Topic 10, *data*, involves the “sources” required for AI to “provide users with relevant and informative answers.” While most documents emphasize relevant data, one also mentions “I think it’s used to make it easier to monitor people.”

The final topic, 11, focuses on *invention*. In this topic, students discuss AI in terms of “creation”, “system”, and “program”. However, these AI inventions are often described as abstract, non-understandable, and uncontrollable—essentially opaque black boxes. Two of the most representative documents in this topic include “invented in the Czech Republic” and “works at first, turns out to be a lie after a while.” It is reasonable that this topic is most closely related to the *don't know* topic (see Figure 3).

Manual Semantic Analysis While the automatic topic modeling analysis identified 12 distinct themes, the manual semantic analysis provided deeper insights. For example, concerning Topic 4, *facilitate*, students emphasized how AI simplifies life. They noted:

- “It helps to make our life easier.”
- “AI is a system of programs that make people’s daily life easier and interesting at the same time.”
- “When I say AI, I mean modern technologies, technological equipment, and this concept that makes our work easier. It makes our work easy and comfortable.”

Some students highlighted AI’s capacity for decision-making and learning. They view AI as a form of intelligence that, although human-created, can think for itself and evolve by learning from its mistakes:

- “AI that answers questions based on past data, which can answer certain questions directly.”
- “An intelligence that can think for itself, make its own decisions, but is created by humans.”
- “AI is the copying of human intelligence by machines. The problem is that, like a human being, it learns from its mistakes and does not make the same mistake again.”

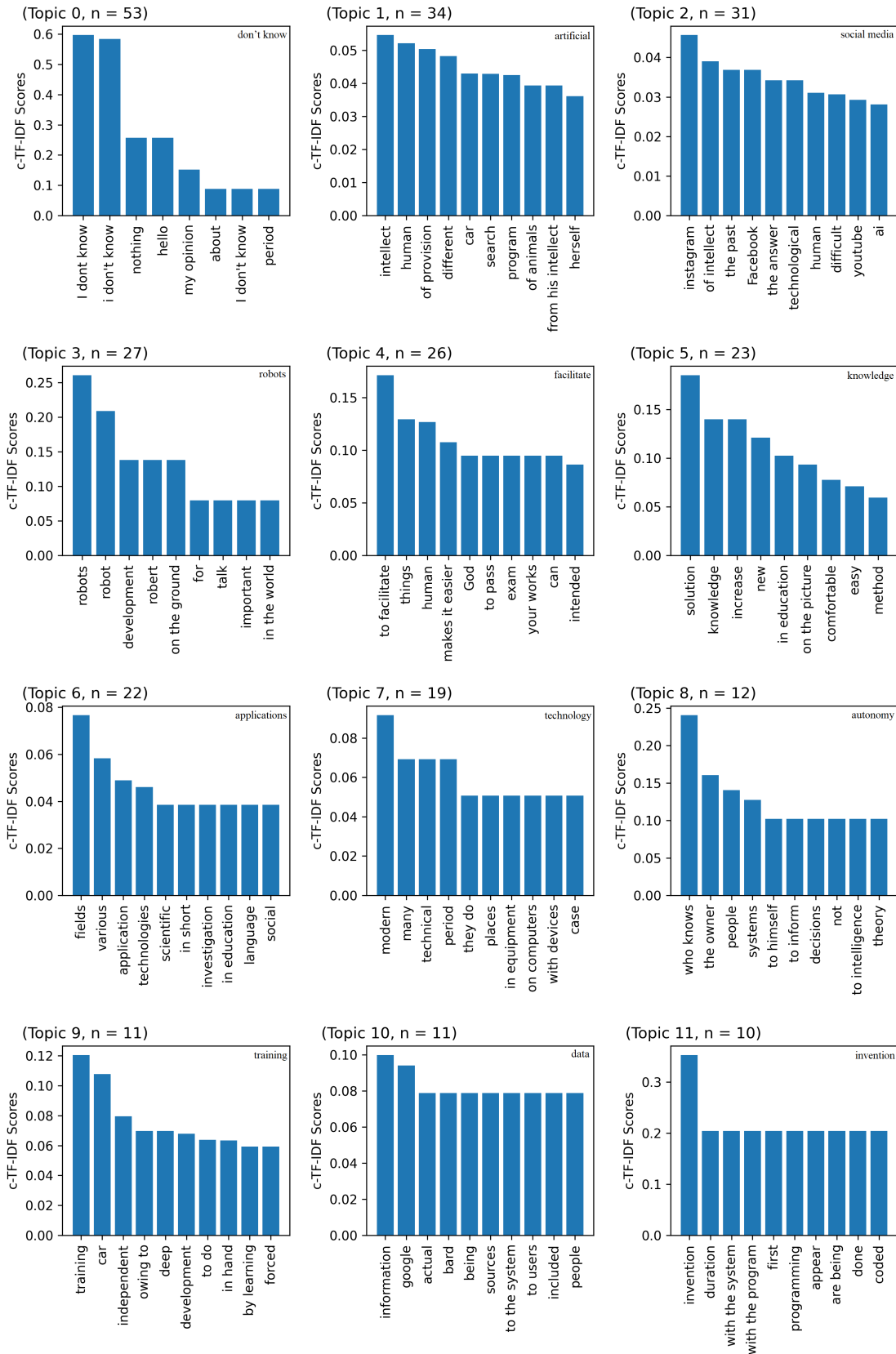


Figure 2. Topic modeling results. The word in the upper right corner presents the name of each topic.

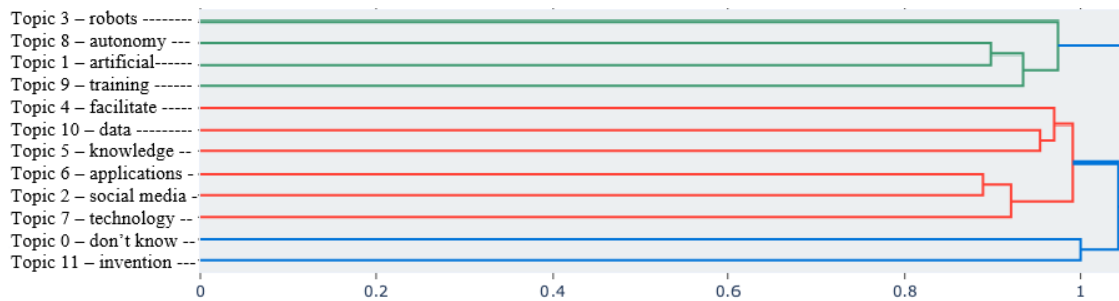


Figure 3. Hierarchical clustering result showing the closeness and subclusters of our 12 topics.

However, some participants expressed concerns about AI's artificial nature and its potential to dominate human intelligence. Fears about a dystopian future and unrealistic scenarios were also mentioned:

- “In my opinion, it is an unrealistic form of intelligence which does not carry naturalness in itself.”
- “That is, false intelligence.”
- “The intelligence that governs people.”
- “A great war with robots that will destroy our future.”
- “Flying cars.”

Students were also asked about AI's uses. Many mentioned its application in scientific research, robotics, and everyday technologies. They highlighted AI's presence in systems, generative tools, and strategic games. Common examples included:

- “Navigation devices, Instagram, Google, banking services are examples of AI. Various forms of any topic we are looking for come before us, which is the result of AI.”
- “When we need any information, we turn to Siri, Alexa, or Google Assistant, which are artificial intelligences currently used in phones.”
- “It is used in computers and tablets. If we watch a program that interests us, other programs of that type come again.”

When asked how they believe AI works, students offered various insights. Some think AI operates through specialized devices integrated into technical equipment, while others focus on the role of past data stored in the system's “brain.” They also mentioned:

- “I think it works with special devices. That is, I think it works with devices installed in technical equipment.”
- “It uses all internet resources and brings us the most correct answer.”
- “A mathematical science and technology aimed at applying human logic to machines.”
- “It works by applying certain algorithms and technologies. Receives information, analyzes it, and then analyzes the results and makes changes.”

In summary, manual semantic analysis confirmed the results from topic modeling and offered additional context. Students perceive AI as simplifying daily life and possessing autonomous decision-making capabilities. They recognized diverse AI applications and demonstrated an understanding of AI's operation. However, students often view AI either as an abstract invention they do not fully understand or as something human-like. They also expressed concerns about AI's artificial nature and potential negative impacts.

4. Discussion

This study contributes to the timely discussion on students' AI literacy skills (Zhang et al., 2024) by exploring the perceptions of AI among 73 Azerbaijani K-12 students. Understanding their current knowledge and misconceptions is important for designing educational interventions that prepare them for a future increasingly influenced by AI.

AI is a multifaceted concept, often subject to varying interpretations. According to the OECD's updated definition, an “AI system is a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments. Different AI systems vary in their levels of autonomy and adaptiveness after deployment” (OECD, 2024).

Our findings indicate that Azerbaijani students demonstrate a solid understanding of several AI applications, particularly those related to social media, and are aware of the varying levels of autonomy in AI systems. However, significant knowledge gaps and misconceptions about the nature of AI persist. A key finding is the widespread view of AI as either an abstract invention that is difficult to understand or as something human-like.

This suggests that while students grasp AI's ability to process inputs and produce influential outputs, they may not fully understand how these processes work or the underlying mechanisms that drive AI's behavior. The anthropomorphic view of AI among students often simplifies AI's complexity by attributing human-like characteristics and decision-making processes to these systems, possibly as a way to make sense of a technology that is otherwise opaque and difficult to comprehend.

This aligns with previous research indicating that children and the general public frequently equate AI with robots and attribute human-like traits to AI systems (Kerr et al., 2020; Kreinsen & Schulz, 2021; Long & Magerko, 2020). For example, one representative document in our study describes AI as "like a human being. We can talk." This reflects a recurring theme in the literature where AI is anthropomorphized, reducing its complexity to something more familiar and understandable (Kodama et al., 2017; Mertala et al., 2022).

Engaging with black-box AI systems, which operate without revealing their internal workings, can lead students to develop oversimplified conceptual models that are difficult to alter once established (Hitron et al., 2019). Explainable AI (XAI) offers a promising research direction to address this issue by providing insights into how AI models arrive at their conclusions (Gunasekara & Saarela, 2024; Khosravi et al., 2022).

Incorporating XAI into K-12 education could demystify AI systems and provide students with a more accurate understanding of AI technologies. This approach could bridge the gap between students' anthropomorphic perceptions and the actual functionality of AI by offering transparency and making AI's decision-making processes more comprehensible. Such transparency is essential for fostering a more accurate and nuanced understanding of AI (Chamola et al., 2023; Ciechanowski et al., 2019).

Transparency is also essential for ensuring that AI systems are trustworthy, reliable, and aligned with human values. By making AI interactions more predictable, transparency can alleviate technology-related stress and insecurity among

students (Kandul et al., 2023). Addressing the needs for transparency and explainability not only helps to clarify how AI systems operate but also plays a critical role in mitigating misconceptions and fostering trust in these technologies (Khosravi et al., 2022).

Hands-on exploration with AI tools designed to help learners understand AI techniques has been shown to enhance students' understanding of AI, even among very young learners (Lin et al., 2020; Vartiainen et al., 2020). Tools such as Teachable Machine and MachineLearning4Kids allow students to train AI systems themselves, helping to dispel the perception of AI as an abstract, non-understandable, and non-trustworthy invention.

One student in our study described AI as something that "works at first, turns out to be a lie after a while," reflecting a distrust in the technology's reliability and transparency. By engaging with AI in a hands-on manner, students can see how AI systems operate in real-time, which can provide a clearer understanding of its functions. When these explorations are combined with XAI, students not only learn how AI makes decisions but also gain the ability to influence and teach the system to make different decisions.

A further benefit of XAI is that it can help students analyze and understand if and why an AI model made a wrong decision (Saarela & Kärkkäinen, 2020; Saarela et al., 2021). For example, if students train an AI model using only pictures of yellow bananas, and the AI mistakenly identifies a yellow hat as a banana, XAI could explain that the model relied solely on color in its decision-making process. This kind of transparency is crucial for helping students grasp how AI systems learn and make decisions.

Our study provides an initial look at AI perceptions among K-12 students in Azerbaijan. However, this research is just a starting point. Future studies should focus on developing targeted educational interventions to effectively integrate AI into curricula. Additionally, there is a need to create conceptual frameworks and instruments to measure students' AI competence. Although recent scales have been developed for adults (Laupichler et al., 2023; Pinski & Benlian, 2023), adapting these tools for younger audiences is essential.

Further research should explore educational strategies that incorporate XAI principles to address misconceptions and enhance students' understanding of AI. Collaborating with educators to integrate AI topics across various subjects will deepen students' comprehension of AI concepts (Casal-Otero et al., 2023). These strategies can help to mitigate misunderstandings and ensure that students develop a balanced view of AI's capabilities and limitations.

Qualitative methods, such as interviews and focus groups, could offer deeper insights into how students' perceptions of AI evolve and how educational interventions can be tailored to meet their needs. Ultimately, while our study marks the first step in understanding AI perceptions among K-12 students in Azerbaijan, ongoing research and the development of targeted educational efforts are essential to advancing AI literacy in this demographic.

5. Conclusion

This study makes several important contributions to both research and practice in the field of AI literacy and computational education in K-12 settings, particularly from a country and language that has been historically understudied. Our conclusions can be drawn from both methodological and domain-specific perspectives.

Methodologically, this study demonstrates the value of integrating recent natural language processing (NLP) technologies with traditional analysis techniques. We collected data in Azerbaijani, a language from a historically understudied region, and employed topic modeling to identify overarching themes, followed by semantic analysis to delve deeper into these themes. This dual approach leverages the strengths of both methods and illustrates the applicability of advanced NLP tools in multilingual research contexts.

From a domain perspective, our study revealed key themes in Azerbaijani students' perceptions and understanding of AI. It also identified specific gaps in AI literacy, such as the conflation of AI with robotics and a limited understanding of AI's underlying mechanisms. These insights are particularly valuable given the context in which the data was collected—a non-Western, multilingual environment where AI literacy research is still emerging.

To address these gaps, educators and curriculum developers should design educational materials that incorporate hands-on AI exploration. Interactive activities using tools such as Teachable Machine and MachineLearning4Kids allow students to directly engage with AI systems. These practical experiences help deepen students' understanding of how AI systems operate.

In addition, integrating explainable AI (XAI) principles into the curriculum can demystify AI and counteract the perception of it as an abstract, incomprehensible invention. By making the decision-making processes of AI models more transparent, XAI can help dispel misconceptions about AI being opaque or uncontrollable. This approach can also reduce feelings of alienation and increase

students' comprehension of the technology.

Moreover, it is crucial to incorporate discussions on the ethical and societal implications of AI into educational content. By engaging students in critical thinking about AI's broader impact, educators can prepare them not only to use AI technology effectively but also to reflect on its societal and ethical consequences.

Finally, this research contributes to the global discourse on AI education by providing insights from a non-Western context. Such contributions are valuable for informing international educational strategies and policies aimed at improving AI literacy worldwide. By implementing the recommendations from this study, educational systems can better address the diverse needs of students and prepare them to engage more effectively with transformative AI technologies.

5.1. Limitations and future work

While this study offers valuable insights, it also has several limitations that should be addressed in future research. First, the sample size and demographic diversity of the participants were limited. Future studies should aim to include a larger and more diverse sample to ensure the findings are generalizable across different regions and educational contexts in Azerbaijan.

Second, the study primarily relied on self-reported data, which can be subject to biases and inaccuracies. Incorporating additional methods such as interviews, observations, and practical assessments of AI knowledge and skills could provide a more comprehensive understanding of students' AI literacy. Third, while useful, the topic modeling approach has limitations in capturing the full depth of students' perceptions. We also used semantic analysis to address some of these limitations. However, future research could benefit from using more advanced natural language processing techniques or combining quantitative and qualitative methods to gain deeper insights.

By addressing these limitations, future research can build on the findings of this study to further enhance AI literacy and CE in K-12 settings, both in Azerbaijan and globally.

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