Methodological foundations of teaching the basics of artificial intelligence to lyceum students

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Abstract

Integrating artificial intelligence (AI) into secondary education is crucial in preparing students for an AI-driven world. This study develops and validates a methodological framework for implementing AI education in Ukrainian lyceums. Key contributions include an analysis of existing textbooks, a review of international practices, and the creation of a three-part web quest complex combining theoretical and practical learning. Validated through expert review and pilot testing, the framework enhances student engagement and understanding of AI concepts. The paper provides practical guidelines for educators, emphasizing interactive, project-based learning and the need for robust teacher support.

Keywords

artificial intelligence education, teaching methodology, web quest, interactive learning, educational technology, curriculum development

1. Introduction

The rapid development of artificial intelligence (AI) technologies has led to an increasing demand for AI education at various levels, including K-12 education [1, 2, 3]. As AI becomes ubiquitous in everyday life, it is essential to prepare students for the challenges and opportunities presented by this emerging field [4]. Integrating AI education into school curricula can help develop students' computational thinking skills, foster their interest in computer science, and equip them with the knowledge and skills needed to thrive in an AI-driven world [5].

In Ukraine, the National Strategy for the Development of Artificial Intelligence 2020-2030 emphasizes the importance of introducing AI-related disciplines at different levels of education, including secondary schools [6, 7]. However, the implementation of AI education in Ukrainian lyceums (upper secondary schools) faces several challenges, such as the lack of standardized curricula, limited access to educational resources, and insufficient teacher training [8, 9].

This research paper aims to address these challenges by proposing a methodological foundation for teaching the basics of AI to lyceum students in Ukraine. By analyzing existing AI education frameworks, curricula, and best practices from around the world [10, 11, 12], we seek to develop a comprehensive approach that considers the specific needs and context of Ukrainian education. Our goal is to provide guidelines and recommendations for educators, policymakers, and researchers to facilitate the effective integration of AI education in Ukrainian lyceums.

The main objectives of this study are:

1. To review and analyze existing AI education frameworks, curricula, and best practices from around the world.
2. To identify the key competencies and learning outcomes for teaching AI basics to lyceum students.
3. To propose a methodological foundation for AI education in Ukrainian lyceums, considering the specific needs and context of the Ukrainian education system.
4. To provide recommendations for the implementation of AI education in Ukrainian lyceums, including curriculum design, teacher training, and educational resource development.

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2. Literature review

The integration of artificial intelligence (AI) education in K-12 curricula has gained significant attention in recent years. Researchers and educators have explored various approaches to teaching AI concepts, skills, and applications to students at different levels.

Several AI education frameworks and curricula have been proposed to guide the integration of AI in K-12 education. The AI4K12 Initiative, launched by the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA), aims to develop national guidelines for teaching AI in K-12 [13]. The initiative has identified five "big ideas" in AI: perception, representation and reasoning, learning, natural interaction, and societal impact [14].

Other researchers have proposed AI education frameworks that emphasize the importance of integrating technical, social, and ethical aspects of AI. Dai et al. [15] developed a collaborative AI curriculum for primary schools in China, considering the specific needs and context of the Chinese education system. Yue Yim [12] proposed an intelligence-based AI literacy framework for primary school education, emphasizing the need for a transdisciplinary approach that encompasses both technological and societal impacts of AI.

Various teaching approaches and strategies have been explored to facilitate AI education in K-12 settings. Unplugged activities, which introduce AI concepts without using computers, have been found to be effective in engaging students and fostering their understanding of AI principles [14]. Game-based learning, such as using Pac-Man to teach AI concepts [16], has also been shown to increase student motivation and engagement.

Project-based learning and hands-on activities have been widely used to teach AI in K-12 classrooms. Sperling and Lickerman [17] integrated AI and machine learning in a software engineering course for high school students, using DrRacket functional programming language to implement AI algorithms. Sinha et al. [2] proposed a hands-on active learning approach to teach AI and machine learning to elementary and middle school students, using AI4K12 big ideas and culturally responsive pedagogy.

Preparing teachers to effectively teach AI in K-12 classrooms is crucial for the successful integration of AI education. Williams et al. [1] developed an AI ethics curriculum for middle school teachers, providing them with content knowledge and an understanding of the ethical issues posed by AI. Lee et al. [18] proposed an innovative professional development model called "AI Book Club" to prepare middle school teachers with AI content knowledge and ethical considerations.

Olari et al. [19] investigated the introduction of AI literacy and data literacy in computer science teacher education, highlighting the need for professional development programs to train teachers in these emerging skills. Kim and Kwon [20] explored the AI competencies of elementary school teachers in South Korea, identifying 22 competencies based on the technological pedagogical content knowledge (TPACK) framework.

Despite the growing interest in AI education, several challenges and opportunities have been identified in the literature. One major challenge is the lack of standardized AI curricula and learning materials, which can hinder the effective implementation of AI education in K-12 settings [8, 9]. Developing age-appropriate and engaging AI learning resources, such as unplugged activities [14] and project-based learning materials [17], can help address this challenge.

Another challenge is the limited AI knowledge and skills among K-12 teachers [20]. Providing effective professional development opportunities, such as the AI Book Club model [18] and the introduction of AI literacy in teacher education [19], can help prepare teachers to confidently teach AI in their classrooms.

The integration of AI education in K-12 curricula also presents opportunities for fostering computational thinking skills [5], promoting diversity and inclusion in computer science education [21], and preparing students for future careers in AI-related fields [4]. Collaborative efforts among researchers, educators, and policymakers are needed to seize these opportunities and address the challenges in AI education.

3. Methodology

To develop a methodological foundation for teaching the basics of artificial intelligence (AI) to lyceum students in Ukraine, we employed a multi-phase research approach. This section describes the research design, data collection, and analysis methods used in each phase of the study. Figure 1 illustrates the structure of the research methodology.

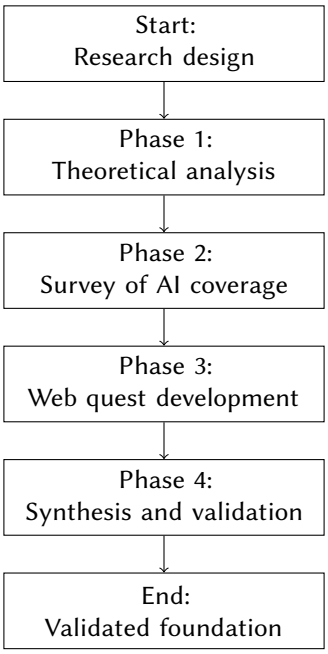

Figure 1: Structure of the research sethodology.

3.1. Phase 1: Theoretical analysis of AI concepts and terminology

The first phase of the study involved a theoretical analysis of key AI concepts and terminology used in high school informatics education. We conducted a comprehensive review of informatics textbooks and educational materials used in Ukrainian lyceums to identify the most common and relevant AI concepts and terms. The analysis focused on the clarity, consistency, and appropriateness of the definitions and explanations provided in these materials.

The data collected in this phase included the AI-related content from 5 informatics textbooks for grades 10-11, as well as supplementary educational materials such as online courses and educational videos. The content was analyzed using qualitative content analysis techniques [22], focusing on the identification of key themes, patterns, and inconsistencies in the presentation of AI concepts and terminology.

3.2. Phase 2: Survey of AI coverage in informatics standards and textbooks

The second phase of the study involved a survey of AI coverage in the current informatics standards and textbooks used in Ukrainian lyceums. We analyzed the national curriculum guidelines for informatics education in grades 10-11, as well as the most widely used informatics textbooks, to determine the extent and depth of AI coverage.

The data collected in this phase included the AI-related content from the national curriculum guidelines and 5 informatics textbooks for grades 10-11. The content was analyzed using a combination of quantitative and qualitative methods. Quantitative analysis involved the calculation of the percentage of pages and chapters dedicated to AI-related topics. Qualitative analysis focused on the identification of the main AI concepts, skills, and applications covered in the materials.

3.3. Phase 3: Development of an educational web quest complex

The third phase of the study involved the development of an educational web quest complex for teaching AI basics to lyceum students. The web quest complex was designed to provide an engaging and interactive learning experience, combining theoretical knowledge with practical activities and real-world applications of AI.

The development process followed the principles of instructional design [23] and the 5E learning cycle model [24]. The web quest complex was created using the Genial.ly platform and consisted of three main components: (1) an introductory module providing an overview of AI concepts and applications, (2) a series of interactive quests focusing on specific AI topics and skills, and (3) a final project allowing students to apply their knowledge and skills to a real-world AI problem.

The effectiveness of the web quest complex was evaluated through a pilot study involving 20 lyceum students from two schools in Kryvyi Rih. The students completed the web quest complex and provided feedback through a survey and semi-structured interviews. The data collected from the pilot study was analyzed using descriptive statistics and thematic analysis [25] to identify the strengths, weaknesses, and areas for improvement of the web quest complex.

3.4. Phase 4: Synthesis and development of the methodological foundation

The final phase of the study involved the synthesis of the findings from the previous phases and the development of a methodological foundation for teaching AI basics to lyceum students in Ukraine. The methodological foundation was designed to provide a comprehensive and coherent approach to AI education, considering the specific needs and context of the Ukrainian education system.

The development process involved the integration of insights from the theoretical analysis, survey of AI coverage, and the evaluation of the web quest complex. The methodological foundation was structured around four main components: (1) key AI concepts and skills to be taught, (2) recommended teaching approaches and strategies, (3) guidelines for curriculum design and resource development, and (4) recommendations for teacher professional development.

The methodological foundation was validated through expert review and feedback from a panel of 5 informatics education experts and 5 experienced informatics teachers. The experts and teachers reviewed the methodological foundation and provided feedback on its clarity, relevance, and feasibility. Their input was used to refine and finalize the methodological foundation.

4. Results and discussion

This section presents the main findings of the study and discusses their implications for the development of a methodological foundation for teaching AI basics to lyceum students in Ukraine.

4.1. Findings from the theoretical analysis of AI concepts and terminology

The theoretical analysis of AI concepts and terminology in informatics textbooks and educational materials revealed several key findings. First, while most materials provided definitions and explanations of basic AI concepts such as machine learning [26], neural networks [27], and natural language processing [28], the depth and clarity of these explanations varied considerably. Some textbooks provided detailed and accessible explanations suitable for high school students, while others used more technical language and assumed prior knowledge of advanced mathematical concepts.

Second, the analysis identified inconsistencies in the use of AI terminology across different textbooks and materials. For example, some materials used the terms “machine learning” and “deep learning” interchangeably, while others made clear distinctions between these concepts. Such inconsistencies may lead to confusion and misconceptions among students.

Third, the analysis highlighted the importance of providing relevant and engaging examples of AI applications to help students understand the real-world impact of these technologies. Materials that

included examples from diverse domains such as healthcare, transportation, and entertainment were found to be more effective in capturing students' interest and promoting deeper understanding.

4.2. Evaluation of current AI coverage in informatics standards and textbooks

The survey of AI coverage in the current informatics standards and textbooks used in Ukrainian lyceums revealed a limited and fragmented approach to AI education. As shown in table 1, the percentage of pages and chapters dedicated to AI-related topics in the analyzed textbooks ranged from 1.5% to 6%, with an average of 3.5%. This indicates that AI is not yet a central focus of informatics education in Ukrainian lyceums.

Table 1
AI coverage in informatics textbooks for grades 10-11

Textbook	Percentage of pages	Percentage of chapters
Textbook by Bondarenko, Lastovetskyi, Pylypchuk, and Shestopalov [29]	2.5%	5%
Textbook by Morze and Barna [30]	1.5%	2.5%
Textbook by Ryvkind, Lysenko, Chernikova, and Shakotko [31]	4%	7.5%
Textbook by Rudenko, Rechych, and Potiienko [32]	3%	5%
Textbook by Rudenko, Rechych, and Potiienko [33]	6%	10%
Average	**3.5%**	**6%**

The qualitative analysis of the AI-related content in the textbooks revealed a focus on basic concepts such as machine learning, neural networks, and expert systems. However, the coverage of these topics was often superficial and lacked practical applications and hands-on activities. Few textbooks included discussions of the ethical and societal implications of AI, which are crucial for developing students' critical thinking skills and preparing them for responsible citizenship in an AI-driven world [34].

4.3. Development and evaluation of the educational web quest complex

The educational web quest complex developed in this study aimed to address the limitations identified in the current AI coverage in informatics education. The web quest complex consisted of three main components: (1) an introductory module providing an overview of AI concepts and applications, (2) a series of interactive quests focusing on specific AI topics and skills, and (3) a final project allowing students to apply their knowledge and skills to a real-world AI problem [35].

The pilot study involving 20 lyceum students revealed positive results in terms of student engagement, knowledge acquisition, and skill development. 85% of the students found the web quest complex to be engaging and motivating, while 90% reported an increased understanding of AI concepts and applications after completing the complex.

The qualitative feedback from the students highlighted the effectiveness of the interactive and project-based learning approach in promoting active learning and fostering problem-solving skills. Students appreciated the opportunity to apply their knowledge to real-world AI problems and develop practical skills such as data analysis and algorithm design.

However, the pilot study also identified areas for improvement in the web quest complex. Some students reported difficulties in understanding certain technical concepts and suggested the inclusion of more visual aids and simpler explanations. Others recommended the addition of more collaborative activities and opportunities for peer learning.

4.4. Proposed methodological foundation for teaching AI basics to lyceum students

Based on the findings from the theoretical analysis, survey of AI coverage, and evaluation of the web quest complex, we propose a methodological foundation for teaching AI basics to lyceum students in Ukraine. The methodological foundation consists of four main components:

1. **Key AI concepts and skills to be taught**
   The foundation emphasizes the importance of covering fundamental AI concepts such as machine learning, neural networks, natural language processing, and computer vision [36]. It also highlights the need to develop students' skills in data analysis, algorithm design, and problem-solving.
2. **Recommended teaching approaches and strategies**
   The foundation recommends the use of interactive and project-based learning approaches to promote active learning and engage students in the learning process [37]. It also emphasizes the importance of incorporating real-world examples and applications of AI to help students understand the relevance and impact of these technologies.
3. **Guidelines for curriculum design and resource development**
   The foundation provides guidelines for designing an AI curriculum that is aligned with the national informatics standards and integrates AI concepts and skills throughout the learning process. It also offers recommendations for developing engaging and accessible learning resources, such as interactive web quests, simulations, and hands-on activities [38].
4. **Recommendations for teacher professional development**
   The foundation recognizes the crucial role of teachers in implementing effective AI education and provides recommendations for teacher professional development [39]. These include the provision of training programs on AI concepts and pedagogical strategies, the establishment of teacher networks and communities of practice, and the development of online resources and support materials for teachers.

The proposed methodological foundation aims to provide a comprehensive and coherent approach to AI education in Ukrainian lyceums, addressing the limitations identified in the current informatics education and leveraging the insights gained from the development and evaluation of the web quest complex.

4.5. Implications and future directions

The findings of this study have important implications for the integration of AI education in Ukrainian lyceums. First, they highlight the need for a more systematic and comprehensive approach to AI education, one that goes beyond the superficial coverage of basic concepts and encompasses the development of practical skills, critical thinking, and ethical reasoning.

Second, the study emphasizes the importance of engaging and interactive learning approaches, such as project-based learning and web quests, in promoting student motivation and knowledge acquisition. This calls for a shift from traditional lecture-based teaching to more student-centered and active learning strategies.

Third, the study underscores the crucial role of teacher professional development in implementing effective AI education. Providing teachers with the necessary knowledge, skills, and resources to teach AI is essential for ensuring the success and sustainability of AI education initiatives.

Future research should focus on the large-scale implementation and evaluation of the proposed methodological foundation in Ukrainian lyceums. This could involve the development of a national AI curriculum, the creation of a repository of AI learning resources, and the establishment of a network of AI education experts and practitioners. Additionally, research could explore the long-term impact of AI education on students' academic and career outcomes, as well as on their attitudes towards AI and its societal implications.

5. Conclusions

This research paper aimed to develop a methodological foundation for teaching the basics of artificial intelligence (AI) to lyceum students in Ukraine. Through a multi-phase research approach, we conducted a theoretical analysis of AI concepts and terminology, surveyed the current state of AI coverage in informatics standards and textbooks, developed and evaluated an educational web quest complex,

and synthesized the findings to propose a comprehensive and coherent approach to AI education in Ukrainian lyceums.

The theoretical analysis revealed inconsistencies and limitations in the presentation of AI concepts and terminology in current informatics textbooks and educational materials. The survey of AI coverage in informatics standards and textbooks indicated a limited and fragmented approach to AI education, with an average of only 3.5% of pages and 6% of chapters dedicated to AI-related topics. The development and evaluation of the educational web quest complex demonstrated the effectiveness of interactive and project-based learning approaches in promoting student engagement, knowledge acquisition, and skill development in AI education.

Based on these findings, we proposed a methodological foundation for teaching AI basics to lyceum students in Ukraine. The foundation consists of four main components: (1) key AI concepts and skills to be taught, (2) recommended teaching approaches and strategies, (3) guidelines for curriculum design and resource development, and (4) recommendations for teacher professional development. The foundation emphasizes the importance of covering fundamental AI concepts, developing practical skills, incorporating real-world examples and applications, and promoting active learning through interactive and project-based approaches.

The implementation of the proposed methodological foundation has the potential to address the limitations identified in the current AI education landscape in Ukrainian lyceums and to prepare students for the challenges and opportunities of an AI-driven world. However, the successful integration of AI education in Ukrainian lyceums will require a concerted effort from policymakers, educators, and researchers to develop a national AI curriculum, create engaging and accessible learning resources, and provide comprehensive teacher professional development opportunities.

Future research should focus on the large-scale implementation and evaluation of the proposed methodological foundation in Ukrainian lyceums, as well as on the long-term impact of AI education on students' academic and career outcomes. Additionally, research could explore the potential of AI technologies to enhance and personalize the learning experience, such as through adaptive learning systems [40] and intelligent tutoring platforms [41].

Declaration on Generative AI: During the preparation of this work, the authors used Claude 3 Opus in order to: Text Translation, Abstract drafting, Content enhancement. After using this service, the authors reviewed and edited the content as needed and takes full responsibility for the publication's content.

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