Soroko N. Artificial intelligence for managing and monitoring STEAM educational environments. *Освіта. Інноватика. Практика*, 2026. Том 14, № 5. С. 128-133. https://doi.org/10.31110/2616-650X-vol14i5-016.

Soroko N. Artificial intelligence for managing and monitoring STEAM educational environments. *Osvita. Innovatyka. Praktyka – Education. Innovation. Practice*, 2026. Vol. 14, No 5. S. 128-133. https://doi.org/10.31110/2616-650X-vol14i5-016.

UDC 37.091.3:004.8:004.9
DOI: 10.31110/2616-650X-vol14i5-016

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ШТУЧНИЙ ІНТЕЛЕКТ ДЛЯ УПРАВЛІННЯ ТА МОНІТОРИНГУ STEAM ОСВІТНЬОГО СЕРЕДОВИЩА

Анотація. *Стаття присвячена проблемі використання штучного інтелекту для моніторингу та організації STEAM-освіти та освітнього середовища закладу загальної середньої освіти. Увага приділяється аналізу наукової літератури для визначення особливостей інструментів штучного інтелекту, їх категорій та характеристик для педагогічної діяльності вчителів. Для забезпечення якості статті були проаналізовані публікації, що включені до баз даних Web of Science та Scopus. Метою статті є аналіз ролі штучного інтелекту в управлінні та моніторингу STEAM-освітнього середовища у закладах загальної середньої освіти. Ми визначили, що важливими є регулярний аналіз зворотного зв'язку, оцінка ресурсного забезпечення (обладнання, цифрові інструменти, навчальні матеріали), аналіз педагогічних підходів (проектне навчання, інтегровані уроки, міжпредметні проекти), залучення учнів та батьків до процесу оцінювання, моніторинг STEAM-освіти для її корекції та інтеграція інноваційних технологій в освітній процес. Етичне та правильне впровадження ШІ в STEAM-освіті стає все більш актуальним, оскільки учні активно його використовують. Серед категорій – генеративні освітні системи, інтелектуальні репетитори, інструменти для створення контенту, системи оцінювання, аналітика та дослідження, обробка природної мови. Було визначено такі характеристики інструментів ШІ: мотиваційний вплив на учнів, персоналізація навчання, аналітика навчання, зворотний зв'язок, розвиток креативного та критичного мислення та підтримка вчителів. Перспективи подальших досліджень включають розробку методологічних рекомендацій щодо використання ШІ для організації та моніторингу STEAM-освіти для вчителів середньої школи.*

Ключові слова: *міждисциплінарний підхід; освітні проєкти; генеративні освітні системи; інтелектуальні репетитори; STEAM.*

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ARTIFICIAL INTELLIGENCE FOR MANAGING AND MONITORING STEAM EDUCATIONAL ENVIRONMENTS

Abstract. *The article is devoted to the problem of using artificial intelligence to monitor and organize STEAM education and the educational environment of a secondary education institution. Attention is paid to the analysis of scientific literature to determine the features of artificial intelligence tools, their categories and characteristics for the pedagogical activity of teachers. To ensure high quality of articles, relevant publications were included in the Web of Science and Scopus databases. The purpose of the article is to analyze the role of artificial intelligence in the management and monitoring of the STEAM educational environment in secondary education institutions. We have determined that regular feedback analysis, assessment of resource provision (equipment, digital tools, educational materials), analysis of pedagogical approaches (project-based learning, integrated lessons, interdisciplinary projects), involvement of students and parents in the assessment process, monitoring of STEAM education for its correction and integration of innovative technologies into the educational process are important. The ethical and proper implementation of AI in STEAM education is becoming increasingly relevant, as students are actively using it. Among the categories are Generative educational systems, Intelligent tutors, Content creation tools, Assessment systems, Analytics and research, Natural language processing. The following features of AI tools were identified: motivational impact on students, personalization of learning, learning analytics, feedback, development of creative and critical thinking, and support for teachers. Prospects for further research include developing methodological recommendations for the use of AI to organize and monitor STEAM education for secondary school teachers.*

Keywords: *interdisciplinary approach; educational projects; generative educational systems; intelligent tutors; STEAM.*

Introduction. STEAM (Science, Technology, Engineering, Arts, and Mathematics) is one of the leading educational approaches in contemporary European countries. Its primary aim is to foster creative thinking among young people, develop innovative skills, and implement an interdisciplinary approach to learning. Systematic monitoring of the STEAM educational environment enables the timely identification of challenges, facilitates effective analysis of educational quality, and informs managerial decision-making. At the same time,

artificial intelligence serves as a tool that effectively addresses the challenges of continuous monitoring, predictive analytics, and adaptive management of the educational environment [1].

Analysis of recent research and publications. The issues of assessing STEAM-oriented educational environments have been addressed in the works of Ovcharuk O. and Soroko N., Mang H. M. A., Chu H. E., Martin S. N., Alcaraz-Domínguez S., Molas-Castells N., among others; meanwhile, the use of artificial intelligence for educational monitoring has been explored in the studies by Salas-Pilco S. Z., Xiao K., and Hu X., Bellas, F., Naya-Varela, M., Mallo, A., et al., Fu, Y., Weng, Z. & Wang, J.

Salas-Pilco S. Z., Xiao K., and Hu X. (2022) propose defining AI as computational systems capable of participating in human activities, such as learning, adaptation, synthesis, self-correction, and the use of data for complex information processing tasks [2]. They emphasize that in education, AI supports and improves the learning environment through intelligent learning systems, intelligent agents, and intelligent collaborative learning systems. AI supports teachers' decision-making by reporting on the lesson's progress in real time and responding to students' needs through personalized learning platforms. In addition, AI has the potential to transform the education system.

Bellas F. et al. (2024) consider artificial intelligence an important factor in transforming education, significantly affecting professions, daily activities, and teaching methods in secondary education institutions. Scientists focus on how robotics and intelligent systems can support long-term learning with AI directly in the classroom. In addition, they note that AI is a systemic factor in transforming education, affecting the professional structure of society, changing people's daily activities, and requiring revisions to educational models [3].

Ovcharuk O. and Soroko N. (2024) examine the challenges and advantages of monitoring the implementation of STEAM-oriented educational environments in general secondary education institutions [4]. The authors propose a set of criteria and indicators for assessing the effectiveness of STEAM-oriented educational environments, analyze the current state of STEAM-oriented educational environments in Ukraine, and identify gaps in the evaluation framework for measuring the effectiveness of STEAM education implementation. An analytical approach is employed to examine existing methods for monitoring STEAM educational environments. The study is based on an analysis of international experience and best practices. The criteria proposed by the researchers encompass material and technical resources (including equipment and access to digital tools), professional development of teachers (availability of training and professional development programs), student engagement in project-based activities and other STEAM initiatives, governmental attention to the issue (existence of policies, regulations, and official documents supporting the implementation of STEM education in educational institutions, as well as the level of funding allocated to STEM-related projects), and the implementation of an integrative approach within the educational process.

Particular attention should be given to the study by Alcaraz-Domínguez, Silvia, and Molas-Castells, Núria (2024), which substantiates the competencies required of teachers for the effective implementation of STEAME projects (Science, Technology, Engineering, Arts, Mathematics, and Entrepreneurship) in lower secondary education within digitally enriched and AI-supported learning environments [5]. The authors develop and validate a specialized competency framework for educators comprising 44 competencies grouped into several categories. This framework aims to systematize pedagogical practice and ensure educational quality in an interdisciplinary STEAME context, aligning with data-informed, technology-enhanced educational management. Although the primary focus of the study is on identifying and validating teacher competencies, the authors also emphasize the importance of systematically assessing STEAME projects and students' learning outcomes – an aspect closely related to AI-based monitoring and learning analytics. The researchers emphasize the importance of teachers developing competencies in the effective use of digital technologies, integrating STEAME disciplines into project-based learning, and evaluating both project implementation processes and student learning outcomes, which form the basis for evidence-based, adaptive management of STEAME educational environments.

Mang H. M. A., Chu H. E. et al. (2023) present a multi-phase study aimed at developing an evaluation rubric for planning and assessing STEAM programs based on socio-scientific issues in science education [6]. The researchers focus on the lack of validated instruments for assessing the quality of STEAM programs, particularly those grounded in the Socio-Scientific Issues (SSI) approach. SSI-oriented STEAM programs integrate scientific knowledge with real-world social, ethical, and technological challenges (such as climate change, bioethics, and sustainable development), which makes their planning and assessment more complex. Although the researchers do not focus directly on artificial intelligence, their contribution is highly relevant to AI-supported monitoring of STEAM educational environments, as the rubric can be digitized and integrated into AI-driven analytical dashboards; the proposed criteria and indicators are suitable for learning analytics and automated assessment; and the structure of the rubric can serve as a foundation for decision-support system models in STEAM education.

El Fathi T., Saad A., Larhzil H. et al. point out that AI is not only a source of answers but, most importantly, a tool for stimulating students' questions, critical analysis, and self-learning. The approach to AI

in teaching involves formulating open-ended prompts (queries) for ChatGPT, critically evaluating the answers, iteratively refining the query, and understanding one's own thinking. [7]

Ahmad K. et al. conducted an analysis of scientific publications in the field of AI-education for the period 2014–2022 from leading international scientific journals and conferences. They identified several key areas of use of artificial intelligence, namely: automated assessment, prediction of academic success, creation of adaptive learning environments, providing recommendations on individual educational trajectories [8].

Gregorcic, B., Polverini, G., & Sarlah, A. (2024) in their article "ChatGPT as a tool for honing teachers' socratic dialogue skills" discuss the possibility of using multiple versions of ChatGPT to act as a mentor or a student model with whom teachers can engage in Socratic dialogue. [9]. They argue that this could be beneficial for prospective teachers, who often lack easy access to students with whom to practice their teaching skills. Furthermore, due to a lack of experience, prospective teachers are more likely to become overwhelmed by the complexity of real-world teaching situations. A chatbot's controlled, private, and secure environment could serve as a good starting point.

Labadze L., Grigolia M. & Machaidze L. note that further research into the impact of integrating chatbots into the educational process may help tailor educational interventions to individual student needs, potentially optimizing teachers' pedagogical strategies [10].

AlAfnan, M. A., Samira Dishari, Marina Jovic, & Koba Lomidze emphasize that ChatGPT is a potential replacement for search engines that provide many results and a platform for students to prepare for submissions and study various examples. For teachers, ChatGPT can provide an opportunity to integrate technology into the classroom and provide students with examples for discussion and assessment within seminars [11].

It should be noted that the study Baidoo-Anu, David and Owusu Ansah, Leticia «Education in the Era of Generative Artificial Intelligence (AI): Understanding the Potential Benefits of ChatGPT in Promoting Teaching and Learning» [12]. Scientists have identified features of AI that are important in the educational process, namely: «Personalized Tutoring», «Automated Essay Grading», «Language Translation», «Interactive Learning», «Adaptive Learning». Scientists claimed that ChatGPT can provide personalized tutoring and feedback to students based on their individual learning needs, and according to their progress. For example, a conversational agent based on a generative model can provide personalized math tutoring to students, thereby improving learning outcomes. Researchers have determined that ChatGPT can be trained to evaluate student essays, identify key features of well-written essays, and provide feedback similar to that provided by graders. This could free up teachers' time to focus on other aspects of teaching.

It is worth noting the study by Le N. and Taherdoost H. «Pervasive AI and IoT in STEAM Education: Advancing Future Learning Through Intelligent Systems and Computational Technologies» [13]. They argue that pervasive AI (AI) and the Internet of Things (IoT) can enhance the STEAM education model and prepare students for a "digital" future. The idea of the article is as follows: AI (chat bots, learning analytics, personalized learning systems) is used to create individual learning paths, analyze performance, and support self-directed learning; IoT (networks of sensors, devices, automated laboratories) is being implemented in classroom work so that students can experiment with real-world data, modeling, and "smart" learning environments (for example, interactive labs, smart classrooms, etc.).

Researchers Avci H., Lunn S. J., & Hazari Z. suggest that preparing teachers to teach with AI requires focused professional development (for example, critical appraisal, contextual adaptation) that integrates AI technologies with educational goals [14]. They note that tools such as ChatGPT, Claude, and Perplexity aid in content creation, although their use in classrooms remains limited due to ethical concerns and biases; DreamBox Learning and Khanmigo provide adaptive, curriculum-aligned learning, while MagicSchool and Eduaide.AI assist in lesson planning and instruction; Canva Magic Design and PowerBuddy support visual communication and personalized assessment with a focus on data privacy. While these tools are gaining popularity, their use across subject areas and grade levels remains understudied. The growing number of AI tools can also lead to decision fatigue, as educators often lack the time and support to evaluate which tools best suit their needs. This highlights a gap in the literature regarding practical, industry-specific recommendations to support the purposeful and sustainable integration of AI into educational settings.

The **purpose of this article** is to analyze the role of artificial intelligence in managing and monitoring STEAM educational environments in general secondary education institutions.

Research methods applied: Analysis and synthesis of scientific literature. Relevant publications in the Web of Science and Scopus databases were included to ensure high-quality articles. Systematization to substantiate and classify existing AIs into defined categories, theoretical generalization to formulate research conclusions.

Results and Discussion. Yim I.H.Y., Su J. [15] define the role of AI for three participants in the educational process: educators, teachers, and researchers. They claim that for educators to provide students with the knowledge and skills in AI that the labor market demands, encourage all citizens to be AI-literate, and promote holistic AI literacy education that integrates environmental elements into the curriculum. They note

that it is essential to consider ethical issues, including inclusivity, equity, accountability, transparency, and social responsibility. The researchers propose a roadmap for the sustainable implementation and development of AI education, namely, involving teachers in the development of teaching tools and understanding their perceptions of AI literacy education, as well as providing pedagogical strategies, resource development, and needs-based professional development for both prospective and in-service teachers. Scientists recommend that teachers carefully consider the use of AI for children's cognitive development. In addition, the content of the teaching should align with students' cognitive development, as this affects their readiness and ability to learn. In this regard, the tools used by the teacher to conduct the educational process should be appropriate for the students' age and learning objectives, and teachers should understand students' cognitive development to plan age-appropriate tasks and teaching tools. Greater collaboration among teachers with diverse pedagogical experiences across different levels of education can lead to more innovative and effective learning processes. The researchers suggest that researchers should communicate their research findings and the validity of their conclusions to teachers and educators, as such data is crucial for assessing the quality of the educational tools or pedagogical approaches they recommend. It could also help other researchers update their research on existing and emerging pedagogical strategies. The scientists suggest that a challenge for researchers could be to create a standardized AI assessment tool that can be used across educational levels to compare students' AI literacy. Such an approach would allow for the standardization of assessment criteria and instructional feedback, thereby better supporting the broader adoption of AI teaching in K-12 classrooms.

Leon C., Lipuma J. and Oviedo-Torres X. (2025), using Nvivo, Excel, VOSviewer for bibliometric analysis, analyzed 41 scientific articles from 2020 to 2025 and identified the main areas of AI development in STEM education, namely: personalized learning, Intelligent Tutoring Systems, learning analytics, automated and adaptive assessment systems [16].

Huang X. & Qiao C. (2024) proposed a specialized educational model for an AI course integrated with a STEAM approach [17]. It combines the content of artificial intelligence education, the STEAM approach, and project-based learning. It consists of several interrelated components. The authors experimentally prove that the model has several important advantages, namely: improves students' computational thinking; increases motivation for STEM disciplines; develops teamwork and creativity; helps students better understand the principles of artificial intelligence.

According to our analysis of the scientific literature, we identified the following features of AI tools (Table 1): motivational impact on students, personalization of learning, Learning Analytics, feedback, development of creative and critical thinking, and teacher support.

Table 1.

Features of using AI tools in the educational process

The impact of using AI in education	*Functional features of use AI*	*AI implementation methods*	*Examples of use in education*	*Possible outcome*
Motivational impact on students	Increasing student interest and engagement in the learning process	Gamification, interactive dialogues, generation of creative tasks	AI quizzes, interactive simulations, generative design tasks	Increased learning motivation, student activity
Personalizing learning	Adapting learning material to individual needs and learning pace	Adaptive algorithms, performance analysis, learning systems	Individual explanations of topics, adaptive tasks, individual learning trajectories	Improving the quality of knowledge acquisition
Learning Analytics	Analysis of educational data for pedagogical decision-making	Collection and processing of educational data, prediction of success	Monitoring of test results, error analysis, prediction of academic difficulties	Optimization of the learning process
Feedback	Developing students' metacognitive skills	Analysis of answers, explanation of errors	AI tutors that explain the reasons for incorrect answers	Development of critical thinking
Development of creative thinking	Stimulating creative thinking and interdisciplinarity	Idea generation, concept visualization	Creation of models, projects, visualizations	Development of STEAM competencies
Teacher support	Automation of pedagogical tasks	Generation of educational and didactic materials, automatic assessment	Creating tests, lesson plans, analyzing work	Reducing the workload on the teacher

Source: developed by the author based on research [2], [3], [6], [7], [9], [15], [16], [17].

Based on the analysis of scientific sources and the summarized Table 1, the following categories of AI systems can be distinguished (Table 2): Generative educational systems, Intelligent tutors, Content creation tools, Assessment systems, Analytics and research, Natural Language Processing.

Table 2.

Main AI categories and examples

Categories	*Examples*
Generative educational systems	ChatGPT, Gemini, Claude, Copilot, Bard, Grok
Intelligent tutors	Khanmigo, Socratic, QANDA, Khanmigo, Brainly AI Tutor
Content creation tools	Canva AI, Eduaide.AI, Curipod, DALL-E 3, Artguru, Midjourney
Assessment systems	Turnitin, Gradescope, Brisk, Wiris Quizzes, Conker
Analytics and research	Perplexity, EduChat, Excel AI, Tableau, Power BI
Natural Language Processing	Grammarly, Scribbr, Paperpal, Perplexity

Source: developed by the author based on research [12], [13], [14].

When we tested the AI tools mentioned above, it was found that almost all of these tools can be used as STEAM education monitoring tools, Generative educational systems та Intelligent tutors, except for DALL E 3, Artguru, and Midjourney, which are image generators and editors.

Conclusions. Therefore, effective implementation of STEAM education requires strategic planning, which should include: developing long-term plans for the development of the STEAM educational environment, optimizing the use of financial resources for the purchase of equipment, ensuring professional development of teachers, attracting grants and partners, creating teacher support networks (using professional communities, such as Scientix), motivating teachers to implement innovative teaching methods, using an equipment indexing system to assess classroom occupancy, developing digital panels to visualize progress in the integration of STEAM education, regular feedback analysis, assessing resource provision (equipment, digital tools, teaching materials), analyzing pedagogical approaches (project-based learning, integrated lessons, interdisciplinary projects), involving students and parents in the assessment process, monitoring STEAM education for its correction, and integrating innovative technologies into the educational process. The issue of ethical and appropriate implementation of AI in STEAM education is becoming increasingly relevant, as it is actively used by students. The main categories of AI for education are identified, namely: Generative educational systems, Intelligent tutors, Content creation tools, Assessment systems, Analytics and research, Natural Language Processing. The following features of artificial intelligence tools for the educational process, in particular STEAM education, are highlighted: motivational impact on students, personalization of learning, Learning Analytics, feedback, development of creative and critical thinking, and teacher support. Prospects for further research include the creation of methodological recommendations for the use of AI in the organization and monitoring of STEAM education for teachers of general secondary education institutions.

Conflict of Interest. The author declares no financial, personal, or other interests that could be considered a potential conflict of interest regarding the publication of this article.

Funding. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data Availability. This is a theoretical study and does not involve the use of any additional datasets.

Use of Artificial Intelligence. This research utilized generative artificial intelligence tools to support specific non-substantive aspects of the writing and editing process. The following AI-assisted tools were employed:

• Scopus AI was used to assist in refining search queries during the literature review phase, helping to identify relevant keywords and optimize Boolean logic for database searches.

• Grammarly was employed for grammar, spelling, punctuation, and stylistic consistency checks throughout manuscript drafting and revision.

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| Матеріал надійшов до редакції: 31.03.2026 р. | Прийнято до друку: 01.05.2026 р. | Опубліковано: 29.05.2026 р. |