



Uses of AI and LA in secondary education to promote meaningful learning: a systematic mapping review

Usos de la IA y la AA en la educación secundaria para promover un aprendizaje significativo: una revisión sistemática de mapeo

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Abstract

Generative AI (GenAI) and Learning Analytics (LA) are rapidly transforming education by enabling personalization, adaptive systems, and predictive interventions, yet their integration also raises challenges related to data privacy, infrastructure, and teacher readiness. This study aims to analyse the combined potential of GenAI and LA in enhancing learning while identifying barriers to implementation in formal education. A systematic literature review was conducted using the PRISMA framework to ensure transparent selection and analysis of relevant studies. Results indicate that LA facilitates data-driven decision-making through mining, visualization, and predictive models, while GenAI supports adaptive feedback and content generation; together, they enable personalized learning pathways that improve outcomes. However, ethical concerns, technological requirements, and professional training remain significant obstacles. Overall, GenAI and LA offer strong opportunities to enhance education, but their sustainable adoption requires careful attention to ethical, technical, and pedagogical dimensions.

Keywords

Generative artificial intelligence; learning analytics; personalized learning; meaningful learning; secondary education.

Resumen

La IA generativa (GenAI) y las analíticas de aprendizaje (AA) están transformando rápidamente la educación al permitir la personalización, los sistemas adaptativos y las intervenciones predictivas. Sin embargo, su integración también plantea desafíos relacionados con la

privacidad de los datos, la infraestructura y la preparación del profesorado. Este estudio tiene como objetivo analizar el potencial combinado de GenAI y AA para mejorar el aprendizaje, a la vez que identifica las barreras para su implementación en la educación formal. Se realizó una revisión sistemática de la literatura utilizando el marco PRISMA para garantizar la selección y el análisis transparentes de los estudios relevantes. Los resultados indican que AA facilita la toma de decisiones basada en datos mediante la minería, la visualización y los modelos predictivos, mientras que GenAI apoya la retroalimentación adaptativa y la generación de contenido; juntos, permiten rutas de aprendizaje personalizadas que mejoran los resultados. Sin embargo, las preocupaciones éticas, los requisitos tecnológicos y la capacitación profesional siguen siendo obstáculos importantes. En general, GenAI y AA ofrecen grandes oportunidades para mejorar la educación, pero su adopción sostenible requiere una cuidadosa atención a las dimensiones éticas, técnicas y pedagógicas.

Palabras clave

Inteligencia artificial generativa; analítica del aprendizaje; aprendizaje personalizado; aprendizaje significativo; educación secundaria.

1. Introduction

The project underpinning this article is part of a Catalan initiative involving two universities, aimed at addressing the lack of systematic evidence in Catalonia on how Generative AI (GenAI) and Learning Analytics (LA) can support active methodologies while complying with local ethical and regulatory requirements. This initiative emerged from a research call launched by the Department of Education to bridge this gap.

The integration of GenAI and LA in education in Catalonia must first be grounded in both local policy frameworks and international guidance. In Catalonia, must be considered the AI of Catalonia (Marco, 2020) and orientations issued by the Department of Education (Departament d'Educació, 2024) that require schools to make pedagogically justified decisions about AI use. At the global level, UNESCO (2023; 2024) has produced a set of policy documents that establish expectations for responsible AI in education. Identifies age-appropriate use, privacy protection, and a human-centred pedagogical approach as baseline conditions for GenAI adoption. Besides, defines 12 competencies across human-centred thinking, AI ethics, applications, and system design, with progression levels from understanding to creation. The UNESCO AI Competency Framework (2024) establishes a structured model of competencies for educators and learners across dimensions such as human-centred thinking, ethical AI use, application design, and critical engagement with algorithmic systems. In the context of secondary education, this framework implies that AI integration must a) preserve teacher pedagogical agency rather than automate decision-making, b) promote critical AI literacy among students, c) ensure transparency and explainability of AI-supported assessment and feedback, and d) align AI use with equity, inclusion, and human rights principles. In consequence, this study does not treat UNESCO guidance as merely contextual background, but as a normative benchmark against which mapped practices can be interpreted. Specifically, the review examines whether the identified uses of GenAI and LA can support teacher-centred orchestration rather than technological substitution, foster student data literacy and critical AI understanding,

and incorporate safeguards aligned with ethical AI principles while contributing to equitable personalization rather than risk stratification or profiling.

Second, regarding the research context and considering Learning Analytics and Human-Centred Learning Analytics (HCLA) (Buckingham Shum et al., 2019), analytics tools results to be effective when co-designed with educators, aligned to learning design, and evaluated as sociotechnical systems rather than purely technical solutions. Classroom orchestration research (Prieto et al., 2018a; Prieto et al., 2018b; Martínez-Maldonado, 2019) further shows that teachers benefit from multimodal analytics tools that reduce orchestration load, provide timely information on group processes, and offer actionable insights rather than raw data. Recent studies (Amarasinghe et al., 2024; LuEttaMae et al., 2024) demonstrate how learning analytics can assist teachers in both designing and orchestrating complex collaborative tasks. Their research emphasizes the importance of aligning analytics dashboards with pedagogical objectives, activity scripts, and classroom interaction patterns. Rather than providing raw behavioural traces, analytics tools are conceptualized as structured supports integrated into teachers' instructional planning processes. Furthermore, Amarasinghe et al (2021) introduce the concept of orchestration load, analysing how different forms of analytics-based support—mirroring versus guiding—affect teachers' cognitive demands and instructional adaptability. This distinction is crucial for evaluating LA tools in secondary education, where technological support must reduce unnecessary cognitive load while preserving teacher interpretative authority. Hence, all these insights can establish practical design requirements for GenAI and LA systems that must be evaluated for the Catalan context.

Third, recent research on Generative AI in education highlights both transformative opportunities and critical challenges. Studies have explored its potential to support personalized learning through adaptive content generation, automated feedback, and language support, as well as its role in fostering creativity and collaborative knowledge construction (Kasneji et al., 2023). However, emerging evidence also warns of risks related to bias, misinformation, and over-reliance on AI-generated outputs, which can undermine critical thinking and academic integrity.

The project is situated within this integrated policy, competency, and research context. To address this, it proposes a thorough review of the national and international scientific literature on the use of AI and LA in different active methodologies, followed by an analysis of case studies in Catalan educational centres to develop principles and methodological proposals applicable to the design of practices and activities that facilitate personalized learning, and a model of evaluation focused on active learning and the ethics of AI and LA. Hence, the central research problem, therefore, is how to effectively adapt and implement GenAI and LA in Catalan education, leveraging data literacy as an asset, while maintaining an ethical and inclusive approach for personalized learning. Solving this problem is imperative not only for the quality and effectiveness of education but also for preparing the next generation to live and thrive in a digital and data-driven world. However, although the project is focused on Catalonia, the results are expected to be transferable and adaptable to other areas of Europe. Ethical considerations will be rigorously addressed, including informed

consent and data protection of participants. Project feasibility will be ensured through appropriate task distribution among the research team, adhering to the established timeline.

The general objectives of the project are:

- Explore and promote the use of GenAI and LA as tools to foster meaningful learning, support collaborative learning construction, and enhance personalization in secondary education.
- Provide practical guidelines and methodological principles to integrate these technologies into a variety of active methodologies to enhance learning personalization.

The specific objectives of the project are:

- Conduct a thorough review of national and international scientific literature on the topic.
- Analyze case studies in Catalan educational centers to understand how GenAI and LA have been implemented in educational practice and evaluate their effectiveness.
- Develop teaching methodological principles and practical guidelines that facilitate meaningful learning and personalization, focusing on integrating GenAI and LA into active methodologies

This project will employ a mixed-methods approach, subdivided into four key phases:

- Literature review: A systematic review and mapping of the literature using academic databases such as Scopus, Web of Science and ERIC, with specific filters based on keywords and time.
- Case study analysis: Select secondary education centers based on criteria of public and/or subsidized secondary education centers with digitalization promotion projects. Teachers will be surveyed with validated questionnaires and semi-structured interviews to assess data competency and collect pedagogical practices using GenAI. Additionally, a focus group with experts (technologists, educators, administrators, humanists) will evaluate the applicability of GenAI in the classroom.
- Development of implementation proposals: The analysis of the collected data will serve to develop implementation proposals assisted by scenario simulation tools. Specialized software will be used to model, simulate, and analyze different scenarios. These proposals will be reviewed by experts in roundtables.
- Evaluation model: Based on participatory evaluation (PE) to measure the impact and effectiveness of the proposed implementations. This technique will ensure that the proposed implementation in educational activities is relevant, effective, and well-received by all involved parties

This article focuses exclusively on the first phase of the project: a systematic mapping review. It is organized into four main sections to comprehensively address the research objectives. The Methodology includes the systematic mapping review. The Results section presents the findings from the mapping, offering some insights into the effectiveness and challenges of using AI and LA in educational settings. Finally, the Conclusions summarize the key findings, discuss the study's limitations, and suggest directions for future research, emphasizing the potential of AI and LA to transform education while acknowledging the need for careful implementation.

2. Methodology

Although the project includes case studies and methodological guidelines, only the systematic mapping review is reported here. The analysis procedure will follow a PRISMA/PICOC methodology with bibliometric analysis. In particular, PICOC stands for population, intervention, comparison, outcomes and context.

- Population (P): the scope of the projects (i.e. local, regional, national, international) and the main topic of the projects (i.e. mental health, educational technology, gender gap, etc.).
- Intervention (I): the intervention applied in the research projects.
- Comparison (C): to which the intervention is compared. For example, a comparison between various calls for projects or between nationally and internationally funded projects
- Outcomes (O): what the review seeks to achieve, such as identifying trends or lacks or selecting a set of project results focused on a particular objective.
- Context (C): the context of the research projects must be defined, which is an extended view of the population.

The research question is formulated as: What are the uses of AI and LA in secondary education to promote meaningful and personalized learning? However, this article focuses on answering the mapping questions of literature research. The mapping questions are formulated as:

- What principles are used?
- What educational practices and methodologies are applied?
- What are the evaluation models?
- How is the ethical dimension reflected?

The inclusion criteria are as follows, considering the exclusion criteria the contrary:

- Language: Catalan, English, Spanish
- Year of publication: from 2018 to 2024
- Type of publication: journal article, book chapter, book, conference proceedings
- Place of publication: journal, conference

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- Studies that combine the concepts of AI and LA + Learning X in the context of secondary education.
- Studies that describe the design of a technological solution, prototypes, or tools applied in the context of secondary education.
- Studies that propose models.
- Studies that describe experiences/practices/cases involving AI + LA in the context of secondary education.

We considered two main indexed databases such as Web of Science (WoS) and SCOPUS. Moreover, we performed the same search at Eric database and Google Scholar (ordered by relevance and taken first three pages). Results are provided in the results section with the search string.

The procedure for reading, discarding, and selecting the definitive articles involved a process to ensure the inclusion of only relevant and high-quality studies. Initially, two researchers independently read each article to assess its relevance to the research question. This dual-review process ensured that any potential biases or oversights by a single reviewer were minimized. The researchers focused on determining whether the article described a practice implemented by a secondary education center or an educator involving the application of AI and LA. Specifically, the researchers looked for evidence that the AI and LA applications were contextualized within secondary education settings, evaluating whether these applications contributed to meaningful learning and personalized learning experiences. Articles that only presented theoretical solutions, models, or simulations of AI and/or LA without any practical application in a real educational context were excluded. This rigorous selection criterion was vital to ensure that the study's findings were grounded in actual educational practices and could provide practical insights and recommendations for educators and policymakers. Finally, any discrepancies or disagreements between the two researchers regarding the inclusion or exclusion of an article were resolved through discussion and consensus, and if necessary, a third researcher was consulted.

3. Results

All counting results and search string used are shown in Table 1.

After executing PRISMA protocol (see Figure 1) we found 77 studies, which we finally discarded 20 and set 57 for further reading. 14 of the 57 resulting studies were used to answer the mapping questions (see Table 2).

4. Discussion

This section reflects on principles and practices that guide the effective use of these technologies, examines evaluation models that ensure robust and scalable assessment, and addresses critical ethical considerations surrounding data privacy.

4.1. Principles and practices

The principles underpinning the use of AI and LA in education, as identified by Bissadu & Hossain (2024), Booth et al. (2024), and Parsons & Curry (2024), emphasize

Table 1. Search results for each indexed database

Database	Search date	Search string	Results
Scopus	19/04/2024	("artificial intelligence" OR "AI" OR "machine learning" OR "natural language processing" OR "NLP" OR "generative AI" OR "GenAI") AND ("learning analytics" OR analytic*) AND ("secondary education" OR "secondary school" OR "high school" OR "K-12" OR "K12" OR "middle school")	173
WoS			108
ERIC			34
Google Scholar			40

the importance of secure computing, personalized feedback, and collaborative instructional design. The adoption of machine learning tools such as Weka, the deployment of tutoring systems, and the exploration of AI's role in instructional design reflect how advanced technologies can support student learning and teacher effectiveness.

Educational practices highlighted in this study include AI-assisted game-based learning (Chen & Chang, 2024), problem-based learning enhanced through co-design with teachers (Hutchins & Biswas, 2023), and dynamic transitions between individual and collaborative learning supported by AI orchestration tools (LuEttaMae et al., 2024). These methodologies show how AI and LA can be integrated into diverse educational contexts to promote engagement, motivation, and adaptive learning.

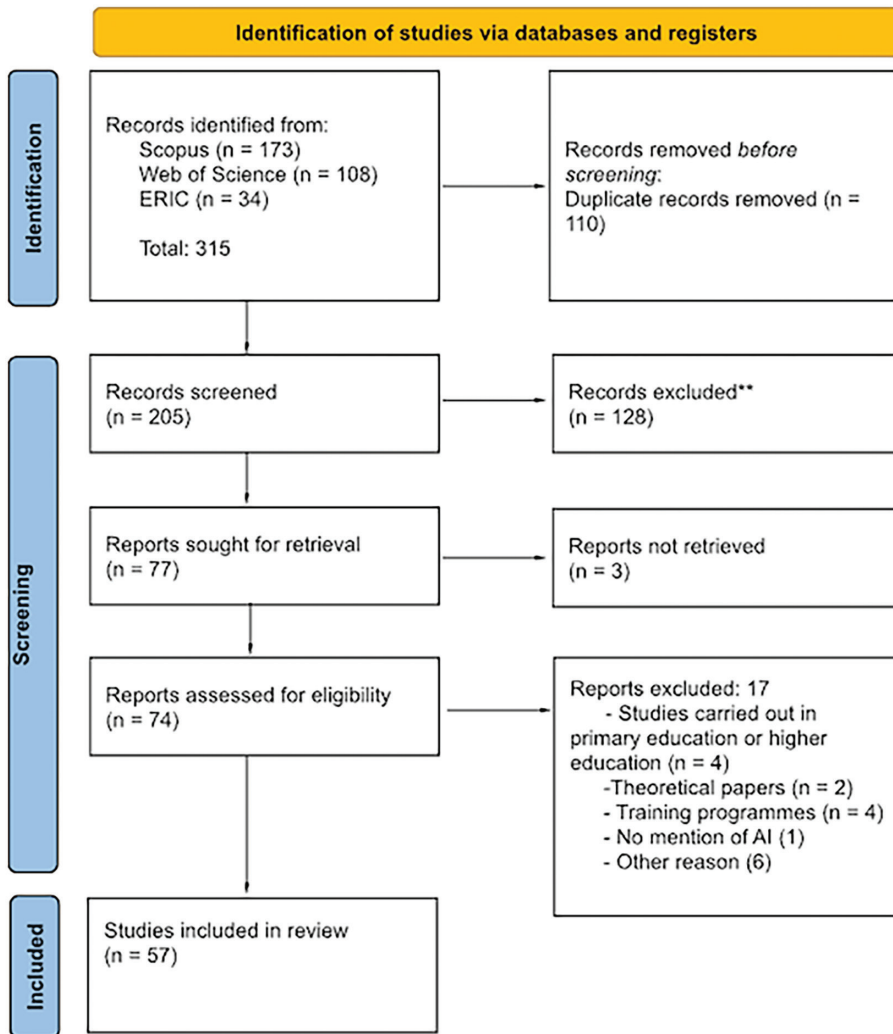
4.2. Evaluation models

The evaluation models discussed in the literature highlight the importance of robust and multi-variable assessment approaches. Wilson et al. (2024) and Liao et al. (2024) point to the use of machine learning and NLP techniques to develop scalable and precise assessment tools, highlighting the potential for AI to provide more insights into student performance. Demartini et al. (2024) and Hussain & Khan (2023) further illustrate the application of predictive analytics to support educational decision-making and personalized interventions, demonstrating the scalability and effectiveness of these models in diverse educational settings.

4.3. Ethical considerations

Ethical considerations are a recurring theme across the reviewed studies. Much of the literature emphasizes data privacy, fairness in predictive models, and the avoidance of demographic bias (Arantes, 2023; Sperling et al., 2024). These aspects are foundational, particularly given the sensitivity of student data and the risks of

Figure 1. Identification of studies via Scopus, WoS, and ERIC databases



reinforcing existing inequalities. The research by Echeverria et al. (2023) and Wilson et al. (2024) highlights the importance of involving educators in the design process to ensure that AI tools align with ethical standards and educational goals, emphasizing transparency, fairness, and inclusivity.

However, the mapping also reveals that ethical reflection often remains confined to compliance-oriented dimensions. Moving from a privacy-focused ethics model toward a broader framework of algorithmic responsibility and pedagogical agency is essential for ensuring that GenAI and LA contribute to equitable and meaningful learning rather than reinforcing technocratic or market-driven logics. Predictive

Table 2. Summary of Mapping questions, findings, and representative studies

Mapping question	Main findings	Representative studies
What principles are used?	Use of AI and machine learning (Random Forest, Gradient Boosted Trees) to predict student performance and identify at-risk learners; application of data analytics for decision-making and early interventions; importance on secure computing, personalized feedback, and fairness/bias analysis to ensure equitable opportunities.	Bissadu & Hossain (2024) [high school 9 th -12 th]; Booth et al. (2024) [high school 9 th -10 th ; N=1.100]; Parsons & Curry (2024) [12 th]
What educational practices and methodologies are applied?	Personalized learning via adaptive technologies; collaborative learning supported by AI orchestration tools; problem-based learning enhanced with teacher co-designed dashboards; use of educational games and simulations to promote digital literacy and critical thinking; AI-based guidance systems for academic path selection.	Chen & Chang (2024) [7 th ;N=195]; Hutchins & Biswas (2023) [middle school;N=9]; LuEttaMae et al. (2024) [middle school;N=76]; Majjate et al. (2024) [high school tertiary level; N=500]
What are the evaluation models?	Predictive analytics (Random Forest, Gradient Boosted Trees) to forecast outcomes and risks; incremental learning models using real-time data; quasi-experimental approaches to assess AI tools; use of time-dependent indicators (earliness, stability); NLP and cognitive diagnostics for assessment and feedback.	Wilson et al. (2024) [middle school; N=933]; Liao et al. (2024) [high school 9 th ; N=125]; Demartini et al. (2024) [high school 9 th ; N=125]; Hussain & Khan (2023) [high school 9 th -12 th ; N=90.000];
How is the ethical dimension reflected?	Emphasis on fairness in AI models and avoidance of demographic bias; strong focus on data privacy and security of sensitive student information; involvement of teachers in AI design to align tools with classroom needs; mitigation of risks of algorithmic decision-making and commercialization.	Arantes (2023); Sperling et al. (2024) [primary school students aged 7-15 N=1.200; secondary school students aged 16-19 N=450]; Echeverria et al. (2023) [middle school; N=118]; Wilson et al. (2024) [middle school; N=933]

systems that identify “at-risk” students may unintentionally shape expectations and instructional decisions through automation bias. Teachers may not defer to system recommendations without critically interrogating their underlying assumptions. Moreover, the increasing integration of GenAI into feedback and content generation introduces challenges related to transparency and explainability. In many reviewed studies, adaptive responses are described in terms of effectiveness, yet limited attention is paid to whether teachers and students can understand how recommendations are generated. Without explainability, meaningful pedagogical mediation becomes difficult. In addition, professional agency must remain central. Human-Centred Learning Analytics emphasizes that AI systems should augment teacher decision-making rather than replace it. The most ethically coherent implementations in the mapping are those that incorporate co-design processes and preserve teacher interpretative authority over data visualizations and recommendations. Furthermore, structural considerations must be acknowledged. The adoption of AI tools frequently depends on proprietary platforms, raising concerns about commercialization, data governance, and long-term dependency. Ethical AI integration in secondary education therefore extends beyond classroom practices to institutional and systemic levels.

Moreover, when interpreted through the lens of the UNESCO AI Competency Framework (2024), the mapped studies reveal an uneven alignment with international standards. Most interventions prioritize predictive accuracy and adaptive feedback, but relatively few explicitly address the development of AI literacy or critical engagement among students. While personalization mechanisms are prominent, evidence of structured activities that cultivate students’ understanding of how AI systems function remains limited. Teacher involvement in co-design processes (e.g., orchestration tools and dashboards) aligns positively with UNESCO’s emphasis on preserving pedagogical agency.

4.4. Implications for practice and policy

The findings from this study indicate that the successful integration of AI and LA requires an approach that includes teacher training, infrastructure development, and continuous evaluation to address emerging ethical and practical challenges. Policymakers and educational leaders must prioritize data privacy and equity to ensure that AI technologies benefit all students, particularly those from underserved communities.

Moreover, the involvement of educators in the co-design and implementation of AI tools is necessary for ensuring that these technologies meet the practical needs of classrooms and support meaningful learning experiences. As highlighted by Hutchins & Biswas (2023) and LuEttaMae et al. (2024), collaborative approaches that involve teachers in the development process can lead to more effective and contextually relevant AI applications. However, UNESCO’s framework extends beyond privacy to include accountability, transparency, and long-term societal implications of AI in education. The mapping indicates that these broader dimensions remain underdeveloped in empirical implementations.

5. Conclusions

The integration of AI and LA into secondary education presents an opportunity to enhance personalized learning and address various educational challenges. This study, as an initial stage of a project funded by the Department of Education of the Generalitat of Catalonia, highlights several key principles, practices, methodologies, and ethical considerations drawn from recent research, offering insights into the potential and complexities of these technologies. Subsequent phases of the project will report on case studies and guideline development.

This study shows that the effective use of AI and LA in education relies on defined principles, evaluation models, and strong ethical safeguards. In terms of principles, secure computing, machine learning techniques, and personalized feedback mechanisms were identified as key foundations, enabling early detection of at-risk students and the design of adaptive learning paths. Educational practices include AI-assisted game-based learning, adaptive tutoring, collaborative orchestration tools, and problem-based learning dashboards co-designed with teachers, all of which enhance engagement, motivation, and responsiveness to student needs. Evaluation models draw on predictive analytics, NLP, and quasi-experimental approaches to generate scalable, real-time insights into student performance and inform personalized interventions. At the ethical level, fairness, data privacy, and teacher involvement are central, ensuring that AI adoption promotes inclusivity and does not exacerbate existing inequalities. Overall, the study contributes to evidences that AI and LA can improve learning outcomes and decision-making in education, provided that their implementation balances technological innovation with ethical responsibility and meaningful collaboration among educators, learners, and policymakers.

6. Limitations

Despite the findings, this study has several limitations. First, the generalizability of the results is constrained by the specific contexts in which the studies were conducted, often focusing on particular educational systems or geographic locations. Additionally, the rapid evolution of AI and LA technologies means that findings can quickly become outdated as new tools and methodologies are developed. There is also a potential bias in the selection of studies, as research with positive outcomes may be more likely to be published and included in reviews. Furthermore, ethical considerations, while addressed, are continually evolving, and the frameworks used may not cover all potential issues. Lastly, the practical implementation of AI and LA requires significant resources and training, which may not be readily available in all educational settings, potentially limiting the broader applicability of these findings.

7. Future research directions

Future research should continue to explore the long-term impacts of AI and LA on student outcomes and educational equity. Studies should focus on developing more flexible models that can adapt to diverse learning environments and student needs, as

well as investigating the broader societal implications of AI in education. Additionally, there is a need for further research into the ethical frameworks that can guide the responsible use of AI in education, ensuring that these technologies enhance, rather than hinder, the learning experience.

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