

Preparing teachers for the AI Development in Education as an Innovative Asset



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CENTRO STUDI VILLA MONTESCA

F O N D A Z I O N E



Preparing teachers for the AI Development in Education as an Innovative Asset

Report on the potential contribution that the main student-centered pedagogical theories can offer to accompany the impact of AI in education

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The PAIDEIA Project is a groundbreaking initiative funded by the European Commission through the European Agency for Education and Culture (EACEA). Our mission is to revolutionize education by integrating Artificial Intelligence (AI) into teaching and learning, empowering educators, and enhancing student outcomes.

CONSORTIUM

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1. INTRODUCTION AND BACKGORUND

1.1 Talking with AI about AI

The purpose of this document is to provide a concise, and undoubtedly worthy of further study, vision of the impact of AI on pedagogical thought and on the main educational theories.

We explore the potential new views that AI can develop in the conception of the approach to education and to personal development proposed by the most relevant scholars and pedagogues. In the various chapters, we will address the topic from multiple perspectives, adopting an applied and practical approach while maintaining a firm grasp on the theoretical significance of pedagogical thought and its value in relation to the various philosophical and scientific currents that have emerged over the past century. Some educational theories have not only characterized the previous century but have also become an integral part of the common understanding of what education is and, ultimately, what its true purpose is in relation to the broader responsibility that current generations bear towards those that follow.

However, in this introduction, we will not examine in detail the present and future implications of artificial intelligence (AI) in education for these theories. Rather, we will seek to understand how some conclusions and practical guidelines derived from these theories—now widely regarded as common intellectual heritage—may be subject to conceptual and practical challenges brought about by the advent of AI.

To explore this, we have decided that the most effective approach is to engage directly with AI itself, initiating a dialogue with one of the most widely used chatbot systems to examine the perspectives it generates on these issues. If this may be perceived as a provocation—and in certain contexts, it undoubtedly is—the ultimate aim is what we might call a Socratic dialogue on artificial thought, asking the AI to reveal itself.

What will likely become most evident to the reader of this chapter is the general caution with which the chatbot evaluates itself. This caution is, in all probability, a consequence of the way AI systems are trained and the human oversight that meticulously ensures —both to avoid undesirable consequences, including legal ones— that AI-generated conclusions are fallible, potentially inaccurate, inappropriate, or lacking in depth. Another striking characteristic is the AI's markedly didactic tone when addressing complex topics, a tendency that becomes even more pronounced when it speaks about itself.

This approach is not without interest; indeed, it offers valuable points for reflection, some of which may merit further investigation using more traditional research methods. However, it also compels us to question the hasty and widespread adoption of AI-driven theories and tools. It

suggests that every engagement with AI-generated content should be accompanied by a deliberate process of reflection—what we might term "slow thinking."

As the reader will no doubt observe, engaging in dialogue with AI and prompting it to discuss itself does not lead to a critical exchange with a thought-provoking and stimulating interlocutor. Instead, what emerges clearly is an overwhelming and encyclopedic approach—one that reproduces content acquired through a fundamentally formal learning process. In this sense, it is somewhat reminiscent of how a young bourgeois schoolteacher in the nineteenth century might have spoken about history or geography.

A common criticism of this approach is that, unlike our nineteenth-century schoolteacher, AI is evolving at a staggering pace. In just a few years, it will likely be able to engage in far more nuanced and sophisticated interactions than it is currently capable of. Indeed, AI's application in education is still in a stage that we might describe as "Neanderthal." At this primitive phase, the tools available to artificial systems remain rudimentary, making it exceedingly difficult to predict the future with any certainty. It is, therefore, perhaps unwise to place too much confidence in any current forecasts. After all, educational theorists have historically been prone to misjudging the future; what endures from their theories is not always the future they envisioned but rather the core of their thought and the profound, transformative impact it had on their own time—an impact that continues to resonate today.

What we can assert with some certainty is that, when engaging with AI systems — however advanced— they must always be approached with an awareness of what we might call the "Matrix Syndrome": the tendency to perceive a world that, behind a thick veil of technology, may in reality be quite different from how it appears.

Q. Good morning, can you give me some indications about the introduction of AI in education? (ChatGPT-4.5, 2025)

Good morning! The introduction of AI in education is a rapidly evolving field with significant implications for teaching, learning, and educational management. Here are some key aspects to consider:

I. AI Applications in Education

- **Personalised Learning:** AI can analyse students' learning patterns and tailor educational content to individual needs, offering personalised feedback and adaptive learning pathways.
- **Automated Assessment and Feedback:** AI-powered tools can provide instant feedback on assignments, quizzes, and even essays, reducing the burden on teachers and offering students immediate insights.
- **Virtual Tutors and Chatbots:** AI-driven tutors can support students in their studies,

answering questions and guiding them through complex topics.

- **Intelligent Content Creation:** AI can generate and organise educational materials, including interactive simulations, quizzes, and summaries, enhancing learning experiences.
- **Teacher Support and Administrative Tasks:** AI can assist teachers by automating administrative tasks such as grading, scheduling, and student performance tracking, allowing more time for instruction.

2. Benefits of AI in Education

- **Increased Accessibility:** AI tools can support students with disabilities by offering speech-to-text, text-to-speech, and other assistive technologies.
- **Data-Driven Insights:** AI can analyse large datasets to identify learning gaps, predict student performance, and help educators make informed decisions.
- **Engagement and Motivation:** Gamification and AI-driven interactive learning experiences can make education more engaging for students.
- **Challenges and Concerns**
- **Ethical and Privacy Issues:** AI systems collect vast amounts of data, raising concerns about data security, student privacy, and algorithmic bias.
- **Dependency on Technology:** Over-reliance on AI may reduce critical thinking skills and interpersonal interactions among students.
- **Equity and Accessibility:** Not all schools have equal access to AI technologies, potentially widening the educational divide.
- **The Role of Teachers:** AI should complement, not replace, human educators. The challenge lies in integrating AI without diminishing the importance of teachers' roles.

3. The Future of AI in Education

- The integration of AI is expected to grow, with advancements in natural language processing, personalised learning models, and AI-driven educational platforms.
- Hybrid learning models, combining AI tools with traditional teaching methods, will likely become more common.
- Ethical frameworks and regulations will be crucial in ensuring that AI is used responsibly in education.
- Would you like me to focus on any specific aspect?

Q. Yes please give me an idea about the future risks and how we can mitigate them (ChatGPT-4.5, 2025)

As AI becomes increasingly integrated into education, several risks must be addressed to ensure

that its implementation is ethical, effective, and beneficial for all learners. Below are some key risks and potential mitigation strategies:

1. Risk: Algorithmic Bias and Inequality

Issue: AI systems can inherit biases from the data they are trained on, potentially reinforcing stereotypes and inequalities. This could lead to unfair treatment of certain groups of students based on gender, race, socioeconomic status, or learning abilities.

Mitigation Strategies:

- Use diverse and representative datasets to train AI models.
- Conduct regular audits to detect and correct biases in AI systems.
- Implement human oversight, ensuring that AI decisions are reviewed by educators.
- Promote transparent AI models, where decision-making processes can be understood and questioned.

2. Risk: Privacy and Data Security Concerns

Issue: AI-driven educational platforms collect vast amounts of student data, raising concerns about data security, consent, and potential misuse.

Mitigation Strategies:

- Enforce strict data protection regulations (e.g., GDPR, FERPA).
- Use data anonymisation techniques to protect student identities.
- Educate schools and students on digital literacy and data rights.
- Ensure clear consent policies, so students and parents understand how data is used.

3. Risk: Over-Reliance on AI and Loss of Human Interaction

Issue: AI could reduce the role of human educators, leading to less personal interaction, which is essential for emotional and social development.

Mitigation Strategies:

- Ensure AI is used as a supplementary tool, not a replacement for teachers.
- Promote blended learning approaches, where AI supports but does not dominate education.
- Train educators to integrate AI effectively while maintaining human engagement.
- Emphasise the development of soft skills (e.g., communication, empathy) that AI cannot replicate.

4. Risk: Misinformation and Lack of Critical Thinking

Issue: AI-generated content may contain inaccuracies, potentially misleading students and discouraging critical analysis.

Mitigation Strategies:

- Teach critical digital literacy, helping students assess AI-generated content.
- Use AI tools that provide source transparency and fact-checking capabilities.
- Encourage human validation of AI-generated information.
- Promote a "slow thinking" approach, where students and educators reflect critically on AI outputs.

5. Risk: Unequal Access to AI Technology

Issue: Not all schools or students have equal access to AI-powered educational tools, potentially widening the digital divide.

Mitigation Strategies:

- Develop affordable and open-source AI solutions for education.
- Implement government and institutional policies to ensure AI accessibility in underprivileged areas.
- Provide teacher training so educators can effectively use AI tools across different contexts.

6. Risk: Ethical Dilemmas and Autonomy

Issue: As AI takes on more decision-making roles (e.g., grading, personalised learning paths), ethical questions arise regarding autonomy, fairness, and accountability.

Mitigation Strategies:

- Establish clear ethical guidelines for AI use in education.
- Maintain human oversight in key educational decisions.
- Encourage a multi-stakeholder approach (educators, policymakers, students, and ethicists) to AI governance.

Conclusion

While AI has the potential to revolutionise education, it must be implemented responsibly to avoid unintended consequences. The key lies in balancing technological innovation with ethical considerations, ensuring that AI enhances rather than replaces human educators, and safeguarding students' rights and well-being.

Q. Another issue is: do you think that the AI will change the relevant educational theories? (CLAUDE 3.5 2025)

I think AI will significantly transform educational theories in several important ways, rather than simply replacing them.

Traditional educational theories focus on how humans learn and develop, often emphasizing social interaction, developmental stages, experiential learning, and different learning styles. AI brings new dimensions to consider:

Personalization at scale will likely become central to new educational theories. AI can adapt to individual learning patterns, speeds, and preferences in ways that weren't possible before,

potentially transforming how we think about differentiated instruction.

The role of the educator will need reconceptualization. Rather than knowledge transmission, theories may emphasize the teacher as curator, facilitator, and mentor who helps students navigate AI-enhanced learning environments.

Assessment theories will likely evolve beyond traditional testing. AI enables continuous evaluation of learning processes rather than just outcomes, potentially leading to more nuanced theories about measuring competency and understanding.

Theories about knowledge acquisition may shift as AI tools become learning partners. The emphasis might move from memorization toward information synthesis, critical evaluation, and creative application.

I believe we'll see the emergence of hybrid theories that consider how human cognition develops in partnership with AI tools, similar to how Vygotsky's theories addressed tools as extensions of human capability.

What aspects of educational theory are you most interested in seeing evolve with AI?

Q: Do you have any idea about the impact of AI on Montessori's way of thinking (CLAUDE 3.5 2025)

Thinking about AI's impact on the Montessori Method is fascinating. The Montessori approach emphasizes child-directed learning, hands-on experiences, and carefully prepared environments. There are several interesting ways AI might interact with these principles:

One area of potential harmony is personalization. Montessori already focuses on individualized learning paths and respecting each child's developmental pace. AI could enhance this by providing even more granular insights into learning patterns while still preserving the child-directed nature of activities.

However, there's tension around the centrality of physical, sensory experiences in Montessori. Maria Montessori believed strongly in concrete materials and tangible exploration as foundations for abstract thinking. AI interfaces, even tactile ones, may not provide the same sensorial development that traditional Montessori materials offer.

The role of the guide (teacher) in Montessori is to observe carefully and intervene minimally. AI could potentially enhance this observation, noting patterns a human might miss, but the human guide's intuition and presence might remain irreplaceable for aspects like social-emotional development.

Montessori's emphasis on concentration and deep work could be both supported and challenged by AI. On one hand, well-designed AI could adapt to a child's focus state; on the other, digital interfaces often struggle to foster the sustained concentration that Montessori environments cultivate.

Perhaps most interesting would be how Montessori's concept of "freedom within limits" might

evolve. AI could potentially create more responsive boundaries that expand as the child demonstrates readiness, while still maintaining the structure that Montessori believed was essential for development.

Q. What aspects of the Montessori Method do you think would be most affected by AI integration? (ChatGPT-4.5, 2025)

The Montessori Method, with its emphasis on hands-on learning, self-directed exploration, and holistic development, presents both opportunities and challenges when integrating AI. Here are the aspects that could be most affected:

I. Child-Led Learning and Autonomy

Impact of AI:

- AI-driven adaptive learning platforms could support personalised education, allowing students to explore topics at their own pace.
- However, AI might introduce structured digital guidance that could reduce the child's independence, shifting focus from open-ended exploration to algorithm-driven suggestions.

Potential Solution:

- AI should be “a tool for enrichment”, not a replacement for student-driven inquiry. It should allow children to explore freely rather than directing them too rigidly.

2. Hands-On, Sensory Learning

Impact of AI:

- Montessori places strong emphasis on manipulatives and real-world interactions (e.g., wooden blocks, sandpaper letters). AI, being primarily digital, may lead to less physical engagement, replacing hands-on learning with screen-based interactions.

Potential Solution:

- AI should enhance rather than replace tactile experiences—e.g., AI-powered interactive materials (like smart blocks or AR-enhanced objects) could complement Montessori tools.

3. Teacher's Role as a Guide

Impact of AI:

- Montessori educators are facilitators rather than direct instructors. AI could assist by providing insights into individual student progress, helping teachers tailor their support.
- However, there is a risk that AI could replace human observation, leading to a less personal connection between teacher and student.

Potential Solution:

- AI should serve as a data-driven assistant to the teacher, providing feedback without diminishing the teacher's role in observing and nurturing students.

4. Social and Emotional Development

Impact of AI:

- Montessori promotes collaborative and real-world interactions among children. If AI tools replace human engagement (e.g., AI tutors over peer discussions), social learning could decline.

Potential Solution:

- AI should encourage peer interactions, e.g., by suggesting group activities rather than individualised, screen-based tasks.

5. Intrinsic Motivation vs. Gamification

Impact of AI:

- Montessori emphasises intrinsic motivation, while many AI-based learning tools rely on gamification (badges, rewards, scores). This could shift motivation away from internal curiosity to external reinforcement.

Potential Solution:

- AI should be designed to align with Montessori principles, avoiding excessive extrinsic rewards and instead promoting exploration, curiosity, and mastery.

Final Thoughts:

AI in Montessori education must be thoughtfully integrated to support rather than undermine its core principles. The key is ensuring AI remains a “facilitator of natural learning experiences” rather than a rigid guide that limits autonomy, hands-on exploration, and human connection.

Q: And what about the Steiner’s approach? (CLAUDE 3.5 2025)

The potential impact of AI on Steiner (Waldorf) education presents even more interesting tensions than with Montessori, given Steiner's unique philosophical foundations.

Rudolf Steiner's approach is deeply rooted in anthroposophy and emphasizes the spiritual dimensions of human development. The Waldorf method deliberately delays technology exposure, prioritizing imagination, creativity, natural materials, and rhythmic experiences with the physical world.

There are several key areas where AI would significantly challenge Steiner's educational philosophy:

The Waldorf emphasis on teacher-student relationships as a spiritual exchange might be fundamentally challenged by AI tools. Steiner believed in the teacher as an artist who responds intuitively to children's developmental needs, something AI cannot replicate at the metaphysical level Steiner envisioned.

The deliberate technological progression in Waldorf education (which traditionally introduces complex technologies only after children have developed imagination and critical thinking) would

be disrupted by early AI integration.

Waldorf's focus on handcrafts, movement, and artistic expression as pathways to cognitive development could be diminished if AI tools replace these tactile, embodied experiences.

However, AI might complement Waldorf education in certain areas:

AI could potentially support the narrative-based learning that's central to Waldorf by generating rich, age-appropriate stories that align with developmental stages.

For older students in Waldorf high schools, AI could become a subject of critical inquiry itself, examining the philosophical and ethical questions that Steiner education already emphasizes.

The tension seems more pronounced with Steiner than with Montessori, given Waldorf's explicit stance on technology's role in human development.

Q. Last but not least...and what about the role of the Bruner's Spiral curriculum? (CLAUDE 3.5 2025)

Looking at Jerome Bruner's spiral curriculum concept, the integration of AI presents some fascinating possibilities and challenges.

Bruner's spiral curriculum is based on the idea that complex topics can be taught at any age in an intellectually honest form, with students revisiting these concepts repeatedly at increasing levels of complexity. This creates a "spiral" of learning where knowledge deepens with each pass.

AI could potentially enhance this approach in several ways:

The spiral curriculum requires careful tracking of each student's conceptual understanding to determine when and how to revisit topics. AI could excel at monitoring this progression, identifying precisely when a student is ready to spiral upward to a more complex treatment of a concept.

Bruner emphasized that learning should be active and constructive. AI tools could provide interactive simulations and problem-solving environments that allow students to construct knowledge at their own pace while still following the spiral structure.

The scaffolding concept that Bruner helped develop could be more precisely calibrated with AI assistance. The support provided could adjust in real-time as students demonstrate growing mastery, gradually fading as they become more independent.

However, there are challenges too:

Bruner placed great emphasis on social interaction and cultural context in learning. The risk with AI is that it might individualize learning to the point where these crucial social dimensions are diminished.

The spiral curriculum relies on intuitive leaps and moments of discovery that teachers recognize and nurture. AI would need sophisticated capabilities to identify these subtle moments of readiness for conceptual advancement.

Bruner believed in the importance of narrative as a fundamental way humans organize knowledge.

AI would need to preserve this narrative quality rather than presenting information in disconnected, purely logical structures.

What I find most interesting is how AI might help realize Bruner's vision more fully by making the spiral curriculum more responsive to individual learners while still maintaining its coherent structure across knowledge domains.

Q. All in all, are you optimistic? (CLAUDE 3.5 2025))

Yes, I'm cautiously optimistic about AI's potential impact on education, though I believe the integration will require thoughtful implementation.

What makes me optimistic is seeing how AI could enhance what's already valuable in diverse educational approaches. It could help personalize learning in ways that Montessori educators have long aspired to provide rich narrative experiences that Steiner would value (though perhaps in different contexts than he envisioned) and make Bruner's spiral curriculum more responsive and adaptive.

The key will be to ensure that AI serves as a tool that amplifies human relationships in education rather than replacing them. The most promising path forward seems to be one where AI handles aspects of education that are procedural or information-heavy, freeing human teachers to focus on what they do best: inspiration, mentorship, emotional support, and cultural transmission.

I'm also optimistic because educational philosophies have always evolved with new technologies. Just as books, printing presses, and computers were incorporated into education while preserving core human values, AI will likely find its appropriate place.

That said, my optimism comes with the caveat that we must be intentional about preserving the embodied, social, and spiritual dimensions of learning that these educational philosophers rightly emphasized. The challenge will be balancing technological enhancement with these timeless human elements of education.

What's your perspective on this? Are you optimistic about the future of AI in education?

Q. Not completely. We risk losing the valuable contribution of very experimented theories, don't we? (CLAUDE 3.5 2025)

Your concern is valid and thoughtful. There is indeed a risk that in our enthusiasm for AI, we might overlook or undervalue the profound wisdom accumulated in established educational theories.

These theories weren't developed arbitrarily - they emerged from decades (sometimes centuries) of careful observation of how humans learn and develop. Montessori's insight into hands-on learning, Steiner's understanding of imagination and developmental stages, and Bruner's grasp of how knowledge builds recursively - these aren't just preferences but reflect deep truths about human cognition and development.

The risk is that AI might be implemented in ways that prioritize efficiency or novelty over these

hard-won insights. For example:

We might sacrifice the tactile, embodied learning experiences that Montessori showed are crucial for cognitive development.

We could lose the rhythmic, imaginative elements that Steiner demonstrated to support healthy development.

The carefully structured progression of Bruner's spiral curriculum might be replaced by more fragmented, algorithm-driven learning paths.

What concerns me is that technological change often moves faster than our ability to evaluate its effects. Educational approaches need time to be tested, refined, and validated - time that the rapid pace of AI development might not allow for.

I think the healthiest approach is one of integration rather than replacement, where AI is designed to explicitly support and enhance the principles of these proven educational theories, rather than being implemented in ways that inadvertently undermine them.

Q. What are your final conclusions about AI in education, in short? (ChatGPT-4.5, 2025)

AI in education presents both significant opportunities and serious risks. It can personalise learning, automate administrative tasks, and enhance accessibility, but it also raises concerns about bias, privacy, over-reliance on technology, and reduced human interaction.

Q. Is it worth accepting the risks? (ChatGPT-4.5, 2025)

So, my answer is yes, but with caution. The benefits of AI can greatly enhance education, but only if its implementation is ethical, balanced, and teacher-guided. AI should be a supportive tool, not a replacement for educators, critical thinking, or human relationships. The key is to mitigate risks proactively through ethical AI design, teacher involvement, and careful regulation.

Just to end the discussion, being a Human (almost) intelligent ...a quote

"Human beings are a disease, a cancer of this planet. You're a plague, and we are the cure." — Agent Smith, The Matrix (1999)

2. AI AND ITS IMPACT ON THE MAIN STUDENT-CENTERED PEDAGOGICAL THEORIES

2.1 The Rise of AI and its impact on education: Pedagogical consequences and effects

Before Artificial Intelligence (AI) is rapidly transforming every aspect of human activity, including education. By integrating technologies such as machine learning, data analytics, and adaptive systems, AI promises to revolutionize traditional pedagogical frameworks, enabling personalized learning experiences and more efficient educational processes. As AI technologies continue to evolve and gain widespread adoption, their influence on teaching and learning presents both opportunities and challenges for educators, students, and institutions (Celik et al., 2022).

This report delves into how key student-centred pedagogical theories can inform and shape the impact of AI in education. It also explores the broader implications for stakeholders, including students, teachers, and educational institutions. Unlike approaches that primarily focus on risks, our emphasis lies on leveraging the opportunities AI presents, both because the risks and how to manage them are addressed by other project outputs (e.g. D2.5), and because AI is a technological phenomenon that has exploded in the last two years, but is still in its infancy from the point of view of theoretical and practical reflection for the educational field, with potential that's largely yet to be discovered and addressed. Its rapid development challenges educators and policymakers to strike a balance between preserving valuable aspects of traditional practices and adapting to new possibilities. Moreover, policies that severely restrict or ban the use of new technologies in educational contexts – sometimes at the level of national legislation – may offer moderate short-term benefits (Sanders et al., 2024). However, such measures risk isolating schools from societal progress and leaving them ill-equipped to understand and influence the evolving world (Campbell et al., 2024).

Historically, new technologies have always necessitated a re-evaluation of entrenched educational practices. The introduction of AI is no different. As always, with the introduction of new technologies that have a major impact on the school world, we need to understand what, of the way “things have always been done”, needs to be perhaps updated, supplemented or revised, but retained in substance, and what needs to be accompanied toward radical change, which means change the school system in all major areas: planning, teaching, learning, assessment and feedback. In general terms and for what we can observe and foresee at the moment, within a field that is constantly and tumultuously developing, AI may have the potential to support and flesh out, in a sustainable, widespread manner and not applicable only in special and privileged cases, many of

the pedagogical ideals and principles of the great innovators of schooling, the European teachers and pedagogists who theorized and practiced active, participatory, exploratory, less dogmatic, and more flexible and adaptable to individual needs: among others, Maria Montessori, Jean Piaget, Célestin Freinet, Loris Malaguzzi, Rudolf Steiner, Johann Heinrich Pestalozzi, as well as non-European names but of great influence in Europe such as Lev Vygotsky, John Dewey, Paulo Freire. A partial list can give an idea of these potentials in different areas of teaching/learning:

2.1.1 Personalization of Learning


One of the most transformative aspects of AI in education is its capacity to deliver personalized learning experiences. Pioneers such as Montessori (2023) and Pestalozzi (Green, 1905) emphasized the importance of adapting education to individual needs, paces, and interests. In traditional systems, this principle often remains aspirational due to economical and logistical constraints. However, AI-powered adaptive learning systems and intelligent AI tutoring systems can tailor content to individual students, providing support or challenges based on real-time assessments. This adaptability enhances engagement and helps learners progress at their own speed. For example, AI-powered platforms like DreamBox for mathematics or Carnegie Learning's Cognitive Tutor employ algorithms that analyze students' problem-solving approaches and provide tailored feedback. This model encourages a growth-oriented mindset, where learning is seen as an individualized journey.

2.1.2 Active Learning and Experiential Education

John Dewey (1916) and Célestin Freinet (1968) advocated for “learning by doing,” emphasizing active engagement over passive reception of knowledge. AI technologies like simulations, augmented reality (AR), and virtual reality (VR) can bring these principles to life. These tools enable students to solve real-world problems in immersive environments, whether building physical models, exploring historical events, or navigating scientific phenomena. Moreover, advancements in AI are making such experiences more accessible and cost-effective than ever.

2.1.3 Inclusion and Accessibility

Creating an inclusive education system that meets the needs of all learners was a core ideal of educators like Ellen Key (1900) and Alexander Neill (1960). AI can contribute significantly by providing customized support for students with diverse abilities. For example, AI-powered tools can assist learners with cognitive, motor, or sensory disabilities by offering tailored speech, visual, or text-based solutions. These innovations can help realize the dream of a school system that is



inclusive and attentive to every individual's needs. Moreover, AI has the potential to reduce educational disparities by making learning more accessible to underserved populations. AI-powered platforms offer a more flexible and affordable alternative to traditional learning environments, giving students access to quality education regardless of geographic or economic constraints. For example, students in remote or under-resourced areas can benefit from online platforms that provide AI-driven tutoring and interactive resources. There are, of course, some criticalities to take into consideration: the benefits of AI in education are not equally distributed, leading to concerns about a "digital divide." Access to AI-driven education often depends on resources such as high-speed internet, devices, and infrastructure, which are not universally available. Moreover, if AI systems are built with biases—based on the data on which they are trained—they may unintentionally reinforce existing inequalities rather than alleviate them.

2.1.4 Autonomous and Collaborative Learning Environments

Inspired by the democratic visions of Neill (1960) and Korczak (2018), AI can foster environments where students collaborate, experiment, and make decisions independently. AI platforms can facilitate group projects, guide self-directed learning, and enable students to manage their own activities. Such environments encourage autonomy and teamwork while supporting participatory and democratic learning practices.

2.1.5 Continuous Monitoring and Feedback

Lev Vygotsky's concept of the "zone of proximal development" emphasizes the importance of timely and tailored support (Vygotsky, 1978). AI can play a vital role here by providing continuous monitoring and real-time feedback, enhancing the traditional assessment processes, enabling instant feedback for students and detailed analytics for teachers. AI algorithms can quickly analyze large volumes of data to identify patterns, helping educators understand student strengths and weaknesses in greater depth. This allows for formative assessments to become more frequent and personalized, promoting continuous improvement rather than episodic testing. Teachers can gain deeper insights into each student's progress, allowing them to intervene only when necessary. This ensures a seamless learning experience while addressing difficulties effectively. Furthermore, AI's role in grading assignments, particularly in large classrooms or online courses, can reduce the workload for teachers. Automated grading systems, as seen in tools like Gradescope or Turnitin's AI-driven feedback mechanisms, have shown potential in efficiently evaluating student work. Although automated grading is limited to quantifiable assessments, future developments may allow AI to evaluate more nuanced and subjective assignments, such as

essays, through natural language processing.

2.1.6 Critical Thinking and Citizenship Education


Paulo Freire's vision of critical education emphasized empowering learners to question, analyse, and engage with societal issues (Freire, 1998). AI can support this by enabling students to analyse data, evaluate diverse perspectives, and form informed opinions. Additionally, AI tools can facilitate discussions on ethics, social justice, and the impact of personal and collective choices, fostering active and critical citizenship.

2.1.7 Social-Emotional Learning (SEL)

The development of social-emotional skills – central to the philosophies of Janusz Korczak (2018) and Loris Malaguzzi (1995) – can be enhanced through AI. Virtual assistants and AI-powered platforms can help students develop empathy, self-regulation, and interpersonal skills by offering feedback on interactions and guiding reflection on social behaviors.

2.1.8 Changing Roles of Teachers

The aforementioned Freire, Dewey, Vygotsky, and Montessori argued that the teacher's role is to facilitate learning through practical and meaningful experiences, rather than simply transferring knowledge or playing the role of an authority. The teacher is a facilitator, helping students move from what they can do independently to what they can do with help. For Carl Rogers (1969), education should also be student-centred, with the teacher acting as an empathic guide to help the learner develop his or her potential, and Rudolf Steiner (1927) proposed an education that included intellectual, emotional and spiritual development, with teachers encouraging creativity and authenticity. AI can support this vision. As AI takes on a greater role in the classroom, the role of teachers must change accordingly, fostering the shift from content delivery to guidance and facilitation. Teachers are no longer merely information providers; rather, they act as mentors who guide students in interpreting and synthesizing the vast amount of information AI systems can provide. This shift calls for teachers to develop new skills, particularly in understanding and using AI-driven insights to support students' development. The changing role of teachers raises concerns regarding the potential deskilling of the teaching profession. As AI automates more educational tasks, some argue that it may diminish the value placed on teachers' expertise and creativity. On the contrary, this shift must be as a positive evolution, enabling teachers to focus on higher-level tasks such as fostering critical thinking, creativity, and socio-emotional skills that are less amenable to automation.



What we want to emphasize is that AI should not be used to impose a certain strategy or pedagogical vision, but to support each teacher's pedagogical ideas and teaching practice, in a “blended” pedagogical model, where AI complements traditional teaching methods rather than replacing them: in this hybrid approach, AI would handle tasks such as personalized content delivery and basic assessments, while teachers focus on nurturing students' social and emotional development. Such a model could provide the best of both worlds, combining the efficiency of AI with the irreplaceable human elements of education.

In conclusion, AI can become a cross-cutting tool in the service of different methodologies, as long as it is developed in order to create meaningful learning experiences and it's used ethically and responsibly. AI tools must therefore be designed to respect the privacy and well-being of students and avoid reducing the educational experience to an impersonal digital interaction. With these considerations in place, AI can become a valuable ally for students, teachers, and the educational system as a whole, contributing to educational environments that honour each student's uniqueness while preparing them for a rapidly changing world.

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3. CRITICAL THINKING AND LATERAL READING PEDAGOGICAL STRATEGIES IN SCHOOLS: PERSPECTIVES, OPPORTUNITIES, AND RISKS IN THE AGE OF ARTIFICIAL INTELLIGENCE

3.1 Introduction

The proliferation of AI tools capable of generating convincing texts, synthesizing vast amounts of information, and even mimicking human communication raises both opportunities and challenges for education. One of the most pressing is the need to equip students with enhanced critical thinking skills (Darwin et al., 2023). Modern AI technologies have become increasingly sophisticated in their ability to generate content that seamlessly blends fact and fiction, making the distinction between authentic and synthetic information increasingly subtle (Wu, 2024). This technological advancement creates a complex environment where students and educators alike must navigate an information landscape with traditional markers of credibility that may no longer suffice (McGrew et al., 2018).

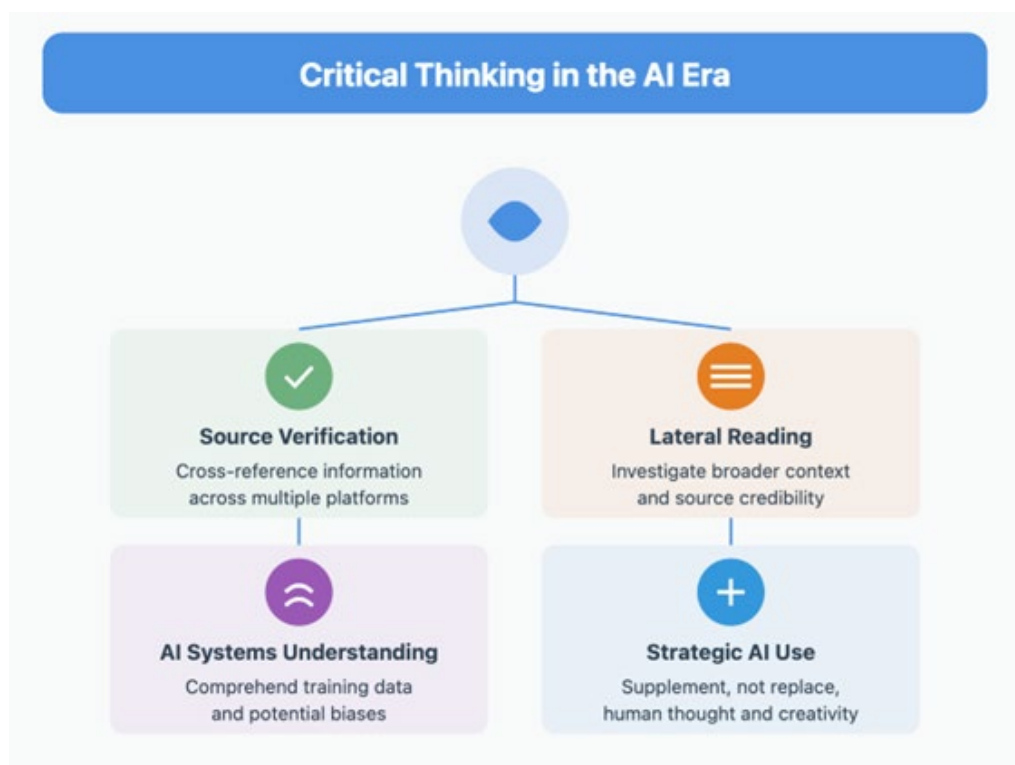
In this scenario, students must develop the ability to evaluate AI-generated content critically, understanding both its capabilities and limitations (Zhang et al., 2024) and educators need to adapt their teaching methods to incorporate AI literacy while maintaining academic integrity (Zhang, Li & Yu, 2024). From a different perspective, educational institutions must establish frameworks that acknowledge AI's role while preserving the fundamental goals of education (Moroianu et al., 2023). In all these cases, artificial intelligence can be a valuable ally in tackling old problems in new ways. In any case, the solution cannot be to drastically restrict the use of AI: what is forbidden in the classroom proliferates outside; but to take from this new scenario the opportunity to strengthen skills that have long been considered fundamental in every sphere, both in and out of school: critical thinking and, as a peculiar development of this, lateral reading (Wineburg & McGrew, 2019). Indeed, approaches geared toward banning or over-regulating are likely to prove counterproductive for several reasons: prohibited technologies tend to proliferate outside controlled environments, potentially leading to unguided and inappropriate use; students miss opportunities to develop essential skills in managing and leveraging AI tools responsibly; the educational system risks becoming disconnected from the technological context students will face in their future careers.

Critical thinking, always central to education, takes on new dimensions in the AI era (Alexander, 2014). Indeed, it must now encompass the ability to verify sources and cross-reference

information across multiple platforms (Goldman et al., 2012). Moreover, it requires skills in lateral reading, where students learn to leave their immediate source to investigate its broader context and credibility (Kohnen et al., 2020), understanding of how AI systems work, their training data, and potential biases (Breakstone et al., 2021) and capacity to use AI tools strategically and ethically as supplements to, rather than replacements for, human thought and creativity.

Lateral reading emerges as a crucial extension of critical thinking in the digital age (Wineburg & McGrew, 2019). This approach involves not just evaluating content at face value, but understanding its broader context, source credibility, and potential biases (McGrew et al., 2018). In an era where AI can generate convincing but potentially flawed content, the ability to read laterally – checking multiple sources, verifying claims, and understanding the broader context – becomes an essential skill for academic success and lifelong learning (Cho et al., 2018).

This evolution in educational approach represents not just a response to technological change, but an opportunity to strengthen core academic values while preparing students for a future where human intelligence and artificial intelligence increasingly intersect (Wu, 2024). This analysis examines how critical thinking and lateral reading strategies can be integrated into education, focusing on the opportunities and risks presented by AI while exploring broader societal implications (Zhang et al., 2024).



3.2 Critical Thinking in Education

Critical thinking in educational contexts represents a complex cognitive construct that has evolved significantly in its conceptualization and application over the past decades and that has been extensively studied within educational and psychological research frameworks (Abrami et al., 2015). Contemporary understanding of critical thinking has evolved from purely cognitive definitions to encompass metacognitive processes and socio-cultural dimensions that reflect the complexities of modern learning environments (Alexander, 2014).

At its core, critical thinking encompasses the ability to analyze, evaluate, and interpret information systematically in a logical and reasoned manner and while forming well-reasoned judgments and conclusions. It requires a combination of cognitive skills, such as identifying biases, recognizing logical fallacies, and constructing coherent arguments. Additionally, it encompasses the disposition to approach problems with intellectual curiosity, open-mindedness, and a willingness to engage with ambiguity and complexity. For school students, developing critical thinking skills means acquiring the tools to question assumptions, evaluate competing perspectives, and make evidence-based decisions. In particular, meta-analyses of critical thinking research (Tiruneh et al., 2014) have identified several core cognitive processes that constitute critical thinking in educational contexts:

1. **Analytical Processing:** The systematic evaluation of arguments and evidence through decomposition and structured analysis (Van Gelder, 2005).
2. **Evaluative Reasoning:** The application of systematic criteria to assess information validity and reliability (Stanovich & West, 2008).
3. **Inferential Cognition:** The construction of logical conclusions based on evidence evaluation and pattern recognition (Stanovich, 2016).

Recent empirical research has expanded this theoretical foundation to incorporate additional dimensions essential for modern educational contexts and have demonstrated the crucial role of metacognitive awareness in critical thinking development (Veenman et al., 2006).

Contemporary research emphasizes the importance of critical thinking in digital contexts (Goldman et al., 2012) and identifies key competencies including evaluation of source credibility in online environments, integration of multiple information sources and recognition of potential algorithmic biases. Moreover, recent neuroimaging and behavioral studies have highlighted the social nature of critical thinking (Mercier & Sperber, 2011), demonstrating how critical thinking develops through argumentative discourse, perspective-taking, and collective problem-solving. Meta-analyses of educational interventions (Abrami et al., 2015) suggest that effective critical thinking instruction requires:

1. Explicit Strategy Instruction: Direct teaching of critical thinking frameworks
2. Scaffolded Practice: Graduated application of critical thinking skills
3. Transfer Support: Facilitation of skill transfer across domains
4. Systematic Assessment: Regular evaluation of critical thinking development


3.3 Lateral Reading in Education

Lateral reading represents a sophisticated information evaluation strategy that has gained significant attention in educational research, particularly in the context of digital literacy and online information evaluation (Wineburg & McGrew, 2019). Unlike traditional linear reading approaches, lateral reading involves leaving the initial source to investigate its broader context, credibility, and relationship to other sources before engaging deeply with its content (McGrew et al., 2018). Wineburg & McGrew (2017) has established lateral reading as a crucial component of digital literacy, fundamentally different from traditional reading comprehension strategies. This approach emerged from studies of expert fact-checkers' information verification practices, revealing distinct cognitive processes that characterize effective online information evaluation. Recent empirical research (Kohnen et al., 2020) has identified several key elements of lateral reading:

1. Source Investigation: Systematic evaluation of author credentials, institutional affiliations, and potential biases
2. Contextual Analysis: Understanding the broader discourse and temporal context surrounding information
3. Cross-Reference Verification: Comparing claims across multiple authoritative sources
4. Strategic Skepticism: Maintaining calibrated skepticism while evaluating information validity

Evidence-based teaching methods for lateral reading, as outlined by Breakstone et al. (2021), include explicit modeling of strategies through think-aloud demonstrations, structured opportunities for guided practice with feedback, and progressively challenging tasks to build proficiency. Research also highlights practical applications, such as integrating multiple browser tabs and windows, strategically using search engines, evaluating search result patterns, and understanding digital information architecture (Kohnen et al., 2020).

The impact of lateral reading on students' abilities is significant. Wineburg and McGrew (2019) document improvements in information evaluation accuracy, source credibility assessment, recognition of misinformation, and critical analysis skills. Neuroimaging studies (Cho et al., 2018) further reveal that lateral reading engages executive function networks, working memory systems, and attention control mechanisms, reflecting the cognitive complexity of this approach.



Lateral reading's relevance extends beyond individual skill development. Research by Kahne and Bowyer (2017) demonstrates its role in combating misinformation, fostering digital citizenship, and enhancing media literacy. By addressing these modern educational challenges, lateral reading equips learners with the tools needed to critically navigate an increasingly complex and interconnected digital world.

3.4 Critical thinking, lateral reading and artificial intelligence in education

The interplay between critical thinking, lateral reading, and artificial intelligence in contemporary educational settings is complex. The emergence of artificial intelligence has fundamentally transformed the educational landscape, creating both unprecedented opportunities and significant challenges for teaching and learning. This transformation necessitates a reconceptualization of how we approach critical thinking and information evaluation in educational contexts. The traditional frameworks for developing student analytical capabilities must now evolve to address the unique challenges posed by AI-generated content and AI-mediated learning experiences.

Critical thinking in the AI era requires new cognitive competencies, including the ability to understand algorithmic influences and recognize patterns in AI-generated content. This expanded conception of critical thinking reflects the complexity of modern information environments. Effective information evaluation now requires sophisticated cross-platform verification techniques and an understanding of how AI systems generate and present information. This evolution in lateral reading practices reflects the changing nature of information creation and dissemination in digital spaces.

Opportunities and risks

There are significant opportunities for enhancing educational experiences through the integration of AI technologies with critical thinking and lateral reading instruction (Adiguzel et al., 2023; Wu, 2024). AI-powered systems can create personalized learning pathways that adapt to individual student needs while providing real-time feedback on critical analysis tasks (Hu, 2024). These capabilities, when properly leveraged, can significantly enhance students' ability to evaluate and synthesize information across multiple contexts (Zhang et al., 2024). In particular, AI technologies offer significant opportunities to enhance critical thinking and lateral reading education. These include:

- I. Personalized learning: AI-driven platforms, such as intelligent tutoring systems, can

adapt to individual student needs, providing tailored exercises and feedback that target specific critical thinking skills (Hu, 2024). For instance, an AI system can identify a student's difficulty in recognizing logical fallacies and generate targeted practice scenarios to address this gap, following established principles for critical thinking instruction (Abrami et al., 2015). This personalization allows for more efficient learning and can help close skill gaps among diverse student populations (Moroianu et al., 2023).

2. **Content generation and analysis:** Tools like ChatGPT can simulate debates, generate scenarios for analysis, and assist students in exploring multiple perspectives on an issue (Darwin et al., 2023). For example, students can input a controversial topic, and the AI can present arguments for and against it, prompting critical evaluation, which aligns with research on argumentative reasoning (Mercier & Sperber, 2011). These tools can also help students deconstruct complex ideas by presenting simplified explanations or alternative viewpoints.
3. **Immediate feedback:** AI tools can evaluate student responses in real-time, identifying weaknesses in reasoning and suggesting improvements (Adiguzel et al., 2023). This instantaneous feedback loop allows for iterative learning and fosters a deeper understanding of critical thinking principles, supporting metacognitive development (Veenman et al., 2006). For example, an AI might flag unsupported claims in an essay or suggest additional sources for further exploration.
4. **Access to diverse resources:** AI-powered search engines and recommendation systems can help students discover a broad array of sources, promoting lateral reading practices (Wineburg & McGrew, 2019). These tools can also filter information based on credibility metrics, guiding students toward reliable content, which is crucial given the challenges in civic online reasoning (Breakstone et al., 2021). For instance, an AI system could highlight peer-reviewed studies or reputable news outlets, helping students navigate the vast digital landscape more effectively.

At the same time, several concerning trends merit careful consideration, particularly when students rely too heavily on AI tools for information processing and analysis (Tamrin et al., 2024). These dependencies can manifest as decreased autonomous thinking capabilities and reduced original analytical skills. Furthermore, students often struggle with the complexity of distinguishing AI-generated content from human-authored materials, leading to challenges in information verification and evaluation (McGrew et al., 2018). Indeed, the integration of AI into education also introduces significant risks, including:

- I. **Over-reliance on AI:** Dependence on AI tools may erode students' ability to perform critical analyses independently (Darwin et al., 2023). If students rely solely on AI for

answers, they may fail to develop the analytical skills needed to evaluate information critically (Stanovich, 2016). This over-reliance could lead to a diminished capacity for independent thought and problem-solving.

2. **Misinformation amplification:** AI systems may inadvertently prioritize or generate misleading information, making it crucial for students to verify content rigorously (Kahne & Bowyer, 2017). For example, generative AI tools can produce realistic but factually inaccurate texts that require careful scrutiny, highlighting the importance of lateral reading skills (Wineburg & McGrew, 2019).
3. **Bias in AI algorithms:** AI systems are not immune to biases, which can skew the information presented to students (Zhang et al., 2024). These biases can arise from training data or algorithmic design, potentially perpetuating stereotypes or misinformation. Educators must address this issue by teaching students to recognize and account for such biases when using AI tools, building on established frameworks for critical thinking instruction (Tiruneh et al., 2014).
4. **Ethical concerns:** The use of AI raises ethical questions about data privacy, the ownership of intellectual property, and the potential for manipulation (Moroianu et al., 2023). Educators must ensure that students understand these ethical dimensions and are equipped to use AI responsibly (Wu, 2024). For example, students should be aware of the implications of sharing personal data with AI platforms or relying on AI-generated content in academic work.

Pedagogical Strategies

A comprehensive framework for integrating critical thinking and lateral reading instruction in AI-enhanced educational environments must consider the importance of explicit strategy instruction combined with carefully scaffolded practice opportunities (Abrami et al., 2015). This approach allows students to develop sophisticated evaluation techniques while maintaining their autonomous thinking capabilities.

Classroom implementation of these strategies takes various forms: particularly effective activities comprehend source analysis projects, where students engage in comparative analysis of AI-generated and human-authored content over multiple class sessions. These exercises provide structured opportunities for students to apply lateral reading strategies while developing critical evaluation skills (Wineburg & McGrew, 2017).

Similarly effective are digital detective exercises, which guide students through systematic verification processes while documenting their investigative methodologies. These activities help

students internalize evaluation strategies while developing practical skills for navigating complex information landscapes (McGrew et al., 2018).

To integrate critical thinking and lateral reading into secondary education effectively, curricula should emphasize:

1. **Source evaluation:** Teaching students how to identify credible sources and recognize signs of bias or unreliability. This includes understanding domain authority, cross-referencing claims, and distinguishing between primary and secondary sources. Educators can use real-world examples, such as viral social media posts, to illustrate the importance of source evaluation (Breakstone et al., 2021).
2. **Fact-Checking practices:** Encouraging the use of fact-checking tools and platforms, such as Snopes, FactCheck.org, and Media Bias/Fact Check. Students should learn to compare information across multiple platforms to identify discrepancies. Fact-checking exercises can be integrated into assignments and assessments to reinforce these skills (Kohnen et al., 2020).
3. **AI literacy:** Introducing students to the capabilities and limitations of AI, including how algorithms operate and how to detect AI-generated content. This includes hands-on activities where students analyze outputs from AI tools to identify errors or biases. For instance, students could evaluate an AI-generated news article for accuracy and completeness (Zhang et al., 2024).
4. **Interdisciplinary approaches:** Combining critical thinking exercises with subjects like history, science, and literature to illustrate their broad applicability. For example, students could analyze historical texts for bias, evaluate scientific claims using data-driven methods, or critique literary works through different interpretative lenses (Alexander, 2014).

Practical activities can help reinforce these skills. Examples include:

1. **Debates and simulations:** Students can engage in debates on contemporary issues, using lateral reading to support their arguments with verified information. AI tools can be used to simulate opposing viewpoints, enhancing the complexity of debates. These activities foster not only critical thinking but also public speaking and collaboration skills (Mercier & Sperber, 2011).
2. **Source comparisons:** Assignments that require students to analyze multiple sources on a single topic, assessing their credibility and perspectives. For example, students could compare news articles from different outlets to identify potential biases and evaluate the reliability of each source (Stanovich, 2016).
3. **AI Interaction:** Structured interactions with AI tools, where students critique the

outputs and identify potential inaccuracies. This could include tasks such as detecting factual errors in AI-generated texts or rewriting AI outputs to improve clarity and accuracy. These exercises help students develop a nuanced understanding of AI's strengths and limitations (Wu, 2024).

4. Case studies: Analyzing real-world examples of misinformation, such as viral social media posts or misleading news articles and exploring how lateral reading could have mitigated their impact. Students could also create their own case studies to teach peers about the importance of verification (Darwin et al., 2023).
5. Peer review: Incorporating peer review into classroom activities, where students critique each other's work for logical coherence, use of evidence, and clarity of argumentation. This practice not only improves critical thinking skills but also fosters a culture of constructive feedback and collaboration (Cho et al., 2018).

Implementation challenges

At the institutional level, schools often struggle with resource limitations and technical infrastructure requirements. Professional development needs are substantial, as many educators require extensive training to effectively integrate AI-awareness into their critical thinking instruction (Adiguzel et al., 2023). Pedagogical challenges are equally significant. Teachers face difficulties in integrating these new approaches into existing curricula while managing time constraints and ensuring skill transfer across different subject areas. Assessment methodology also presents unique challenges, as traditional evaluation methods may not adequately capture the complexity of these integrated skills. These are precisely the starting points and goal of the PAIDEIA Project.

Implementing these strategies in secondary schools is not without challenges. Teachers may require professional development to become proficient in lateral reading techniques and AI literacy. Additionally, schools must ensure equitable access to digital tools and resources, addressing disparities that could hinder some students' ability to engage fully with these practices. Time constraints within standardized curricula may also pose a barrier to integrating these skills effectively (Tiruneh et al., 2014). Finally, the rapid pace of technological change necessitates ongoing updates to curricula and teaching methods to remain relevant.

A systematic approach to implementation emphasizes curriculum mapping and cross-disciplinary coordination. Successful integration requires sustained professional development programs that build collaborative learning communities among educators. These communities serve as crucial support systems for teachers as they navigate the complexities of integrating AI awareness into

critical thinking instruction (Hu, 2024).

The Broader implications of AI

As AI continues to evolve, its implications for society will extend far beyond education. Preparing students to think critically and verify information rigorously is essential for fostering informed citizens capable of navigating a world shaped by AI. This includes understanding the ethical dimensions of AI, such as its impact on employment, privacy, and decision-making processes. Schools have a responsibility to equip students with not only the technical skills to use AI but also the ethical frameworks to assess its consequences (Moroianu et al., 2023). By cultivating these competencies, educators can help students contribute to a more equitable and informed society.

Integrating critical thinking and lateral reading strategies into secondary education is imperative in the age of AI. These pedagogical approaches empower students to evaluate information critically, navigate digital landscapes effectively, and engage with AI tools responsibly. While challenges remain, the potential benefits—from enhanced cognitive skills to greater resilience against misinformation—underscore the importance of prioritizing these strategies in modern education. By doing so, we can equip the next generation with the tools they need to thrive in an increasingly complex and AI-driven world. Education systems that embrace these strategies will not only prepare students for academic success but also cultivate thoughtful, informed citizens who can contribute meaningfully to society.

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4. THE COGNITIVE IMPACT OF AI ON THE CHILDREN'S MIND: AN ANALYSIS BASED ON AN HISTORICAL REVIEW

Recent developments in the study of the functioning of the mind in the early years of life have led to a reevaluation of many conventions and assumptions that, over the centuries, have shaped views on the structure and dynamics of learning. One of the first educational theorists to be concerned with the impact that a new understanding of the child's mind might have on the relationship with the adult world was Maria Montessori. Her conclusions, summarized in her foundational work "The Absorbent Mind" (Montessori, 1967), are the result of continuous observation, a practice whose methodology and approach also drew from her scientific and medical training. As is well known, Montessori was one of the first women in Italy to earn a medical degree, and in order to pursue this ambition, she had to overcome considerable cultural resistance, particularly due to the societal prejudice that deemed physical contact with the human body inappropriate for women. It is important to note that medical science at the end of the nineteenth century relied primarily on observation for diagnostic purposes. Few were the opportunities available to doctors to make more accurate diagnoses using sophisticated investigative tools, such as the ones we take for granted today. Thus, Montessori was a doctor who practiced the art of observation. This diagnostic method became the methodological foundation of her scientific pedagogy.

Montessori understood that the child's mind begins its cognitive development before birth, and that in its "spiritual embryo" state, the child embarks on an extensive and anthropologically complex journey of knowledge-building. The very metaphor of the "spiritual embryo" refers to the idea of the mind as something beyond the material and visible. In fact, the metaphor suggests something else: it alludes to a system of knowledge that is inherently active and organized, developing day by day in the pursuit of both the material and intellectual worlds. According to Montessori, the development of the child's mind is the result of a long, complex, and intricate process of engagement with knowledge. This process begins with the idea of a "cognitive prairie" that every newborn face, which, through continuous exploration and experimentation, becomes the child's own system of knowledge.

Starting from such an assumption immediately highlights a significant implication in practical terms. If the child's mind is the explorer observing a new world to make it their own, the adult has a crucial role in ensuring that the world unfolding before the "spiritual embryo" is not obstructed by any barriers that might hinder this fervent process of discovery. On the contrary, adults must work to make this process of observation as smooth and fruitful as possible. The adult's role is



not to remain neutral—far from it. They must not refrain from intervening in this profound search for knowledge. However, their intervention must be non-intrusive, so as not to interfere with the natural and organic development of the child's mind. As mentioned, the adult must contribute to creating the conditions that facilitate the child's ongoing work of discovery. The child's cognitive life, filled with daily goals that are incessantly identified as objectives to be reached, becomes possible thanks to a natural methodological approach similar to that employed by a scientist (Gopnik, 2009).

What we typically think of when referring to cognitive sciences is the way in which minds arrive at a reliable and structured conception of the world. To achieve this understanding, we generally rely on a set of human cognitive abilities and tools that complement the scientist's cultural and scientific system. The relationship with the external world, as emphasized by the sociology of science, serves as a means of validating the set of theories conceived and understanding how these theories may, to some extent, converge into a more structured analysis and validation. Essentially, scientists accept a series of rules and representations that guide the development of their knowledge system.

Some authors have observed how this system of representations and rules can also be found in the observational work that the child performs in their cognitive development, particularly in the earliest stages of their life experience (Gopnik & Meltzoff, 1997). It is also clear—and this emerges from a broader view of the potential outcomes of scientific research—that epistemologically, no process is entirely exempt from the risk of errors, underestimations, and the profound influence of the surrounding environment. There are numerous potential factors that could divert the scientist's task, leading to incorrect conclusions and conceptualizations about the phenomena being observed and analyzed.

It is therefore plausible to assume that similar errors and analytical difficulties may also occur in the development of the child's knowledge, and that there may be negative or undesired consequences for the outcomes of their epistemological constructs. In the specific case of the child as a "scientist," as some have observed, it is not necessarily the case that research and observation conducted from an erroneous point of view cannot still, in some way, be considered positive elements in the overall outcomes of the child's cognitive development (Bruner, 1990). In fact, unlike the adult scientist, who has a clearly defined research set within a given context, the child has a much broader cognitive "prairie," which also serves the social dimension of their mind. The child's goal is to acquire a new vision of the surrounding world. Every concept they learn, every piece of data they absorb, helps them construct language. These are new elements, all to be explored, each representing a small daily challenge.

According to the bioecological model of human development, the social environment plays a significant role in shaping the individual's development (Bronfenbrenner & Morris, 2006). This


theoretical model posits that the individual is embedded within a network of structures (bio-micro-meso-exo-macro-chronosystems) that shape their development. The ecological theory is particularly useful for understanding the profound relationship between the environment and the child's learning process. As early as the first decades of the twentieth century, Vygotsky, a psychologist and educator, in developing the concept of the zone of proximal development, emphasized the crucial role that the environment plays in the child's cognitive development (Wertsch, 1985).

4.1 The role of the environment in cognitive development: technological challenges and new educational paradigms

It is important to consider that the environment the children born in the present moment is markedly different from the environment envisioned by earlier theories and the contexts they referred to. This new environment is deeply characterized by different tools and cognitive frameworks compared to those encountered by a child born in the 1950s. While one might observe that, at its core, the child's role as a "scientist" does not change, and that the techniques of observation and experimentation remain largely unchanged, what could profoundly shift is the child's relationship with the deeper technological systems surrounding them. These systems will soon influence their ability to develop cognitive skills and will require them to engage with new abilities, fully aware that, as this child grows into adolescence and adulthood, they will lose certain abilities while developing new ones.

In this new system of knowledge, some of what we might call "information providers" are managed by generative artificial intelligence (AI). While it is clear that the child scientist does not directly engage with systems like ChatGPT in their observational work, it is equally evident that such systems exist within their natural environment and interact with those who are part of it. Often, it is the adults who, in creating this novel and unprecedented environment, make the task of adaptation a challenge for the child. Therefore, before considering how and why artificial intelligence could be used as a tool to support cognitive development in early childhood, and how adults might employ AI to promote the cognitive development of children, we must first address a broader issue: how adults, often unconsciously, create a new social environment into which children are born, and how this environment—inconceivable only a few years ago—can be prepared to best support their cognitive development.

The idea that the environment must be prepared, taking into account the new social and cognitive relationships shaped by the use of AI systems, broadens, in a sense, a concept that Maria



Montessori articulated more than a hundred years ago. What the Italian educator defined as the "prepared environment" is, quite simply, a physical and mental space that the adult has the complex task of constructing in order to create a system of tools and relationships aimed at promoting learning, providing them to the child for their full cognitive development (Montessori, 1946). As visionary as Montessori was, she could not have foreseen what would happen when generative AI became an active and invasive participant in cognitive relationships between individuals, determining a significant part of the exchange of information. However, the concerns she expressed remain largely relevant today. She, too, was concerned with how the adult can interact without invading the child's observational and exploratory space. It could be said that she would have asked the adult to manage all available tools in a way that would not interfere, but rather encourage the child's independent discovery of information, allowing all of their cognitive capacities to develop at their natural pace and in accordance with individual predispositions.

The recognition of the strategic importance of the learning environment in the child's development is not, however, unique to Maria Montessori. Many other educational theorists have also addressed this issue.

Loris Malaguzzi, founder of the movement known as Reggio Children, highlighted in pedagogical discourse that the learning environment is not a neutral element in a child's cognitive development; rather, it serves a specific role as the "third teacher." (Malaguzzi, 1993) The conclusions drawn by the aforementioned and numerous other pedagogues (Mezirow, 2008) on the subject of the learning environment lead us to consider that the educator's awareness in fostering a continuous and consistent relationship with AI-based technological support tools—particularly, though not exclusively, those that act as information providers—must be highly refined. This requires a deep understanding of how these tools are utilized and the potential impact they may have on children's cognitive formation, even when they engage with such tools indirectly. To illustrate with a practical example, we are already aware of AI-driven tools capable of autonomously conducting focus groups or facilitating online discussions among adults, aimed at developing specific knowledge or assessing knowledge acquisition within a group. These virtual tutors can be employed in various ways, and it is easy to predict that their use will become increasingly prominent and widespread. Such tools can assist teachers by supporting the work that student groups complete at home, or by providing virtual academic assistance to struggling students without requiring the physical presence of the teacher.

If we envision these systems being used daily and integrated into educational practices, eventually becoming institutionalized, it becomes crucial that their development and application consider how they may alter the learning environment—even for those who, due to early developmental stages, are not yet directly or independently engaging with them. It is likely that the adults whom

young children encounter during the initial stages of life will have become fully familiar with these systems, viewing them as integral to daily life. Consequently, children's perception of a virtual tutor could seamlessly integrate into their learning environment and cognitive framework as if it were a natural, rather than artificial, component.

A more comprehensive analysis of the learning environment and the impact of AI is developed in the specific section of this paper.

It is imperative to expand the discourse surrounding the use and cognitive impact of these tools beyond adults, to consider the impact these routinely used tools for study and teaching may have on young children's perception of their learning environment throughout the rich and intricate process of exploration that we refer to as development.

As mentioned, it must be concluded that discussions surrounding artificial intelligence in early childhood still largely center on which tools may be used in primary or even pre-primary education, and on how these tools can be implemented and their impact on children. Based on our observations, this discourse is insufficient; it must expand to include a crucial element related to the transformation of the learning environment, influenced by the use of these tools by adult users. It is now evident that the widespread, mobile use of devices alters not only individuals' cognitive approaches but also societal cognition as a whole. Therefore, it is equally clear that a mind developing within this new cognitive environment will be shaped by these changes, growing within an intricate network of technological relationships.

Pedagogy, therefore, cannot take the implications of these observations for granted. It must delve deeper—not only into how these tools can be utilized for children's cognitive development but also into how they alter the status of social relationships within the child's perceived environment, where they undergo their first exploratory experiences. It will be essential to extend research to examine how these initial encounters might lead children to interact with adults who are highly familiar with these tools in their daily lives, inevitably influencing young learners.

In short, artificial intelligence in early childhood not only generates potential technological tools to support knowledge—tools whose use and appropriateness require careful reflection—but it also reshapes the symbolic landscape that young scientists explore, upon which they build their cognitive constructs. To adequately fulfill their role as explorers and make the most of their innate curiosity, adults must take even greater care in preparing the environment, going beyond the concerns of Montessori and Malaguzzi and adding new considerations. The environment is prepared not only by constructing appropriate tools that become foundational elements but also by fostering a heightened awareness of the structured preparation expected in the educational effort. This environment is also shaped by the mental framework of educators, who may be deeply influenced by the constant, daily use of artificial intelligence tools.

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5. NEW PERSPECTIVES OF AI IN PROBLEM-BASED AND PROJECT-BASED LEARNING

5.1 Problem-based learning and Project-based learning: differences and similarities

Problem and project-based learning (PBLs) are approaches where students learn while actively engaging with meaningful problems. Both begin with and are framed around real-world situations. Both are cross-disciplinary, incorporating a variety of concepts from across the board into one learning experience. They are also both powerful tools for developing durable skills such as problem solving, critical thinking, group working, creativity, empathy, and information literacy, among others.

On the surface, names help identify the outcome. Project-Based Learning leads students and teachers toward the completed project. Problem-Based Learning leads the teachers and students to problem identification and solutions.

44 The process of exploring the problem and solutions is where the two strategies diverge. Problem-based learning involves picking apart and finding solutions to real-world problems. Students research the issue, investigate differing perspectives and experiences around the matter, explore solutions from a variety of angles, and put together a comprehensive plan to solve the problem. The end product is a comprehensive plan to solve a complex and multifaceted situation. We can say that Problem-based learning starts with a real-world problem, as does Project-based learning, but the process and outcomes differ slightly. Rather than study a problem, find solutions, and move on, project-based learning encourages learners to produce an artefact to demonstrate the mastery of content, a sort of final product.

In terms of regular teaching, “learning through problems” is mainly characterized by the following aspects. First, problem-based learning is usually centered on real-world problems that are challenging and close to students' real lives, stimulating students' interest and participation. Second, in project-based learning, students play a leading role. They need to take the initiative to explore and study problems and develop strategies and methods to solve them. Third, both PBLs often integrate knowledge and skills from multiple subjects, prompting students to apply and deepen their interdisciplinary understanding in the process of problem solving. Lastly, both of them not only focus on the final outcome but also emphasize reflection and assessment during the learning process. Students need to reflect on and evaluate their learning at each stage of the

project.

While the framing and style of both PBLs are different, they are fairly similar in theory. Both are student-centered strategies that encourage the teacher to serve as the facilitator. They are often completed with students working in groups, utilizing multiple sources of information. Both foster collaboration and practical application of knowledge, both are characterized by self-directed learning under the instructor's guidance, both can greatly improve students' enthusiasm for learning, help mobilize students' autonomy in learning, promote active thinking and a deeper understanding of knowledge by applying the learned disciplinary knowledge to practical situations, and by carrying out experiments, designs, creations or other forms of practical activities.

5.2 How AI can enhance PBLs experience

The integration of artificial intelligence (AI) tools offers vast potential to enhance PBL experiences, facilitating personalized learning, real-time feedback, and data-driven insights, among others. Indeed, there has been a rise in the number of educational applications embedding AI capabilities to improve the PBL process. AI can be applied in a wide range of collaborative learning contexts and several multimedia tools can facilitate PBL processes. AI can support these learning models.

AI technologies such as intelligent tutoring systems, adaptive learning platforms, collaborative tools, and simulation software can all contribute to a richer and more effective learning experience in both problem and project-based contexts and in a variety of ways by automating tasks, providing personalized guidance, and creating dynamic learning environments.

The combination of augmented reality and AI in education is not only a growing area of research but also a transformative force. Immersive learning tools, such as augmented reality applications infused with AI capabilities and speech recognition are able to create more vivid and realistic learning environments, support experiential learning, enhance the immersive experience of students, and effectively stimulate their interest in learning and enthusiasm for inquiry, whether students solve problems or make a project.

AI tools can create simulations that are otherwise difficult or impossible to replicate in a classroom setting, such as:

Virtual Field Trips - students can take virtual field trips to places they might not be able to visit physically, and AI can enrich this experience by interpreting and analyzing data from the virtual environment, providing contextual information, and answering students' queries in real-time.

Simulated Labs - in PBLs experiences in the field of biology, chemistry, and engineering, students can conduct experiments in a fully simulated environment, where AI assists in ensuring correct

procedures, safety protocols, and immediate feedback.

Furthermore, some platforms have the potential to help facilitate collaboration through the use of AI, so to interact with the learning, offering guidance and feedback on the educational experience. For instance, VoiceThread is an interactive communication tool that allows voice, video, and text commenting. Students can share multimedia files (i.e. images, videos, PowerPoint presentations, PDFs) and invite others to comment using one of the available modalities (e.g., video or text). Another platform is Padlet, an online virtual “bulletin” board where students and teachers can collaborate, reflect, and share links and pictures in a secure location. Both platforms can support the PBLs collaborative path.

During the PBLs processes, students often need to gather information, conduct research, and analyze data. AI tools can assist in automating research, filtering relevant academic papers, and even extracting key insights from large datasets (e.g., using natural language processing to summarize articles or identify trends in data).

To increase students' learning interest and help them better understand theoretical knowledge in real-world applications, students can use AI-powered simulation tools (Bloomberg Terminal, FlexSim, NASA, etc.) to test and validate their hypotheses in virtual environments, conduct experimental design and data analysis. Of course, students can use AI to pose questions about the topic of the PBLs process, using chatbots such as Replika, ChatGPT that can provide real-time support synchronously and to find relevant information using intelligent search engines such as Bingchat and Baidu AI. It is also possible to apply AI to generate smart contents (SC) that allow the abbreviation of textbooks into a more digestible study guide with chapter summaries, practice tests and flashcards.

Furthermore, AI systems can assist students in planning and managing PBLs projects by providing structured scaffolding. These systems can break down large projects into smaller, manageable tasks, track progress, and set deadlines. There are some project management tools which integrate various AI plug-ins and predict the time and resources needed at different stages of the project, so to develop a more effective project plan.

AI can also enhance collaboration in group-based PBLs. Collaborative Virtual Environments can facilitate role-playing simulations. In these simulations, students take a role and interact in learning scenarios designed to achieve specific learning outcomes. The simulation can be extended to include multiple students working collaboratively in different roles. Collaborative platforms powered by AI can then monitor group interactions, track individual contributions, and even mediate discussions by suggesting resources or encouraging more balanced participation.

After making a project plan, students should use AI-powered Intelligent Tutoring Systems that can act as personalized virtual mentors during the PBLs process. These systems provide guidance, ask probing questions, and give hints when students encounter difficulties in solving problems.

The systems can simulate one-on-one tutoring, making the process more interactive and responsive. At the same time, they allow for a balanced distribution of tasks to avoid overloading some members and underloading others.

Finally, AI analytics can aggregate and analyze large datasets generated by PBL activities, offering instructors valuable insights into student learning patterns, misconceptions, and areas for intervention. These impacts of the use of AI in the PBLs process are summarized in Table I below:

| Characteristics of PBL | Support of AI | Specific functions |
|---|--|---|
| Exploration of authentic contextual issues: Closely related to students' real life | Creating authentic problem solving situations | Virtual Reality (VR) technology is utilized to simulate various situations in the real world, and Augmented Reality (AR) technology is used to superimpose digital information into the real world, providing students with a more vivid and interactive learning experience. |
| Student leadership: Self-directed exploration and research questions | Technical support to provide personalized learning resources and enhance student autonomy | Analyze students' learning preferences, interests, and history using an Artificial Intelligence (AI) recommendation system to provide personalized learning content. Provide instant learning support and feedback through AI virtual assistants to help students understand complex concepts or solve problems in their learning, thus fostering self-directed learning. |
| Integration of interdisciplinary knowledge: Integration of interdisciplinary knowledge and skills | Integrating multi-disciplinary content to provide students with a broader perspective | Integrate information from different disciplines using intelligent algorithms to process and analyze large amounts of data and information from different disciplines. Provide students with information from a multidisciplinary perspective through AI technology. |
| Working in teams: Students work together in teams to solve problems | Promote communication and collaboration in the learning process and increase the effectiveness of teamwork | Utilizes an AI-integrated online platform to enable real-time sharing of information and progress. Project management software to help student teams assign tasks, set deadlines and prioritize. |
| Emphasis on reflection and evaluation: Reflection and evaluation at each stage of learning | Analyze strengths and weaknesses in student programs to provide more accurate assessments | Using AI analytics tools to track student performance in programs |

Table 1 Impacts of the use of AI in the PBLs process¹

¹ From: Xiaoqi Tanga, Xu Dingb, Xinyan Mac, Siman Zhangd, Junfeng Diaoe "An Exploration of Project-Based Learning Supported by Artificial Intelligence". Hainan Normal University, The School of Education, Haikou, 2024

5.3 Some ethical considerations that need to be addressed

AI-supported PBLs process can be more intelligent, personalized, and dynamic, providing more accurate guidance and provision, as well as increasing the interactivity and technological integration of the learning process.

However, this integration must be approached thoughtfully, taking into account ethical considerations, accessibility concerns, and the need for faculty development. In particular

- Access and equity: ensuring that AI tools are accessible to all students, regardless of their technological background or abilities, and addressing potential barriers to access.
- Transparency: promoting transparency in the use of AI algorithms, clearly communicating to students how their data will be used and empowering them to make informed choices.
- Ethical guidelines: developing and adhering to ethical guidelines for the responsible use of AI in education, considering issues such as equity, privacy, and accountability.
- Algorithm bias: AI systems are often complex and operate as "black boxes," meaning it can be difficult for users (students, educators) to understand how decisions are made. If an AI makes a mistake in assessing a student's abilities or needs, it might be hard to pinpoint where the error occurred or who is responsible. Thus, AI systems may perpetuate or exacerbate existing biases in educational practices, potentially disadvantaging certain student groups.
- Privacy and data security: the collection and analysis of student data by AI tools raise privacy concerns related to data security, consent, and transparency. AI systems often rely on data to personalize learning. Protecting student data, particularly sensitive information, is critical, and educators must ensure that privacy is maintained.

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6. AI AND THE LEARNING ENVIRONMENT: THE SPACE AS “EDUCATIVE MEDIATOR” IN THE AI ERA

6.1 What is a Learning Space?

Many pedagogues have debated the question of how to structure a physical or mental space dedicated to the cognitive effort that accompanies learning. Although this discussion about a fundamental aspect of the educational process has primarily focused on early childhood, its relevance extends across the entire span of educational life. The diversity of contributions to the topic of the learning environment and the varied approaches adopted by different scholars underlines how this issue remains highly relevant and open to further research. In contemporary educational practice, particularly in post-primary education, it remains largely unresolved.

When entering secondary school, particularly in Mediterranean or Central European countries, one still often encounters an educational setting modelled on the concept of the "school-workshop." This organizational spirit is embodied in the spatial arrangement: rows of desks with the educator positioned at the center. Such a spatial configuration is not merely a matter of organization; it reflects a particular state of mind.

The central element of 19th-century schools was the desk. This educational furnishing served a dual purpose. First, it helped discipline children, particularly those from impoverished backgrounds, who were not accustomed to sitting still and listening to an adult for extended periods. Second, it provided an economical solution for furnishing classrooms. However, this spatial arrangement also carried an implicit pedagogical dimension. It symbolically reinforced the teacher's role as a guide and their pre-eminence in the transmission of knowledge.

The term "transmission" itself invites reflection. Derived from the Latin *transmitto*, meaning "to send across," it implies an activity in which an object or concept is moved from one point to another. The transmitter, in this context, is someone engaged in a creative effort, generating and elaborating information. The receiver, on the other hand, assumes a passive role, merely decoding and awaiting the delivery of this information.

Italian educator and sociologist Danilo Dolci critiqued this term, proposing a linguistic micro-revolution by replacing it with the term "communication." This term, derived from the Latin *communio*, emphasizes the concept of sharing and is closely related to the idea of community (Dolci, 1952). Observing contemporary educational settings reveals instances where this traditional arrangement has been overturned and reimagined in innovative ways. Yet, even in the 21st century, such schools remain exceptions—found primarily in Northern Europe and

sporadically across the European Union.

Today, the majority of European secondary schools still operate as "school-factories," featuring learning environments conceived in an outdated manner. These spaces are suited to transmitting knowledge but not to fostering communication or creating a sense of community. From Dewey's insights to Maria Montessori's approaches, the learning environment remains a subject of exploration and discovery.

6.2 Learning environments and technology

A brief reflection on technology is also necessary. This aspect is particularly relevant, as the purpose of this chapter is to propose considerations for a future—albeit not a distant one—where classrooms are expanded and enriched through tools based on artificial intelligence.

In recent years, digital technology has permeated schools. The pandemic forced millions of students worldwide to abandon any reservations and adopt online educational activities. For a time, following a sudden and immediate shift in perspective, e-learning became a daily reality for students and teachers alike. Even prior to this, many governments had embraced digital technology in schools, making significant investments to equip classrooms with tools deemed increasingly essential for 21st-century education.

Smartboards, for instance, have been introduced to facilitate interaction with various tools, enabling audiovisual engagement and stimulating learning experiences tailored to a generation of digital natives. As sociology has aptly noted, "the medium is the message" (Levison, 2016). While acknowledging McLuhan's assertion and its implications, in the educational context, the analysis of the message remains a critical focus.

The primary objective must center on fostering critical thinking. While studying various subjects—history, geography, Italian, physics, mathematics, and others—undoubtedly develops specialized competencies, the foundation of this structure is critical thinking. Accepting this premise necessitates designing all educational tools and strategies to build upon this foundation. Consequently, it becomes imperative to strengthen an educational approach that integrates digital skills with the cultivation of critical thinking.

It is worth noting that this debate is not new. In early 20th-century France, for instance, there was already a discussion about using cinema in education (Orano, 1909). While the potential of cinema as an educational tool was recognized, it required new competencies from both teachers and students (Romani, 1922). In that context, cinema remained largely a narrative and emotional medium. Today's digital tools, however, demand far greater attention and hold far-reaching, unpredictable implications.

6.3 Learning environment: from the challenge of computers to AI


By the late 1990s, scholars of learning environments observed that the mere presence of computers—and, by extension, technology in general—in a given environment did not significantly stimulate cognitive creativity. In fact, the existence of tools alone did not necessarily elicit more creative reactions from users or lead to a positive shift in collective intelligence. (Salomon & Perkins, 1996). From this perspective, technology should act more as a midwife than a mother, facilitating the process—sometimes in crucial ways—rather than performing the actual work of teaching. Technology emerges as a set of tools that, in many cases for the first time, allows us to actualize the visions informed by our understanding of thought and learning.

For instance, the design and pedagogical use of a writing program like “Writing Partner” (Zellermayer, Salomon, Globerson, & Givon, 1991) must also be considered in light of understanding why and how to foster students' metacognitive skills related to writing. Before the “PC revolution,” such understanding was rooted in a Vygotskian conception of the process by which external guidance could be internalized into self-guidance, underpinned by the premise that self-regulation is crucial for learning. However, applying techniques linked to the use of a specific tool to improve writing requires sophisticated knowledge capable of ensuring an intellectual partnership between the writer and the medium during the writing process.

In today's era of technological evolution applied to education and creativity dynamics, access to tools has become significantly easier, leading to the impression that the skills required to use them are relatively intuitive. However, a closer examination of the cognitive relationship between media reminds us of earlier reflections on the physical relationship between writing and cognitive development (Montessori, 1952). The reality of metacognition in everyday educational contexts, including the use of technology-based support tools, must not obscure the fundamental mental development processes underpinning every educational strategy.

Having outlined some challenges posed by technology, we return to the learning environment and attempt to conceptualize it as Maria Montessori envisioned it. Her observations emphasize that the development of free thought cannot occur in a constrained environment (Montessori, 1952). Exploration, observation, and community dynamics must be actively stimulated by the environment. Montessori's concept of a “prepared environment” underscores the dual role of educators: beyond presenting elaborated concepts, they must also ensure that cognitive construction occurs in an environment conducive to its development—one that nurtures rather than suppresses, allowing the purest elements to emerge.

Some may argue that Montessori's considerations, while fascinating, are primarily directed at



early childhood and primary education. While this is only partially true, these insights extend beyond specific ages or learning stages, applying to any moment of cognitive effort required for growth. Neuroscience today provides additional support, offering precise explanations of human brain functioning that Montessori could only intuitively grasp with the tools of her time (Fogassi & Regni, 2020). The human brain requires constructs and challenges—not only in childhood but throughout life. For this reason, the principles of the "prepared environment" are equally relevant in secondary education.

This raises a critical question: in the era of artificial intelligence, what does a prepared environment look like in secondary schools? How should the environment be structured to accommodate AI? Building on Dewey's reflections on the social educational environment (Dewey, 1916) and his struggles to find suitable furniture for a comfortable learning experience, we see an opportunity to develop the psycho-pedagogical concept of space.

In practical terms, today's market offers affordable solutions enabling even resource-deprived schools to create suitable environments, making them comfortable for both students and teachers. However, these solutions must reflect a spatial concept rooted in the relationships between students and teachers. The physical learning environment inherently represents a strategic choice, yet it remains a mental space requiring the active interaction of individuals and their free expression within the elements of the setting. This perspective could provide valuable insights into preparing environments with artificial intelligence.

Returning to a principle grounded in common sense, we may encapsulate this idea in an aphorism: "Leave nothing to chance".

6.4 Learning environment and AI: conceptual and organizational aspects

At this point, we aim to identify concrete suggestions for schools seeking to prepare an environment ready to embrace the challenges posed by artificial intelligence (AI). Based on the premises outlined earlier, the central issue is to ensure that the impact of AI is not left to chance. For instance, within a school community, there are often teachers who are more inclined to embrace the challenges of digital complexity and begin actively utilizing a range of available tools. In their classrooms, this results in specific types of work and strategies, albeit sometimes instinctive, that lead to the development of new technological approaches to teaching. Conversely, other classrooms, often led by teachers less willing to embrace such challenges or adhering to more traditional mindsets, may lack the same opportunities to provide their students with these advantages.

This brings into focus an essential organizational consideration. Schools must plan for the integration of AI, dedicating time and intellectual resources to understand how AI will transform the educational offering, how it should be integrated, and ideally, how it can strengthen existing frameworks. The process cannot rely solely on individual teachers' instincts or predispositions toward innovation. While the enthusiasm and innovative spirit of some educators should undoubtedly be leveraged, it must benefit the entire school system. Their enthusiasm must be systematically distributed throughout the cognitive organization of the school and its learning structure. This approach aligns with the concept of schools as learning organizations, a perspective that carries significant implications for the strategic management of educational institutions (Boldrini & Bracchini, 2024).


6.5 Strategic and psycho-pedagogical considerations

Schools, as organizations, should not focus exclusively on the practical aspects of which tools to use and how to use them. Equally crucial are psycho-pedagogical considerations and the ensuing decisions required to ensure that tools are employed with a clear understanding of their impact and realistic expectations of the outcomes they are likely to stimulate. Thus, the integration of AI in education must be approached strategically, rather than reduced to a collection of tools implemented haphazardly or left solely to enthusiastic teachers to explore independently.

Schools are learning organizations before they are entities that facilitate learning. It would be a missed opportunity if AI tools supporting pedagogical directions were not genuinely inspiring for the entire educational community, including students, rather than benefiting only a select few. Therefore, careful planning, open discussions, and active engagement with the school community are necessary. This includes understanding the exploratory avenues the school wishes to pursue, identifying goals, and determining specific areas of focus. These steps are crucial to avoid cognitive distortions and to prevent an approach that, while energizing for some, may be overly stressful or alienating for others unable to adapt to imposed models.

Once the strategic direction for AI integration is defined, the skills developed by the teaching staff must be shared across the institution. This necessitates targeted professional development, with teachers more inclined toward technological innovation supporting those who may be apprehensive or indifferent. It is also essential to identify and activate external resources, not only financial but also intellectual, potentially drawn from the school's surrounding community, including parents and local stakeholders with relevant expertise.

Budget constraints are a well-known challenge for schools, particularly at the secondary level. However, it is important to avoid using these constraints as a deterrent to progress. Much like



the availability of affordable, ergonomic furniture to create a conducive learning environment, numerous low-cost or free AI tools can be effectively utilized. Exploring these resources and learning to use them is essential. Consequently, efforts, especially in terms of human capital, should be concentrated where they are most needed, in alignment with strategic priorities.

Individual creativity must always be encouraged. However, it is equally important to ensure that such creativity benefits the entire school community rather than remaining isolated. Teachers with an aptitude for innovation and exploration must understand that their efforts should align with and support the broader educational goals of the institution.

A critical step in this process is conducting thorough needs analysis. This approach echoes Maria Montessori's early experiences as a medical graduate, which significantly influenced the theoretical foundations of her Method (Kramer, 1995). Late 19th-century medicine, constrained by limited diagnostic tools, relied heavily on observation and narrative diagnosis. Similarly, education today requires an understanding of primary educational needs before deploying advanced tools.

The learning environment shaped by AI innovations represents a futuristic vision. Some may liken it to the world of *The Matrix*, others to a dystopian horror scenario, while still others might envision a technological Eden where machines replace teachers, freeing them for more creative pursuits. However, history shows that technological revolutions often yield mixed outcomes. It is the responsibility of educators and policymakers to discern where to focus efforts and where to exercise caution.

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7. THE SPIRAL CURRICULUM AND THE POSSIBILITY OF AN AI SPIRAL APPROACH

"We begin with the hypothesis that any subject can be taught in some intellectually honest form to any child at any stage of development."

Jerome Bruner (1960)

7.1 Introduction: Bruner's spiral curriculum model

The spiral curriculum is a learning approach developed in the 1960s by the cognitive psychologist Jerome Bruner who affirms that any subject can be taught in interrelated forms to any students at any stage of development. The central idea is that learning should be structured in a way that builds upon previous knowledge, revisiting and expanding on topics over time. This allows learners to gain a deeper understanding of the subject matter while reinforcing their prior knowledge. Using this spiral approach, the student gains greater knowledge, benefiting from the strengthening of information to apprise future learning.

Historically, the spiral curriculum emerged as a response to the traditional linear curriculum model, which often presented topics in isolation. Bruner believed that a more effective way of learning would involve the repetition of key concepts, with each repetition providing an effect on the processing of the information, thus determining a real learning strategy.

Bruner's spiral curriculum was thus presented as an active approach to education, grounded on consequential educative cycles in which the contents are re-defined, step by step, by new informal and non-formal knowledge acquired in the meantime.

In this framework, the purpose of education is not to impart knowledge, but instead to facilitate a student's thinking and problem-solving skills which can then be transferred to a range of situations. The role of the teacher should not be to impart information by rote learning, but instead to facilitate the learning process. This means that the use of the spiral curriculum can support the process of discovery learning. Bruner believed a child (of any age) is capable of understanding complex information, structuring the information in a way that complex ideas can be taught at a simplified level first and then re-visited at more complex levels later on. Therefore, subjects would be explained at levels of gradually increasing difficulty (hence the spiral analogy). In describing the spiral curriculum, Bruner wrote: "...basic ideas... are as simple as they are powerful... to use [these basic ideas] effectively, requires a continual deepening of one's understanding of them that comes from learning to use them in progressively more complex forms... early teaching... should be designed to teach these subjects with scrupulous intellectual

honesty, but with an emphasis upon the intuitive grasp of ideas and upon the use of these basic ideas” (p.12-13, Bruner, 1960).

To sum up, the cyclical key features of the spiral curriculum based on Bruner's work are:

1. Learners revisit a topic, theme or subject several times throughout their school career;
2. The complexity of the topic or theme increases with each revisit;
3. New learning has a relationship with old learning and is put in context with the old information;
4. The information is reinforced and consolidated each time the students revisit the subject matter;
5. The spiral curriculum also allows logical progression from simplistic ideas to more complicated ones.

In addition, the spiral curriculum incorporates much research-based approaches from cognitive science that have also been linked, individually, to improved student performance.

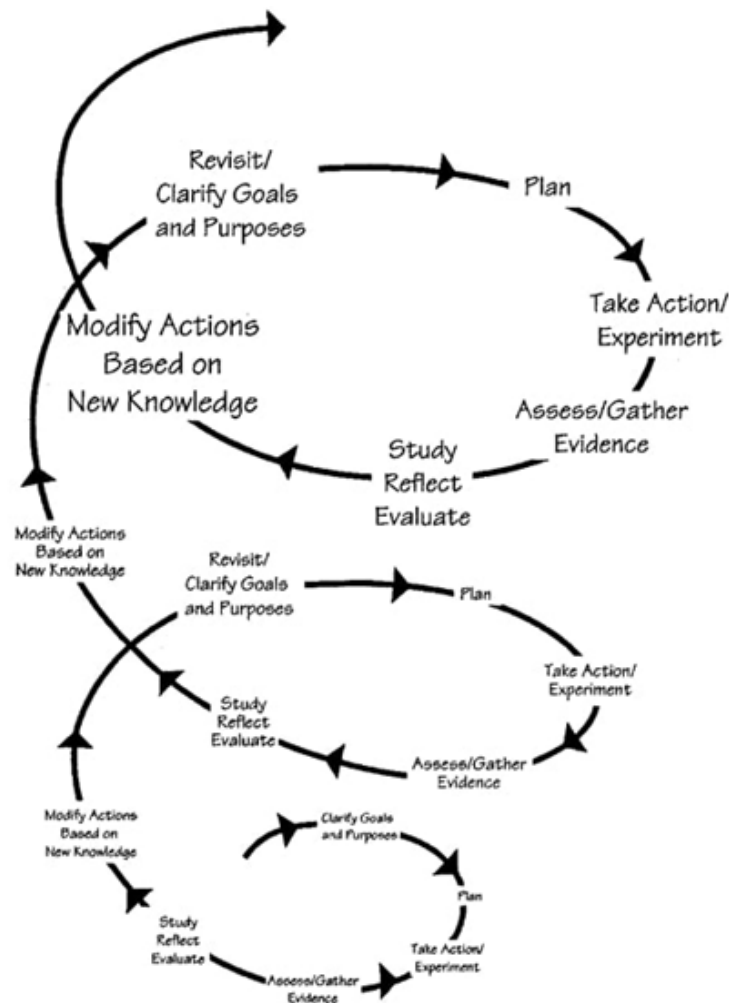


Figure 1 The path of knowledge of the Bruner's spiral curriculum from Johnston, H. (2012)

The path of knowledge of the Bruner's spiral curriculum from Johnston, H. (2012)

In the process of education, Bruner wrote of children as being active problem solvers, ready to explore complex subjects and ideas. In addressing the role of education within this view of young learners, four themes have to be considered:

a. The role of structure in learning and teaching

This means introducing knowledge areas in a way which helps young children see the basic organizing principles within complex concepts and understand the more general nature of a concept before learning its information.

b. Readiness for learning

The teaching of important areas of knowledge is often postponed because they are thought to be too difficult for young children. Certainly, teachers should watch for children's readiness to interact with different ideas. Teachers need not just wait for each child's willingness to encounter a new idea, but can also foster, or scaffold, that readiness by "deepening the child's powers here and now". Scaffolding is a term coined by Bruner himself: teachers do this by structuring activities, based on students' existing knowledge and in a way that helps them to reach the desired learning outcome. The teacher first demonstrates the process as the student watches, then lets the student have a go, steps back, and offers support and feedback when needed.

c. Intuitive thinking

Children can and should be encouraged to think intuitively and not just analytically. In helping children to understand underlying principles in conceptual thought, Bruner wrote, they begin to deal with problems on an intuitive level, looking not simply for the analytically "correct" answer but rather at broadly applied conceptual connections which help them to be problem solvers. "It seems likely that effective intuitive thinking is fostered by the development of self-confidence and courage in the student... Such thinking, therefore, requires a willingness to make honest mistakes in the effort to solve problems" (Bruner, 1960). Too often, Bruner underlined, our educational system rewards answers that are simply right without giving recognition or support to the creative process of thinking intuitively about a problem. Teaching and learning, need to make room for both.

d. Motive for Learning


Interest in a subject is the ideal motivation for learning. External motivations, such as grades or other rewards, carry within them the seeds of loss through the inability to meet an applied

standard of success. Instead, Bruner underlined, it is the task of teachers and learning environments to provide materials and activities that pique children's interest, motivating them from being within to pursue opportunities which will, inevitably, further their own growth. "Motives for learning must be kept from going passive... they must be based as much as possible upon the arousal of interest in what there is to be learned" (Bruner, 1960).

Finally, Bruner's theory of cognitive development, that is distinct from other stage-based theories of cognition, readily lent itself to practical educational applications, which the psychologist himself helped to design and implement, also through the 3-tiered system of internal representations: enactive (action-based), iconic (image-based), and symbolic (language-based). Internal representations could be combined to produce different types of thought: "narrative thought" (temporally/causally sequential, focused on details and action) and "paradigmatic thought" (mental categorization by recognizing abstract, systematic similarities of unrelated phenomena).

7.2 Spiral curriculum and beyond in modern education

The spiral curriculum has contributed immensely to interpreting complex concepts by creating a logical sequence approach in the learning process. This theory has been increasingly researched, and the Spiral approach has been studied up to the present day. Many authors have proposed interpretations and applications. For instance, for Harden and Stamper (1999, p. 141) it involves "an iterative revisiting of topics, subjects or themes throughout the course and it provides, develops and revisits the basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them". Howard (2007, p. 1) states that fundamental ideas, once identified, should be constantly revisited and reexamined so that understanding deepens over time". On the other hand, cognitive researchers have argued that the process of tailoring the complexity of ideas to early stages of learning constitutes "simplification strategies" (Efland, 2000) or a 'reductive bias' in the spiral model (Feltovich et al., 1993; Spiro et al., 1988). They argued that the reduction of complexity that occurs in the spiral curriculum has implications, the most notable being a single representation of ideas at the expense of multiple representations. Instead, they argued that learners should be encouraged to study ideas and concepts in all their complexity. Reduced complexity favours single representations (e.g., a single schema, organisational logic, line of argument, or analogy). The use of simplification in instruction is a helpful tool, particularly in early-stage learning, which enables a learner to interpret a new concept using existing knowledge. However, as Spiro et al. (1988) argued, singular representations carry a risk of missing the many aspects of a complex concept, while learners may also fail to develop diversified ways of thinking.



Therefore, one problem with the notion that the spiral curriculum begins with simple concepts and progresses to mastery is that it fails to recognise that for ill-structured domains the spiral model can lead to misconceptions in early learning, which persist into advanced study. However, while reductiveness is intended to make knowledge acquisition easier, Efland (2000) argued that it may lead to students not understanding what is being taught and struggling to relate the knowledge to their own lives.

Other experts argue that the spiral curriculum model is based on the idea that learning is a linear process; however, it isn't always. Bruner was correct in concept but wrong in scope because his curriculum works well only if narrowed. So, other non-linear models that have been proposed as an alternative to the spiral put less emphasis on linear progression in a knowledge domain and more emphasis on 'meaning-centred' approaches (Slattery, 2006, p.116; Efland, 2002). In these models, the learners' grasp of the interconnectedness of ideas and the importance of transfer of learning between contexts is emphasized: the sequencing of learning objectives can be flexible, and learners can participate in the choice of their learning pathway.

Beyond the vertical integration of topics within a spiral curriculum, advocates of non-linear models argue that there is a need to forge horizontal connections between ideas and knowledge domains. These type of 'network' models promote a more flexible approach to the sequencing and scope of learning objectives. Furthermore, in recent years the spiral curriculum has also been updated to reflect the growing trend towards interdisciplinary teaching. In modern education, subjects are not taught in isolation; instead, there is an increasing focus on how knowledge from different domains intersects. For example, scientific concepts might be taught alongside technological applications, allowing for a more holistic and integrated approach to learning.

Currently, there are few key experiences and updates to Bruner's spiral curriculum that reflect modern educational thinking, where artificial Intelligence can have a huge impact. All these innovations are based on the integration of Technology and Digital Tools. Such modern updates often incorporate digital resources, simulations, and online learning platforms. These tools help students engage in discovery-based learning in ways Bruner did not envision, allowing for more interactive and personalized learning experiences. For example, in STEAM education, apps and virtual labs allow students to repeatedly revisit and experiment with concepts, deepening their understanding over time.

Bruner might not have had digital platforms or educational AI approaches in mind when he described the Spiral curriculum, but his principles resonate profoundly in today's e-learning environments. AI can have the unique advantage of blending structured educational content with interactive elements, making the spiral learning more dynamic and engaging.

7.3 How AI can support spiral learning


The spiral approach provides valuable insights into the integration of AI tools. According to Bruner, learning is an active and social process, emphasizing the role of social interaction and cultural context in knowledge construction. In the context of AI-powered digital learning, student engagement and collaboration become vital in promoting deep understanding. Recent reviews in literature underscore the transformative potential of AI in advancing education and we can say that there are several implications linked to the integration of AI tools in the spiral model.

AI tools are characterized by their inherent flexibility. Learners can chart their own pace, and educators can modify the content with a few clicks. Flexibility is also a boon for the spiral curriculum's emphasis on gradual, cumulative learning. As students revisit topics, the content can evolve in complexity and depth to match their cognitive development.

AI should also emphasize the importance of social interaction. Bruner's theory of learning highlights that students actively make sense of new ideas and concepts by building upon their prior knowledge, engaging in meaningful interactions with peers and instructors, and leveraging effective educational tools. Digital learning environments infused with AI technologies align with Bruner's theory as they facilitate personalized learning experiences, foster collaborative interactions and enhance students' critical thinking and problem-solving abilities. Online collaborative platforms, facilitated by AI, can enable students to engage in discussions, solve problems together, and learn from their peers, fostering a sense of social cohesion. Indeed, AI itself can be a creative and cooperative partner in collaborative activity, making unique contributions in terms of ideas, processes, artefacts and search results. It can also detect and act on group process stages. For example, AI can help identify when the group conversation is drifting away from its stated goals and objectives, helping assess the potential pros and cons of contemplated actions. In this way, it can help the team stay organized and productive by monitoring and characterizing individual contributions to collaboration.

Furthermore, AI tools should be sensitive to the cultural context of learners. This can be achieved through the development of algorithms that incorporate diverse cultural representations, ensuring inclusivity and equity in learning. Bruner's theory emphasizes the importance of actively constructing knowledge through interaction with the environment. AI, when applied effectively, aligns with Bruner's constructivist principles by facilitating interactive and personalized learning experiences.

According to Haddock and his colleagues (2020), AI-powered systems demonstrate the capacity to customize the educational experience for students by adjusting to their unique requirements, adapting to individual needs and offering targeted feedback, focusing on implications for



personalized learning. In the context of the spiral curriculum, this means that AI can adjust the revisiting of topics based on students' mastery levels, ensuring that concepts are revisited at the right time for optimal understanding. Indeed, AI can significantly enhance the spiral curriculum by dynamically adjusting the complexity of learning materials based on individual student progress. Intelligent tutoring systems, for instance, can identify when a student is ready to revisit a topic with added complexity, ensuring that learning is reinforced and deepened over time. They can also analyze student performance data to pinpoint knowledge gaps and deliver customized content and exercises aimed at strengthening learning outcomes. These systems adapt to individual student needs by offering personalized learning paths tailored to their pace and preferred learning styles. This aligns with Bruner's idea that learners construct their own knowledge, allowing for a more learner-centered approach.

This approach ensures that students continually revisit and build upon fundamental concepts, reinforcing understanding over time. Smith and Johnson's, (2021) research supports the notion that AI-powered adaptive learning platforms enhance student outcomes, offering a dynamic approach that aligns with Bruner's spiral curriculum. Indeed, AI-powered systems encourage active learning by offering interactive tools and resources that engage students in hands-on exploration. For instance, AI algorithms can generate dynamic, personalized problems with varying levels of complexity, challenging students to actively apply their knowledge and AI-driven adaptive learning platforms can dynamically adjust content difficulty and pacing, fostering a spiral approach.

But AI can also create immersive and interactive learning environments that encourage exploration and discovery. Virtual labs, simulations, and AI-driven problem-solving platforms can provide students with opportunities to experiment, hypothesize, and learn through discovery.

7.4 Scaffolding and support in AI-Assisted learning

Bruner's theory underscores the importance of scaffolding that means providing support until learners can grasp concepts independently. AI tools, by offering targeted assistance and adaptive feedback, act as digital scaffolds, aiding students in their learning journey. According to Chen et al. (2019) AI provides insights into the effectiveness of digital scaffolding, supporting learners through the process of knowledge construction, a concept central to Bruner's scaffolding theory. AI can also provide effective and adaptive scaffolding by monitoring student progress and providing just-in-time support. AI tools can analyze a student's performance data to tailor learning experiences that match their current understanding and readiness. By providing individualized

pathways, each student can progress through the spiral curriculum at a pace that suits their cognitive development, revisiting and building upon previous knowledge effectively. A longitudinal study by Chen & Wang, (2019) highlighted that AI-supported feedback and scaffolding contributed to enhanced problem-solving abilities among secondary school students. Offering real-time feedback and guidance, AI helps students navigate their learning journeys. As students demonstrate increased competence, AI can gradually reduce the level of assistance, promoting autonomy and confidence. This dynamic scaffolding ensures that students receive the right amount of support when they need it most.

One of the strengths of AI is its ability to analyze vast amounts of data and this capability can be utilized to advance discovery learning and the spiral curriculum. Data-driven insights are invaluable in education. AI systems can track and analyze students' interactions with content and their performance. This data can inform teachers about areas where students may be struggling, allowing them to reintroduce topics or adjust the pace of instruction. This is particularly useful in a spiral curriculum where revisiting concepts at different stages is essential for reinforcement. Such kind of information enables educators to make informed decisions about curriculum design and instructional strategies, ensuring that learning experiences are tailored to the needs of each student. Brown and Davis, (2022) explore the intersection of AI-enhanced assessments and Bruner's spiral curriculum, demonstrating how these assessments promote iterative learning and reinforce key concepts over time. However, Jackson and MacGillivray (2019) examine the use of AI-based assessment tools to efficiently analyze student performance, identify misconceptions, and offer tailored remediation, promoting deep conceptual understanding. What is true is that AI can tailor content based on individual user progression, ensuring topics are revisited at just the right moment. This can be done through Interactive Revisitation (quizzes, simulations, and interactive modules) so that learners can experience topics in fresh, immersive ways upon each revisit, and Instant Feedback where digital platforms provide immediate feedback, allowing learners to gauge their understanding and educators to modify content in real-time.

Finally, AI can support strategies for addressing cognitive load. Bruner's theory acknowledges the limitations of cognitive load in learning. AI can assist by breaking down complex problems into more digestible components, aligning with Bruner's concept of "spoon-feeding" information to learners at an appropriate level of complexity. The research by Johnson and Smith, (2023) addresses cognitive load issues in mathematics education, showcasing how AI interventions can effectively alleviate cognitive burdens, aligning with Bruner's emphasis on manageable information processing.

7.5 Microlearning AI tools rooted in the principles of Bruner's theory

To illustrate the impact that AI can have on spiral learning, ad hoc tools and microlearning platforms, rooted in the principles of Bruner's discovery learning theory, have been already created to support the realization of personalized, engaging, and effective learning experiences. By incorporating spaced repetition, adaptive learning and gamification, these tools ensure that learning is not just a one-time event but an ongoing process of discovery.

AI tools are characterized by content development and delivery that allow learners to quickly engage with new material, reflecting Bruner's idea that learning should build on existing knowledge and be readily accessible. AI-powered authoring tools enable the development of tailored content that meets the unique needs of each learner, ensuring that they are always learning up-to-date content and at the appropriate level of difficulty.

Some platforms, by integrating gamification, tap into the motivational aspects of Bruner's theory, trying to make learning a more enjoyable and rewarding experience. The use of collaborative AI tools also fosters a sense of community and teamwork among learners, aligning with Bruner's belief in the social nature of learning.

By tailoring the learning experience to the individual learner's needs and abilities, by risk profiling and micro-targeting learners with risk-specific assignment of content and learning goals, the tools can create an environment where learning can be more relevant.

Bruner's discovery learning theory provides a powerful framework for designing effective microlearning experiences. By focusing on the active construction of knowledge, the use of schemas and mental models, and the stages of intellectual development, microlearning AI tools can make the learning journey more engaging, personalized and impactful, thus ensuring that the principles of Bruner's Theory of Discovery Learning are aptly utilized, and learners not only acquire new knowledge but also retain and apply it, leading to a deeper and more sustained learning.

7.6 Challenges of AI in Supporting the Spiral Curriculum

We have analyzed the advantages of AI in Supporting the Spiral Curriculum: efficiency and scalability in the implementation of personalized learning; better tracking of the development of skills and knowledge over time; increasing the learner engagement, which is crucial for maintaining interest throughout the iterative cycles of the spiral curriculum; data-driven decision making for providing actionable insights into how students are progressing; accessibility, inclusion and a

more inclusive learning environment. But there are also some challenges, such as the potential over-reliance on AI tools, leading to reduced human interaction. Teachers play a central role in guiding learning, and AI should be a supplement, not a replacement for direct instruction and personal connection. Furthermore, AI-driven educational tools collect vast amounts of data about students. Ensuring the privacy and security of this data is of major concern. Institutions must ensure that AI systems comply with data protection regulations and that students' personal information is safeguarded. Another element of apprehension is related to the fact that not all students may have access to the devices or internet connectivity required to engage with AI-powered tools. There is a risk that unequal access could exacerbate educational disparities. In addition, for AI to be successfully integrated into the classroom, teachers need proper training. They must be comfortable using AI tools to enhance the spiral curriculum, which requires time, professional development, and a shift in teaching practices. Concerns have been raised about the potential biases and limitations of AI algorithms in assessing students' abilities. Finally, developing, implementing, and maintaining AI systems can be costly. Schools, particularly in underserved areas, may struggle to afford the technology and training needed to effectively incorporate AI into the classroom.

7.7 Conclusion and ethical considerations

AI has significant potential to enhance the spiral curriculum by providing personalized learning experiences, real-time feedback, and data-driven insights that can guide instruction. By carefully integrating AI into the curriculum, schools can create more effective, engaging, and inclusive learning environments. However, challenges such as data privacy, accessibility, the need for teacher training, ethical considerations regarding algorithm bias, and the impact of overwhelming reliance on technology must be addressed. Researchers and educators must collaborate to develop robust frameworks and guidelines to ensure responsible and ethical use of AI tools in education. Research by Jones and Lee (2021) underscored the importance of transparency and fairness in AI-driven assessment tools. Their work emphasized the need for educators to critically evaluate the algorithms underpinning AI assessment tools to mitigate biases and ensure equitable evaluation of students' competencies. Recent literature by Garcia (2021) and Chen (2020) has addressed ethical concerns associated with AI in education, such as data privacy and algorithmic biases. Considering Bruner's emphasis on the ethical use of technology, it is imperative to acknowledge and mitigate these challenges. While leveraging AI in education, it is crucial to consider Bruner's ethical assumption: the responsible use of AI should prioritize the holistic development of students, ensuring that technology augments rather than hinders the educational experience.

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8. FOCUS GROUPS IN THE PAIDEIA PROJECT COUNTRIES

Comparative analysis of the results about the contributions that the most relevant theories and pedagogical approaches can offer to the discussion on the theme of the application of AI in schools

8.1 Focus group objectives

The purpose of the Focus Groups (FG) is to explore the contributions that the most relevant theories and pedagogical approaches can offer to the discussion on the theme of the application of AI in schools, and to explore the inclusion of some AI tools in education, particularly to evaluate their impact on pedagogical perspectives. It is a tool used in qualitative research methodology that helps understand the ideas and conceptualizations of the participants.

For this reason, it was suggested that the partners invite types of experts who could offer different points of view and ways of analysing the application of AI in education, who are specialized in a particular approach and able to indicate the challenges that AI poses to the approach they are experts in: in particular pedagogues, sociologists, psychologists, anthropologists, but also experienced school leaders. To prevent a biased attitude toward AI, often found in education and cultural settings, facilitators were advised to begin with a positive perspective before addressing potential risks and drawbacks.

8.2 General information and methodology

Participant Selection and Composition

Each partner country selected between 5 and 10 experts with diverse academic and professional backgrounds, ensuring a multidisciplinary perspective on the topic. The selection criteria included:

- Academic or professional expertise in education, pedagogy, psychology, sociology, or anthropology, with a specific focus on AI in learning environments.
- Experience in AI applications in education, either through research, policy development, or direct implementation in schools.
- Representation across different educational levels (primary, secondary, and higher education) to examine AI's impact comprehensively.

This multidisciplinary approach was designed to incorporate a broad range of perspectives on

cognitive development, critical thinking, learning environments, and curriculum design.

Organization and Execution

Each partner conducted one or two focus groups, each lasting 60 to 90 minutes, between January and February 2025. The sessions were conducted remotely using Zoom or similar platforms and were recorded with participants' informed consent.

To ensure a structured and productive discussion, a dual-facilitator model was implemented:

- Primary facilitator: Managed the session flow and ensured participant engagement.
- Secondary facilitator: Focused on eliciting deeper insights, prompting critical reflection, and ensuring all research themes were addressed.

Discussion Framework and Data Collection

A discussion framework was provided to facilitators, consisting of key thematic areas and guiding questions to maintain consistency across sessions. The main themes explored included:

1. AI and Cognitive Development: Investigating how AI might influence cognitive skills at different educational stages.
2. AI and Critical Thinking: Examining potential risks and strategies for fostering higher-order thinking skills in an AI-assisted learning environment.
3. AI and the Educational Environment: Assessing how AI reshapes learning spaces, interactions, and pedagogical dynamics.
4. AI and Curriculum for Teachers: Exploring the integration of AI literacy into teacher training programs.

Below is the table with the detailed list of areas investigated, their description and the list of guiding questions.

| N. | Area | Description | Questions/Prompts |
|----|---|--|--|
| 0 | General Information and warm up | General information about the PAIDEIA Project and FG participants | Presentation of the FG goals and organizations. |
| 1 | AI and Cognitive Development of students | Contemporary children will grow up in a world heavily characterized by the use of artificial intelligence tools, which will be part of their daily lives, and they will likely not perceive them as dangerous or difficult to manage. This part of the FG focuses on how students, growing up with AI tools as a normal part of life, will differ as digital natives according to cognitive development theories. | <p>How the deployment of Artificial Intelligence may prospectively affect the cognitive development of students in early education?</p> <p>How the deployment of Artificial Intelligence can prospectively affect the cognitive development of students in the second cycle of education?</p> |
| 2 | AI and Critical thinking | In order to develop the creativity and critical thinking of children, problem-based learning approaches are increasingly used. These tools could be strongly influenced by the use of artificial intelligence tools, as the cognitive path they require could be anticipated by easily accessible conclusions offered by tools like ChatGPT. The need to launch a research process may also be greatly simplified or even eliminated because this information would be immediately available by querying virtual systems. This part of the FG focuses on which strategies, according to the contemporary dynamics of project-based learning pedagogy, could be used to address this issue and develop critical thinking. | <p>It is generally affirmed that artificial intelligence could put at risk the skills for the critical thinking of the students. Do you agree?</p> <p>What responses can be found in contemporary pedagogy or social sciences to address this issue and conceive new strategies?</p> <p>What strategies can project-based learning pedagogy adopt to foster creativity and critical thinking in children, despite the ease of obtaining instant answers from AI tools?</p> |
| 3 | AI and Educational Environment | The use of artificial intelligence in schools and in society in general could strongly influence the creation of a new cognitive space, both physical and mental. It is possible that the school of the future will heavily feature augmented reality and artificial intelligence tools used in various | How can the current theories of learning space and the “environment as a teacher” be applied to the challenge posed by artificial intelligence? |

| | | | |
|---|--|---|--|
| | | applications, not only educational but also practical. This part of the FG focuses on evaluating the perspective of artificial intelligence in changing the learning context, both in terms of the physical environment and the cognitive environment. | What are the opportunities and risks in this area? |
| 4 | AI and the possibility of a Curriculum for teachers | The Paideia project aims to address the topic of artificial intelligence by proposing to teachers the adoption of a spiral curriculum that could facilitate the distribution of content and the growth of skills over the various years of schooling, not limiting the education of children's teachers to a single isolated moment but considering it as part of the overall effort of cognitive construction that occurs throughout all school years. This part of the FG focuses on the experience that contemporary pedagogy, especially cognitivism-based psychological approaches, bring to address the introduction of formative processes for the development of skills suitable for a proper and proactive use of artificial intelligence tools. | How can contemporary pedagogy support the introduction of a curriculum to teach skills for effective and proactive use of AI tools in schools? |

These prompts were intended as investigative suggestions, rather than rigid directives. Facilitators were given the flexibility to expand, reduce, or reinterpret the questions based on the dynamics of the discussion, ensuring that each focus group remained as productive and meaningful as possible.

This approach allowed discussions to adapt organically to the expertise and interests of participants, while still maintaining a coherent structure aligned with the research objectives. Facilitators documented key insights for each thematic area and noted significant quotations that exemplified critical perspectives.

8.3 Data analysis

Following the focus groups, the recordings were transcribed and summarised, and a qualitative content analysis was conducted. The analysis follows these steps:

1. Thematic Coding: Identifying recurring themes across different focus groups.
2. Comparative Analysis: Highlighting similarities and differences between countries.
3. Interpretation: Connecting findings to existing pedagogical theories and models.

Limitations and Challenges

While the methodology provided a structured approach, certain limitations were observed:

- Diversity of National Contexts: Variations in educational policies and AI adoption levels across countries may influence perspectives.
- Online Setting Constraints: While convenient, online discussions sometimes limit non-verbal communication and spontaneous interaction.
- Potential Biases: Participants' familiarity with AI and pre-existing opinions might have influenced responses.

Despite these limitations, the methodology ensured a balanced, in-depth exploration of AI's role in education across different pedagogical and socio-cultural contexts.

8.4 Focus Group findings per country

8.4.1 Belgium

In discussing AI and Cognitive Development, participants emphasized that while learning processes fundamentally remain unchanged, the introduction of AI tools can significantly alter the developmental journey. AI has the potential to accelerate or even bypass certain cognitive development steps, creating new challenges. A crucial concern raised was motivation—as one expert noted, "We as educators have a very important guiding role". This highlights how teachers must carefully navigate when and how AI should be integrated, providing targeted feedback to develop critical thinking about AI-generated outcomes. The experts stressed that self-regulation becomes increasingly vital in an AI-dominated educational landscape, particularly for adolescents who must learn to independently determine appropriate AI use when teachers aren't present. They also observed distinct differences between abstract-thinking students and practically oriented learners in their AI interactions.

Regarding AI and Critical Thinking, the focus group acknowledged that teaching critical thinking

becomes simultaneously more challenging and more essential with AI integration. One participant stated: "To think critically well, you first need knowledge, but the will to develop knowledge is already under pressure due to AI." This captures the fundamental tension: students must possess knowledge to evaluate AI outputs, yet AI itself may diminish motivation to develop that foundational knowledge. Another colorful quote, "You put the cat by the milk"—illustrated how easily students might be tempted by readily available AI solutions without proper critical analysis. The experts identified three vital components of critical thinking: ability (knowledge/skills base), inclination (motivation to think critically despite simple answers being available), and sensitivity (recognizing situations requiring critical thinking). Project-based learning emerged as a promising approach, creating authentic challenges where students collaborate across disciplines to develop multiple perspectives.

In exploring AI and Educational Environment, participants emphasized the importance of human connection. "Group size and time are important factors for establishing interpersonal relationships with your students," noted one expert, highlighting how smaller groups allow teachers to better respond to individual learning needs and model critical thinking. The focus group stressed that students perform better when they feel connected to their teachers, and this trust fundamentally motivates learning. Physical contact time was deemed essential for building these relationships, with experts cautioning that AI should not create exclusively digital learning environments that might diminish personal engagement and motivation.

The final theme, AI and Curriculum for Teachers, addressed how education systems should adapt. "You need deep knowledge of the AI landscape to know what it can do," emphasized one expert, underscoring the need for comprehensive AI literacy within broader digital skills development. The curriculum should expose students to various AI tools while encouraging critical reflection on their use. Experts advocated for fostering a "growth mindset" regarding technology, preparing students to confidently adapt to constantly evolving tools. They recommended an interdisciplinary approach that integrates AI across professional contexts while prioritizing understanding fundamental principles rather than specific technologies. Education institutions must reconsider learning objectives and design "AI-proof" evaluation methods that fairly assess student learning in this new landscape.

8.4.2 Bulgaria

Regarding AI and Cognitive Development of Students, participants agreed that artificial intelligence represents both an opportunity and a challenge. While AI can enhance personalized learning by adapting to students' individual needs and fostering engagement, there is growing concern that its overuse might lead to a decline in creativity and independent thinking. The way students approach learning is fundamentally shifting; AI provides quick and structured answers, which may cause students to bypass critical analysis and problem-solving processes. One participant warned that "the biggest risk is that students delegate all tasks to AI without questioning the results," highlighting the concern that AI, if used uncritically, could weaken cognitive effort and reasoning skills. Others acknowledged that AI could be beneficial when applied strategically, emphasizing that "if used critically, AI can enhance students' ability to reach quality results faster." The discussion also focused on AI's role in personalizing education, as adaptive AI-powered systems can tailor lessons to individual strengths and weaknesses. However, participants agreed that AI-generated responses should be carefully examined by students rather than being accepted uncritically.

The discussion on AI and Critical Thinking focused on how AI's ability to provide immediate answers could hinder deeper engagement with content. While AI can be a valuable research assistant, generating ideas and presenting different perspectives, participants stressed the risk that students might accept AI-generated responses without verifying their accuracy. "We must focus on training students to verify and compare AI-generated information with reliable sources," one expert argued, reinforcing the idea that rather than eliminating problem-solving, AI should be used to refine students' analytical skills. Effective AI integration in education should emphasize problem-based learning, in which students are encouraged to test AI-generated content against other sources and critically assess its credibility. The role of project-based learning was particularly emphasized, as it encourages students to treat AI as a starting point for deeper exploration rather than as an unquestioned authority. Some participants suggested that AI tools should be designed to encourage dialogue and debate, helping students develop reasoning skills by presenting counterarguments, with one stating that "AI should be a study buddy, not the main driver of learning." The consensus was that AI should serve as a tool that stimulates inquiry rather than one that provides definitive answers.

When discussing AI and the Educational Environment, participants emphasized that artificial intelligence is no longer just a support tool but is becoming an integral component of the learning process. Smart classrooms, AI-driven assessment tools, and virtual tutors are becoming increasingly prevalent, reshaping both the physical and cognitive spaces of education. The potential of AI to create adaptive learning environments through augmented reality and AI

platforms was widely recognized, as these technologies can provide immersive and personalized educational experiences. However, participants cautioned against the risk of dehumanizing education, stressing that “AI needs proper implementation strategies to ensure it aids and does not replace human interaction.” If not carefully integrated, AI could lead to reduced engagement between teachers and students, limiting opportunities for collaboration and discussion. “The school environment is shifting—AI is no longer a support tool but an integrated component,” one participant observed, emphasizing the importance of a structured approach to AI integration. Many experts agreed that AI-driven platforms should be designed to facilitate, rather than automate, learning, ensuring that educators retain control over AI-generated content and assessments. Some highlighted the necessity of structured teacher training programs to prevent AI from shifting education toward overly mechanized processes.

Finally, in addressing AI and the Possibility of a Curriculum for Teachers, the discussion revealed a strong consensus on the need for structured AI education within teacher training programs. AI literacy should not be an optional component of professional development but a fundamental skill embedded in a spiral curriculum that evolves alongside technological advancements. “AI literacy should be a fundamental skill, not an optional add-on for educators,” one participant asserted, emphasizing that AI should be treated as an evolving technology requiring continuous learning. Many teachers feel unprepared to integrate AI into their teaching, and without continuous training, “AI integration will remain theoretical rather than practical.” The group highlighted the need for structured training programs that provide educators with practical strategies for incorporating AI into classroom activities, ensuring that they remain facilitators of critical inquiry rather than passive consumers of AI-generated content. Participants also stressed that teachers should not only be trained to use AI but should play an active role in shaping AI policies and educational reforms, guaranteeing that AI-driven education aligns with best pedagogical practices. In conclusion, the focus group underscored that AI has the potential to transform education, but its impact will depend on the strategies used for its implementation. If AI is integrated thoughtfully, with a focus on critical engagement and teacher guidance, it can enhance cognitive development, critical thinking, and personalized learning. However, if left unchecked, it may lead to passive consumption of information and diminished cognitive effort. Ensuring that both students and teachers are equipped with the skills to critically interact with AI will be essential in shaping an educational system that leverages AI’s benefits while mitigating its risks.


8.4.3 Ireland

Regarding AI and Cognitive Development of Students, participants agreed that while AI has the capacity to enhance learning, its impact will depend entirely on how it is implemented. There was a consensus that AI should not be introduced into education without clear instructional goals, as its ill-considered use could hinder cognitive development, particularly in younger children. “We can’t just throw AI into the furnace and see what happens. We’ve made this mistake many times before,” one participant warned, pointing to past educational trends that were widely accepted before being debunked, such as rigid learning styles theories. Others emphasized that AI’s impact will be shaped by how educational experiences are scaffolded, as “it depends on how things are being presented, how they’re being scaffolded, what types of tasks they’re undertaking.” The discussion also highlighted the issue of equity in access, as disparities in technological resources and teachers’ AI expertise could create further divisions in student learning experiences. While AI can be a powerful educational tool, “it will be critically important that the learning environment is appropriately set up to allow for cognitive development to be enhanced.” Concerns were raised about students and teachers becoming overly reliant on AI, reducing opportunities for independent thinking. “If students were over-relying on AI tools, or even if teachers themselves were over-relying on them, then there would be reduced opportunities for independent thinking,” one expert noted. The discussion also touched on the broader philosophical implications of AI’s role in education, with some questioning what happens when “AI becomes the teacher. A machine can’t teach you how to think, but it can push what it wants you to know.” When discussing AI and Critical Thinking, participants reflected on how AI’s role in education mirrors past technological evolutions. Some argued that similar fears were raised when broadband internet became widely available, as many believed that instant access to information would reduce students’ ability to think critically. “When the explosion of the internet came along and people had access to broadband, many thought it would reduce people’s ability to think for themselves... but I don’t think it has,” one participant observed. However, others warned that AI’s ability to generate responses instantly could discourage deeper cognitive engagement if students do not learn how to critically analyze the information they receive. “AI alone can neither promote nor hinder critical thinking skills, as the teacher is still very much at the center of teaching and learning,” one participant argued, emphasizing that the effectiveness of AI in fostering critical thinking will depend on pedagogical choices. Educators must develop strategies to ensure AI is used as a tool for inquiry rather than a source of passive information, integrating it into learning in ways that encourage deeper questioning. “Critical thinking might be very much about exploring responses through a large language model like ChatGPT and critically analyzing the response,” one expert explained, stressing the importance of teaching students to interrogate AI

outputs rather than simply accepting them as correct. There was also concern that AI is not designed to foster independent thought, with one participant arguing that “AI can’t promote transformational thinking, and the very creators of it don’t want people to make judgments for themselves because this does not directly benefit them.” Ultimately, participants agreed that AI’s role in education must be carefully structured, ensuring that it supports rather than replaces cognitive development.

The discussion on AI and the Educational Environment focused on how artificial intelligence is reshaping the learning experience. While AI and VR are increasingly integrated into educational models, participants emphasized that teachers remain at the core of learning, with technology serving as a tool rather than a replacement for traditional instruction. “Technology hasn’t had that explosive effect on traditional ways of teaching and learning that many expected. Whether AI will have that disruptive effect remains to be seen,” one participant noted, suggesting that AI’s impact may be more gradual than revolutionary. The potential biases embedded in AI systems were also raised as a concern, particularly when it comes to diverse classrooms. “There’s more bias than opportunities because language models can only take the data that’s available, and their responses are actually biased. If you look at your average classroom, they are not homogeneous anymore, and Gen AI cannot cope with diverse groupings in our schools.” The conversation also addressed the challenges of AI integration, particularly in relation to professional learning for teachers. Some felt that the education sector has been slow to adapt, arguing that “the development of a curriculum is actually a bit late... AI has been moving so fast that people are being caught out by it.” Others emphasized that AI should be used to enhance student-directed learning, rather than simply automating traditional teaching methods. “One of the most crucial skills for 21st-century learning is providing opportunities for independent learning, blended learning, and fulfilling students’ specific needs. AI and its generative power could help teachers do that,” one participant explained. However, concerns were raised about the misuse of AI in education, with some teachers adopting AI tools simply to appear technologically proficient without understanding their pedagogical impact. “Forcing teachers to use technology just for the sake of using a new thing could have a bad influence. I’ve seen teachers just jumping from one AI platform to another just to show, ‘okay, I’m very proficient in educational technologies.’ But do they really know how to use it?” Others highlighted the need for physical and psychosocial learning environments that integrate AI meaningfully, rather than treating it as an afterthought. “Is the room designed in a way that allows children access to technologies that can be easily integrated into a lesson, rather than having the iPad lesson at the end of the day?”

Finally, the discussion on AI and the Possibility of a Curriculum for Teachers underscored the need for structured AI education within teacher training programs. There was broad agreement that AI literacy should be embedded into initial teacher education, ensuring that future educators



develop digital competence alongside traditional teaching skills. “We need to look at preservice teachers’ generic digital competence, then start thinking about their digital teaching competence. And then within that, start thinking about how Gen AI is being used,” one participant suggested, arguing that AI should not be treated as an isolated topic but integrated into broader pedagogical training. Others emphasized that universities have a responsibility to take the lead in AI education, as they are the best institutions to conduct research and guide best practices. “If universities get their houses in order, particularly the schools of education, we have to lead this to some extent because we are the ones who should be at the cutting edge of whatever research is going on.” The conversation also highlighted the rapid pace of AI development, with some expressing concern that policy changes are not keeping up. “I’m working on a project in another jurisdiction. They just completed the AI in education policy. Now, I imagine that by the time they create the curriculum to implement it, it will be at least two or three years down the line. That would be too late, and then the next new thing will be coming.” Participants agreed that professional learning opportunities for teachers should be context-based, rather than relying on a one-size-fits-all approach. “From a professional learning perspective, where you’re working with teachers who’ve been doing this for 20-plus years, the importance of allowing schools the capacity and space to really dedicate their time to gaining knowledge around AI integration is key,” one participant explained, emphasizing that effective AI training should be tailored to teachers’ real-world classroom needs rather than delivered through generic workshops. Finally, there was an agreement that teachers should feel empowered to make pedagogically sound decisions about AI use, rather than feeling pressured to integrate it into every lesson. “The most important thing is giving teachers the power to say, ‘I’m fine if I didn’t use AI for this lesson because I think this skill will only be developed with a pen and paper. But at the same time, I have that AI tool in my bucket.’”

The Irish focus group ultimately underscored that AI’s role in education will be determined by how it is implemented. While AI presents exciting opportunities for personalized learning, critical thinking, and innovative teaching, its integration must be approached carefully to ensure that it enhances rather than replaces cognitive engagement. Ensuring that teachers and students alike develop a critical understanding of AI’s potential and limitations will be essential in shaping an educational system that leverages AI’s strengths while mitigating its risks.


8.4.4 Italy

Artificial intelligence in education elicits mixed opinions, with a general awareness of its potential but also concerns its risks. Some participants emphasize its role in adapting learning paths to individual needs, improving inclusion, and supporting students with learning difficulties. AI-powered tools can provide personalized feedback, identify areas where students struggle, and offer tailored exercises to enhance comprehension. This adaptability is particularly valuable for students with special educational needs, who may require a more flexible approach to learning. However, there is a concern that excessive reliance on AI could weaken critical thinking. "If everything is pre-packaged, students might stop thinking for themselves," one participant notes. AI-generated suggestions may discourage independent thought if students begin to accept machine-provided answers passively rather than engaging in deeper reasoning and inquiry.

A key issue in the discussion is how AI will interact with the teacher's role. While artificial intelligence can assist educators by reducing bureaucratic tasks, facilitating assessment, and providing innovative teaching tools, there is also fear that it might erode the educational and relational role of teachers. Participants stress that AI should complement, not replace, educators. The teacher's ability to interpret students' emotions, motivations, and struggles is seen as irreplaceable. "An algorithm cannot truly understand what a student feels when they are struggling," someone argues. AI might provide data-driven recommendations, but it lacks the empathetic and intuitive understanding that human educators bring into the classroom. There is also a concern about teachers feeling pressured to adapt to AI-driven tools without proper training, which could lead to superficial implementation rather than meaningful pedagogical integration.

A recurring concern is the accuracy and reliability of AI-generated content. AI-based tools often provide plausible but not always correct answers, making it crucial to strengthen students' critical thinking skills. Participants emphasize that students need to develop the ability to verify information rather than take AI-generated responses at face value. "The problem is that if you don't already know something about the topic, you might not notice the errors," one participant observes. AI models, especially those based on probabilistic reasoning, can generate misleading information that sounds credible but may contain factual inaccuracies. This could be particularly problematic in subjects that require precise data, such as science and history, where small distortions can significantly alter understanding.

Ethical considerations play a crucial role in the discussion, particularly regarding algorithm transparency and data protection. Participants express concerns about the opacity of AI decision-making processes and the potential for bias in educational algorithms. "Who decides what an algorithm should consider important? Who checks for biases?" These questions highlight the



necessity for regulation and oversight to ensure AI systems in education operate fairly and inclusively. Additionally, the issue of student data privacy is raised. The collection and processing of student information by AI systems could pose risks if not adequately managed. Ensuring that educational AI complies with data protection laws and ethical guidelines is seen as fundamental to prevent misuse or commercial exploitation of student data.

One of the most pressing concerns is the need for proper training for both teachers and students to ensure AI is used consciously and critically. Without adequate preparation, there is a risk that AI will be implemented superficially or even harmfully. Some participants suggest that teacher training programs should include modules on AI literacy, allowing educators to integrate these tools effectively while being aware of their limitations. Similarly, students must be educated on how to critically engage with AI-generated content rather than passively accepting its outputs. "We can't just introduce it in schools without first understanding how and why to use it," a participant insists. Proper training could also empower educators to use AI in a way that enhances, rather than replaces, their pedagogical skills.

The discussion concludes with a reflection on the future direction of AI in education. Participants recognize AI as an extraordinary opportunity but stress that its implementation must be guided by clear regulations, ethical considerations, and awareness of potential pitfalls. While AI can significantly enhance learning experiences, support differentiated instruction, and reduce administrative burdens for teachers, its impact depends on how it is integrated into educational practices. Without careful planning, AI could lead to unintended consequences, such as the devaluation of human teaching, increased digital inequalities, or a loss of deep learning skills among students.

Ultimately, AI in education should be seen as a tool rather than a replacement, a means to augment human capabilities rather than diminish them. Participants call for a balanced and reflective approach that safeguards the human dimension of education, ensuring that AI serves as an aid to learning rather than a substitute for critical thinking and human interaction.

8.4.5 Malta

As for AI and Students' Cognitive Development, the use of AI in primary education was seen as an opportunity to personalize learning and provide immediate feedback, enhancing student engagement in a digital-native world. However, concerns emerged that excessive reliance on AI could impair the development of fundamental cognitive skills. One participant noted: "AI-driven tools can enhance learning by providing personalized learning, interactive problem-solving, and real-time feedback", but warned that passive use could reduce critical thinking and independent

problem-solving skills.

AI was recognized as a tool to foster critical thinking and independent learning in secondary education. However, participants emphasized the risk that students might fail to critically evaluate AI-generated information, accepting it without further inquiry. "Finding the right balance between AI-driven support and educator-led education will be the key", one participant stated, highlighting the need to educate students to question AI-generated content rather than blindly trusting it.

Regarding AI and Critical Thinking, the discussion centered on AI's dual impact on critical thinking: on one hand, it can stimulate reasoning through well-structured prompts; on the other hand, it risks oversimplifying research and problem-solving, leading students to accept AI-generated answers without deeper engagement. "AI can help develop critical thinking through the use of the right prompts to solve a particular problem", a participant noted, stressing that proper training is necessary to ensure AI is used effectively.

To address these challenges, participants suggested pedagogical approaches such as Critical Pedagogy and inquiry-based learning, which promote critical reasoning and media literacy. Additionally, they emphasized the value of Project-Based Learning (PBL) in fostering collaborative work and creativity: "Collaborative group work encourages discussion, debate, and exposes students to different perspectives" reinforcing an active and reflective use of AI.

Regarding AI and the Educational Environment, the integration of AI into education was viewed as an inevitable transformation toward hybrid learning spaces that merge digital and physical environments. Participants stressed that the concept of "environment as a teacher" can be adapted to encourage critical engagement with AI rather than passive acceptance. Among the opportunities offered by AI, participants cited personalized learning, immediate feedback, and support for students with special educational needs. However, concerns were raised about the risks of bias in AI algorithms and the lack of critical awareness in their application. One participant pointed out that "educators cannot rely only on AI tools", emphasizing that AI must be used within a teacher-guided framework.

To ensure effective AI integration, participants discussed the need for a teacher training curriculum that promotes the proactive use of AI in education. Constructivist and cooperative learning approaches were highlighted as essential to prevent AI from dehumanizing or isolating the learning experience. A key discussion point was whether to develop a dedicated AI curriculum or integrate AI education across all subjects. Most participants agreed that AI literacy and critical thinking should be embedded across curricula through digital literacy programs. Additionally, they emphasized the need to train teachers to feel confident in discussing and demonstrating AI applications in the classroom. "Educators should be confident in discussing this subject and in proposing examples", a participant noted, underscoring that students are already using AI tools, making AI education not optional but essential.

In conclusion, the focus group confirmed that artificial intelligence presents both opportunities and challenges for education. When used consciously, AI can enhance personalized learning, critical thinking, and creativity. However, over-reliance on AI should be avoided, and educators must play an active role in guiding its responsible use. Teacher training and the integration of appropriate pedagogical strategies are key to ensuring that AI serves as a learning enhancement tool rather than a shortcut that replaces critical thinking.

8.4.6 Spain


Regarding AI and Cognitive Development of Students, participants acknowledged that this generation will be the first truly "native AI" cohort, growing up in a world where artificial intelligence is embedded in daily life. While AI will bring significant opportunities for personalized learning and allow educators to track students' progress with greater precision, much remains unknown about its long-term effects on cognitive development. "We are on the cusp of a new era. Before saying it's good or bad, we need to explore it," one participant noted, highlighting the need for further research on AI's role in education. There was a consensus that AI should not be demonized but rather integrated thoughtfully, with structured training from an early age to ensure students learn how to use it responsibly. However, concerns were raised about its role in early education, as young children require real-world interactions to develop essential cognitive and social skills. "AI is beneficial as a support, but at early stages, it should be used sparingly. Other skills need to be worked on first: social skills, notions of time and space... children need other people, teachers, to interact with and to use their minds and bodies in relation to objects and people." Participants agreed that AI will likely be more useful for teachers than for students in early education, provided that it is not misused simply to keep children occupied for long periods.

At the secondary education level, discussions often focused on generative AI tools like ChatGPT, though participants pointed out that these represent only a fraction of the AI landscape. Many students have not grown up with AI and require guidance on how to use it correctly. One major concern was the impact of AI on literacy and traditional skills, particularly writing. "Written exams on paper are disastrous, as computers automatically correct language errors, and they don't learn how to write properly by hand," one participant explained, raising concerns about the decline of handwriting and its cognitive benefits. Others pointed out that AI reduces the need for practical problem-solving skills, as tools like GPS provide instant gratification, leading young people to face fewer real-world challenges. While AI opens new learning opportunities, it also creates new problems, particularly in relation to social media and digital overexposure, which must be addressed in education.

The discussion on AI and Critical Thinking revolved around the risks of algorithm-driven personalization and the reinforcement of cognitive biases. Participants warned that AI filters content based on personal preferences, gradually narrowing users' perspectives and creating echo chambers that reinforce existing opinions rather than challenging them. "Young people need to learn to distinguish between fact, scientifically supported by data, and opinion," one participant stated, emphasizing the need for media literacy education. Some expressed concerns about the broader implications of this shift, arguing that "opinions being presented as facts represent a danger to democracy." Additionally, participants observed that students often show a tendency to criticize their teachers more readily than they question AI-generated content, suggesting a misplaced trust in artificial intelligence. The group agreed that fostering critical thinking requires time and structured practice, yet modern society often pushes for rapid conclusions rather than deep analysis. One proposed strategy was to incorporate exercises in which students analyze and identify errors made by AI, demonstrating its limitations firsthand. While some participants argued that AI is a tool that amplifies existing learning habits—"there have always been brilliant students and lazy students. Now there is so much more information available, which makes AI a magnificent tool for those brilliant students and a dangerous one for those lazy students"—others suggested that pedagogical approaches should focus on developing students' ability to reflect, evaluate, and engage in collaborative problem-solving. Encouraging students to rely on their reasoning before turning to AI was seen as essential. "I ask them to close their computers and use their common sense first to analyze problems and find solutions. Context is really important, and ChatGPT can't be aware of all the variables." Learning diaries, in which students document their reflections on class activities, were proposed as a valuable tool for reinforcing metacognitive awareness.

When discussing AI and the Educational Environment, participants emphasized that while AI will significantly reshape education, teachers will never be replaced by technology. "We are still operating around set timetables in classrooms. We need to open up learning spaces to include many other possibilities," one participant stated, arguing that rigid traditional structures limit the full potential of AI in education. AI offers valuable tools for streamlining administrative tasks, organizing logistics, and enhancing communication, but participants stressed the importance of using AI appropriately rather than relying on it excessively. "We need to learn how to use AI and not abuse it," one expert remarked. A major challenge for educators is determining whether students have completed assignments independently or with the assistance of AI, leading some schools to revert to pen-and-paper exams and oral assessments to ensure authenticity.

Finally, the discussion on AI and the Possibility of a Curriculum for Teachers highlighted the need for structured teacher training, with a particular emphasis on ethical considerations and critical thinking. Participants argued that AI literacy must be integrated into the curriculum, not only for



students but also for teachers, families, and the broader community. “Teacher training, resources, and information about ethical aspects are crucial,” one participant noted, emphasizing that AI education should extend beyond technical skills to include discussions on values and responsible usage. There was broad agreement that fostering critical thinking must be a priority in AI education, ensuring that students are equipped with the analytical skills necessary to navigate a digital world increasingly influenced by artificial intelligence.

The Spanish focus group ultimately underscored that while AI is transforming education, its impact depends on how it is implemented. If integrated thoughtfully, AI can enhance learning, foster critical thinking, and create new educational opportunities. However, if left unchecked, it may lead to passive learning, diminished problem-solving abilities, and an overreliance on technology. Ensuring that both students and educators are equipped with the skills to critically engage with AI will be essential in shaping an educational landscape that maximizes AI’s benefits while mitigating its risks.

8.4.7 Türkiye

Regarding AI and Cognitive Development of Students, participants recognized that AI in early childhood education can enhance personalized learning by adapting to individual interests and abilities, improving problem-solving skills, accelerating language acquisition, and increasing motivation through interactive tools. AI’s ability to adjust content to a student’s learning pace can foster strategic thinking and long-term engagement, but only if its use is properly guided. At the same time, concerns were raised about the risks of excessive exposure at a young age, which could overwhelm children, hinder creativity, and disrupt natural developmental processes. One participant warned that “especially its use at a young age can have a negative impact on cognitive development for creativity,” emphasizing the need for careful monitoring and structured implementation. The discussion also highlighted that AI in secondary education has the potential to refine critical thinking and analytical skills through adaptive learning platforms and data-driven feedback, but it must be integrated with caution. While some experts noted that AI exposure can strengthen neuronal development by offering diverse stimuli, others warned that “it provides easiness and comfort but makes them lazy.” AI’s effectiveness, they concluded, depends on its structured and intentional application, ensuring that students engage with it actively rather than becoming overly dependent on its automated solutions.

The conversation on AI and Critical Thinking revealed a nuanced debate about whether AI supports or undermines students’ analytical abilities. While some participants expressed concerns that AI might limit independent problem-solving by providing easy answers, others argued that it

can foster critical thinking if used as a tool for deeper inquiry. “I think that using it before puberty will harm skills such as critical thinking and creativity,” one participant stated, while another countered that “it depends on the purpose for which artificial intelligence is used. If they use it to develop their knowledge, their critical thinking skills will increase with that knowledge.” The key to effective AI integration, participants agreed, lies in designing educational strategies that encourage students to actively engage with AI-generated content rather than passively accepting it. They suggested incorporating project-based learning, where AI serves as an investigative tool rather than a source of definitive answers. AI’s role, they emphasized, should be shifted from passive information delivery to a model where “students actively participate in information, ask their own questions, conduct discussions and develop their own solutions.” Encouraging questioning, structuring collaborative problem-solving sessions, and using AI for gamified learning experiences were identified as essential strategies to ensure that AI enhances rather than replaces critical thinking.

In discussing AI and the Educational Environment, participants emphasized AI’s growing role in shaping both physical and cognitive learning spaces. AI-powered simulations, augmented reality, and interactive platforms were identified as valuable tools that allow students to engage with the world in innovative ways, fostering deeper exploration and analysis. “If what we see in the environment is considered a teacher, artificial intelligence can enrich learning processes at this point because knowledge can be acquired from anywhere,” one participant observed, reinforcing the idea that AI can expand access to information beyond traditional classroom boundaries. However, significant concerns were raised about AI’s potential to create passive learning habits and limit creativity if students rely too heavily on automated solutions. The risks of misinformation, biased data, increased screen time, and social isolation were also highlighted, with one expert cautioning that “again, the fact that information comes easily and readily available can be considered among the risk factors.” Participants stressed that AI should be designed to support, rather than replace, human interaction, ensuring that students continue to engage in critical analysis and hands-on experiences alongside AI-driven learning tools.

Finally, in examining AI and the Possibility of a Curriculum for Teachers, participants highlighted the importance of integrating AI literacy within a structured pedagogical framework. AI should not be introduced as an isolated subject but rather embedded in an evolving, spiral curriculum that grows alongside students’ learning needs. “Contemporary learning pedagogies encourage active student participation and independent learning. These approaches support the integration of AI tools into the curriculum,” one expert noted, stressing the shift from teacher-centered instruction to a more facilitative role for educators. The discussion underscored the necessity of equipping teachers with practical AI strategies, particularly in areas such as data analysis, modeling, and simulation, ensuring that they can guide students toward responsible and innovative AI use.

Ethical considerations were also emphasized, with one participant arguing that “this education should begin with values education and ethical principles. Because everything starts with moral values.” Participants agreed that professional development programs should prepare teachers not only to use AI but also to critically assess its applications, ensuring that AI-based education remains aligned with best pedagogical practices and fosters a balanced, thoughtful integration into learning environments.

The Turkish focus group ultimately underscored that AI’s role in education must be carefully managed to maximize its benefits while mitigating its risks. While AI offers transformative opportunities for personalized learning, cognitive development, and innovative teaching strategies, its impact will depend on how it is integrated into educational systems. Ensuring that both students and teachers engage with AI critically and responsibly will be essential in shaping an educational landscape that leverages AI’s strengths without diminishing human creativity, inquiry, and interaction.

8.5 Summary of Focus Group findings per country

| Country | AI and Cognitive Development | AI and Critical Thinking | AI and Educational Environment | AI and Teacher Curriculum |
|-----------------|--|---|---|--|
| Belgium | AI may accelerate cognitive processes but also risks by passing key developmental steps. Motivation and self-regulation are crucial for students. AI must be integrated carefully, ensuring active engagement. | Critical thinking requires both knowledge and motivation. AI may reduce students' willingness to develop knowledge. Project-based learning is key to fostering analytical skills. | Emphasis on the human connection in learning. AI should not reduce interpersonal relationships between teachers and students. | Teachers need deep AI literacy to integrate it effectively. A "growth mindset" towards AI should be developed. AI-proof assessment methods are required. |
| Bulgaria | AI enables personalized learning but risks diminishing creativity and independent thinking. Students might | AI should be used to enhance, not replace, problem-solving. Project-based learning is effective in fostering | AI is becoming a core component of learning. Smart classrooms and AI-driven tools must facilitate—not replace—human | AI literacy should be a fundamental part of teacher training. Without proper guidance, AI education remains |

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|----------------|--|--|--|--|
| | rely too much on AI-generated answers without questioning them. | deeper inquiry. AI must be a tool for reasoning, not just for providing answers. | interactions. Teacher training is crucial. | theoretical rather than practical. |
| Ireland | AI's impact depends on implementation. Past trends in education have shown the risk of adopting new technologies uncritically. Over-reliance on AI could reduce independent thinking. | AI should be structured to support inquiry rather than passive information absorption. Teachers remain central to fostering deep learning. AI-generated answers must be critically examined. | AI integration should be gradual rather than disruptive. Bias in AI models is a major concern, particularly in diverse classrooms. | Teacher training should focus on digital competence and AI integration in pedagogical strategies. Universities should take the lead in AI education. |
| Italy | AI helps personalize learning but risks reducing critical thinking if students rely passively on machine-generated answers. Ethical concerns around bias and data privacy are central. | AI-generated content must be verified. Students need training in information literacy to avoid trusting AI outputs blindly. | AI should not replace the teacher's relational role. Teachers must be trained to interpret and integrate AI responsibly. | AI literacy should be embedded in teacher training. Clear regulations and ethical guidelines are needed for AI implementation in schools. |
| Malta | AI enhances student engagement but can impair cognitive skills if not used actively. Balance between AI-driven learning and traditional teaching is essential. | AI can stimulate reasoning but may also oversimplify research and problem-solving. Project-based learning and media literacy are key strategies. | AI is shaping hybrid learning spaces. AI tools must be integrated with critical engagement rather than passive acceptance. | AI education should be embedded across curricula. Teachers must feel confident in guiding AI use in classrooms. |
| Spain | AI will define the first true "native AI" generation. Concerns about | AI reinforces cognitive biases by filtering content. | AI should support education but not be abused. | Teacher training must integrate AI literacy, ethics, and |

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|----------------|--|---|--|--|
| | literacy and handwriting development. AI is more useful for teachers than for students in early education. | Students must learn to distinguish facts from opinions. Learning diaries and problem-solving tasks help mitigate AI's influence. | Some schools revert to traditional exams to ensure authenticity. | pedagogical strategies to ensure responsible AI use. |
| Türkiye | AI can enhance personalized learning but might make students overly reliant on it. Creativity and problem-solving skills may be at risk. | AI should encourage students to generate their own questions and engage in discussions. AI must be used to develop reasoning skills rather than providing easy answers. | AI-powered simulations and interactive tools can enrich learning but should not replace direct human interaction. Risk of social isolation and misinformation. | AI literacy must be embedded in a spiral curriculum. Teachers should be trained in ethical AI use and pedagogical integration. |

8.6 Key takeaways

1. Cognitive Development Risks and Benefits:

- AI enhances personalized learning, but may reduce independent thinking and problem-solving.
- Concerns about over-reliance on AI in early education and its impact on creativity and literacy.

2. Critical Thinking & Problem-Solving:

- AI-generated content must be critically analyzed, not accepted blindly.
- Project-based learning and inquiry-based methods are essential to prevent passive learning.
- Media literacy and ethical AI education should be incorporated into curricula.

3. Educational Environment & AI Integration:

- AI is reshaping learning spaces, but must not replace human interaction.

- Concerns about AI bias, data privacy, and lack of transparency.
- Some countries (e.g., Spain, Ireland) highlight the importance of retaining traditional assessments alongside AI tools.

4. Teacher Training & Curriculum Development:

- AI literacy must be embedded in teacher training programs across all countries.
- Teachers must be prepared to guide AI use, not just adopt tools superficially.
- Universities should lead AI education reforms and provide ongoing training for educators.
- Ethical considerations must be a core component of AI curricula.

8.7 Recommendations

Based on the insights gathered from the focus groups across different countries, we propose the following recommendations for the development of the teacher training curriculum provided by PAIDEIA. These recommendations aim to ensure an effective, ethical, and pedagogically sound integration of AI in education, aligning with the structure and goals outlined in the Spiral Training Curriculum.

1. Ensuring a Balanced Approach to AI in Cognitive Development

- Encourage Active Engagement with AI: AI should be positioned as a learning facilitator rather than a replacement for cognitive processes. Teachers should guide students to use AI interactively, promoting critical thinking and metacognition instead of passive reliance.
- Embed AI Literacy in Early Stages: The curriculum should incorporate progressive AI literacy, ensuring that students are aware of both AI's capabilities and limitations from an early stage.
- Develop AI-Integrated Scaffolding Techniques: Teachers should be trained to use AI as a scaffold for learning, ensuring that it enhances inquiry-based and project-based learning (PBL) rather than bypassing cognitive development steps.

2. Strengthening Critical Thinking and Ethical AI Use

- AI as a Tool for Inquiry, Not a Knowledge Authority: The curriculum should include methodologies that teach students to critically assess AI-generated content, verifying its accuracy and biases.
- Integrate Media Literacy and Algorithmic Awareness: Given AI's influence on information access, media literacy education must be embedded, helping students and teachers recognize biases and misinformation.

- Practical AI Ethics Training: Teachers should engage in case-based ethical discussions on AI in education, addressing issues such as data privacy, algorithmic bias, and the ethical use of generative AI in assessments.

3. Designing AI-Enhanced Learning Environments

- Human-Centered AI Implementation: AI should not replace human interactions but should augment student engagement. The curriculum should emphasize collaborative AI integration where students work together, guided by educators.
- Hybrid Learning Spaces: AI-driven tools should be integrated into blended learning approaches, allowing for a mix of digital and physical interactions to maintain a rich, interpersonal learning experience.
- Adaptation to Diverse Educational Contexts: AI training should be customizable based on different cultural, institutional, and classroom needs, ensuring it does not contribute to digital inequalities.

4. Developing teacher competencies in AI pedagogy

- Spiral AI Training Model: The curriculum should follow a progressive approach, aligned with UNESCO's AI Competency Framework for Teachers, guiding educators from basic AI awareness to advanced implementation strategies.
- Cross-Disciplinary AI Integration: Teachers should be equipped with interdisciplinary teaching methods, enabling them to use AI effectively across subjects rather than treating it as a separate discipline.
- Practical Hands-On AI Training: The curriculum should include real-world AI application exercises, such as designing AI-supported lesson plans, evaluating AI tools, and assessing their impact on learning outcomes.

5. Supporting Continuous Professional Development & AI Literacy

- Ongoing AI Training & Professional Learning Communities: AI literacy should be seen as a continuous process, with teachers engaging in peer learning, AI research discussions, and professional networks to stay updated.
- Guidance on AI Policy & Institutional Implementation: Teachers should be trained to navigate school policies on AI use, ensuring compliance with legal frameworks, intellectual property rights, and ethical considerations.
- Empowering Teachers as AI Change Agents: The curriculum should encourage teachers to become active contributors to AI education policies, fostering responsible innovation and adaptation in their institutions.