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PAPER

The Requirements for Heutagogical Attunement within STEAM Education

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ABSTRACT

As we launch into an era marked by rapid technological advancements, education is experiencing disruptive transformations. Central to this shift is the integration of Artificial Intelligence (AI), predictive hybrid cloud strategies, and large language models (LLMs) like ChatGPT. As technology, AI becomes increasingly central to education; this paper explores the evolution of pedagogy in response to these changes, with a focus on the horizon. This investigation delves into the challenges and opportunities arising from the integration of AI, predictive hybrid cloud strategies, and LLMs into education, especially in the context of self-determined learning or heutagogy. The research looks into the role of collaboration, innovation, and adaptability in shaping curricula that prepare students for the fast-paced and dynamic landscape of the future, supported by AI, autonomous systems, and high-performance computing. The significance of problem- or project-based learning and cross-disciplinary collaboration is addressed, as this paper underscores the potential for preparing someone capable of future careers across various sectors. By integrating technology into education, the vision is of a globally connected, skilled, and innovative workforce ready to navigate a rapidly evolving world. Future research in this area might illuminate the potential of collaboration networks to drive sustainable improvements in learning and well-being.

KEYWORDS

education, future-ready learning, artificial intelligence (AI), project-based learning, cross-disciplinary collaboration

1 INTRODUCTION

In today's technologically advanced era, heutagogy and techno-pedagogy are marked to be important [1] [2]. Building on existing pedagogical models, it would perhaps be suitable to talk about "pantagogy", rooted in the Greek word "pantos", meaning "always". Instead of supplanting older frameworks, pantagogy integrates them, underscoring lifelong learning. It synergizes real-time systems with Large Language Models (LLMs), emphasizing adaptive growth amidst shifting learner

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content. Further information on various factors influencing the teaching-learning-studying capacity of individuals depends on autonomous systems, and this complexity often presents significant challenges to educators [3] [4]. Our research aims to explore how the integration of advanced technologies like artificial intelligence (AI) can support and transform the educational curriculum, promoting continuous learning and fostering critical skills necessary for various cultural contexts and industries. In our context, skills assumes 21st-century key competencies among individuals adapted into enhanced learning with the AI framework. The skills thus include a broad spectrum of relatable meanings, explicitly brought into the technology and engineering context. AI, including smart systems with platforms in technological terms, is expected to be brought up in this paper. By smart systems it is referred to autonomous systems that are increasingly found in the daily systems of digitalized countries.

In recent years, significant attention has been drawn towards the integration of science, technology, engineering, and mathematics (STEM) education [5] [6] [7] [8]. Our study also explores how the concept of STEM (science, technology, engineering, and mathematics) education can be effectively used in developing STEAM (STEM + Arts) curricula to ensure the development of comprehensive skills in students [9].

A pilot search was conducted out of context in Scopus, using the query "TITLE-ABS-KEY (science AND technology AND engineering AND arts AND math OR steam AND artificial AND intelligence OR air AND curriculum)" from which 2,633 documents were found (18.8.2023). A relatively small amount was found with or without (arts), and the AI studies were notably relevant. Evidence from a brief Scopus bibliometric analysis reveals the frontiers. Following aspects from educational and psychological domains and referencing literature from [10], [11], and [12], there is a predominant suggestion of a surge in integrating AI, STEAM, and sustainable development education. This integration is in conjunction with the use of innovative teaching methods such as backpropagation neural network model, 3D printed resources, and digital interactive learning environments. These approaches aim to enhance computational thinking skills and raise interest in related disciplines in both high school and university settings. The potential of these approaches is of interest not only within new technology engineering, but also in other respective areas with minor adaptation and extension.

Emphasizing the interconnectedness and lifelong learning aspects of the Organization for Economic Co-operation and Development's (OECD) Learning Compass 2030, we aim to guide the integration of AI in education, ensuring students' well-being and fostering innovation, particularly in the context of the rapid evolution of natural language processing (NLP) and large language models (LLMs) [13] [14].

In an era where Industry 4.0 is transitioning to Industry 5.0 and beyond, the development of social, methodological, personal, and domain competencies in students becomes paramount [15] [16] [17] [18] [19] [20] [21]. This necessitates redesigning curricula to address key skills in smart systems and technologies, such as AI, through collaborative problem-based learning (PBL), assembling them to achieve well-being.

Promoting ecological well-being and sustainability in education-to-industry domain integration using cradle-to-cradle design principles is another aspect our study explores [22] [23]. This includes investigating how technology-supported learning in STEM education can be refined to go beyond content delivery, developing a broad mix of skills in students, and ensuring cultural appropriateness and safety in quality education. Specifically, this research examines how AI integration into the educational curriculum can prepare students for collaborative work and foster innovation [24] [25]. It also includes an analysis of the role of beliefs in collaborative governance networks and their applicability in policy contexts [26] [27] [28] [29].

Finally, our study will examine how the integration of LLMs in software development [30] and fostering collaboration through national AI research center networks [31] can support the development of a rich educational curriculum that prepares learners for the future.

The chapter three findings will be segmented into four parts, aligning with the scientific philosophy tone established in chapter two. The initial subsections of chapter three delve into the reasons for integrating AI and other cutting-edge technologies into the educational curriculum. This segment will traverse from international agency impact measurements to grassroots justification, showcasing how these technologies can bolster well-being through transparent curricular structures. Subsequent sections highlight the importance of STEAM education, demonstrating its potential to equip students with comprehensive skills. This encompasses fostering collaborative work within policy contexts, considering the changes discussed. While the role of arts in the broader AI landscape might appear somewhat fragmented, a structured approach will be emphasized to assimilate innovations, ultimately fortifying organizational learning. The third segment underscores the imperative of fostering ecological well-being and sustainability when bridging education with industry. Concluding the chapter, the final section investigates the function of LLMs in software development and the enhancement of collaboration via national AI research center networks.

The ultimate goal of our study is to provide insights and recommendations for educators. While recently, AI acts were adopted at the committee level to define, what AI is, how to use experimental AI, conduct research with AI, and engage in business with AI. However, the specific utilization of AI in education and learning has yet to be directly generalized but addressed in transdisciplinary research fields [32]. Our study explores whether AI can be effectively used in education and learning. The discussion on this topic also interests people looking for ways to leverage advanced technologies to transform the educational curriculum, promote lifelong learning, and equip students with the necessary skills to thrive in the rapidly changing world. The findings will contribute to the ongoing discourse on the role of technology in education and inspire further research in this field.

2 METHODOLOGY AND EPISTEMOLOGY IN SCIENCE

2.1 Methodological proposition of theory

The evolution of the educational landscape places increasing emphasis on STEAM education. This cross-disciplinary approach cultivates connections between distinct fields, facilitating comprehensive and real-world relevant learning experiences for students [33]. However, the challenge lies in enhancing and effectively integrating STEAM pedagogies in classrooms. Personal Practical Theories (PPTs) play a significant role in STEAM education. They represent a learner's understanding, beliefs, and practices [33] to [34], especially when the learner employs critical pedagogy and modern methods such as flipped classrooms. PPTs reflect a learner's unique experiences and knowledge, shaping their teaching style and approach within the STEAM context. Moreover, these PPTs can serve to bridge the gap between various disciplines, with teachers using their experiences to highlight the interconnectedness between mathematical patterns and visual arts, or the ties between engineering designs and creative problem-solving. By integrating such personal experiences, STEAM education gains relevance and effectiveness, offering a unique perspective in the classroom with PPT [34].

Joint corporate efforts to develop cross-functional skills offer promising strategies to improve STEAM education. The deployment of innovative tools that assist teachers and educational institutions is crucial in devising, implementing, and evaluating teaching strategies aimed at fostering diverse competencies in students [35] to [33]. These tools promote collaboration and identify areas needing enhancement, making them indispensable for educators striving to refine their STEAM curriculum. In the task of curriculum adjustment, alignment with associated needs may call for more complex and challenging content. Preliminary studies suggest that social theories effectively incorporate industrial and cultural understanding into STEAM education, emphasizing the need for continuous learning, adaptability, and flexibility with PPT [34].

Modern psychology's contribution to organizational development is key in evolving an education system that aligns with industrial needs. The use of field theories provides a basis for the development of theories within societal boundaries [34]. This approach considers the influence of human factors in shaping agile organizational learning, particularly in industries that integrate education. Individuals within industries that integrate education can navigate command-and-control environments by demonstrating commitment to project management, adhering to system guidelines, maintaining independence, and identifying possible inconsistencies as potential change initiatives. Despite the limitations of skills contracts and uncertain futures, fostering an environment that encourages intrinsic commitment among employees can have extensive implications for well-being. Shifting these initiatives to cultivate empowerment can result in extrinsic commitment to education. The progression towards a language processing-focused curriculum improves the education system and enhances morale, rather than relying on outdated learning methods. Thus, genuine education empowerment goes beyond guidelines, aligning them with commitments that nurture future generations' aspirations with PPT [34].

2.2 Philosophical attunement

Promoting positivity and happiness through technology and innovation is essential yet scarce in today's rapidly evolving world [36]. From a philosophical perspective, firsthand experiences of technology's absence can uncover unnoticed practices, phenomena, or challenge assumed behaviors. This necessitates the exploration of topics where trustworthiness and authenticity are prioritized. In the education sector, the significance of adopted technologies is of particular relevance [37]. By accepting short lifecycles and striving for ideal impacts, we can transform the education sector, inspiring and engaging future industry professionals. Encouraging adaptation across various sectors can help employees, researchers, and educators collaborate to resolve cross-sectional conflicts [36].

Instead of merely criticizing society's fundamental problems, it is more productive to propose solutions that can be integrated into our philosophical framework [38]. Addressing the complexities of STEAM education requires us to move beyond simplistic perspectives and confront potential problematic or oppressive behaviors. Building individual identity and a deeper understanding of global technological leadership is essential to comprehending the curriculum and underlying data. Deconstructing the philosophy of STEAM education allows us to go beyond merely challenging prejudice, enabling us to identify and dismantle oppressive social systems. By fostering cultural understanding and adopting a philosophically resonant perspective, we can critically assess the system and encourage growth in a more inclusive and innovative direction [38]. The ongoing exploration of learning losses by the OECD highlights the need for societal systems [39].

In addressing society's fundamental problems and complexities of STEAM education, [40] suggests expanding the view of STEAM to better align engineering education with the pedagogical commitments of the arts. Based on an individual's educational philosophy that emphasizes aesthetics, freedom, autonomy, social justice, democracy, dialogue, empowerment, and reflection, education is promoted to inspire transformative experiences that foster personal growth, critical thought, and societal evolution. This perspective enhances and challenges current conceptions of the educational movement, which are mainly driven by calls for competitive economic growth and technological advancement [39].

3 EDUCATION AND ARTIFICIAL INTELLIGENCE ON CURRICULA

At first glance, education and new technologies may seem like two non-integrative entities. Rather than replacing the teacher in the classroom with an AI, future competencies and awareness of them are in great demand. Incorporating PPTs accordingly and using innovative tools for mastery skills paves the road to transversal competencies. By capitalizing on these resources, teachers can provide students with a more engaging, relevant, and effective STEAM education [34]; [35] to [33]. In sustainability, educational technology without research is directionless, like a space without a manager. Focusing on global research needs in technology and science ensures a competitive education that evolves continuously.

3.1 Compass for the education

Advancements in technology, particularly in fields such as AI, significantly impact various industries, including the educational sector. To successfully integrate these technologies, several challenges need to be addressed. One challenge is understanding AI's limitations which necessitate critical engagement [25]. Learners and teachers must ensure that technology does not replace the human element in the TSL process. By incorporating technology to support students' development across skills, we address transversal that are meaningful [24].

How are technological advancements impacting various sectors, particularly in fields such as AI, and what challenges must be addressed in adopting these technologies? To respond to the adoption, students must be able to go through the impossible. Teaching the possible walkthrough in Figure 1.

Figure 1 [41] is published in The OECD's Learning Compass 2030 under CC BY-NC-SA 3.0 IGO. Compass encourages an adaptable approach to STEAM education by emphasizing the interconnectedness of its disciplines and promoting lifelong learning. This flexible strategy allows for continuous evolution in response to shifting global needs and technological advancements, ensuring learners are well-equipped for the future.

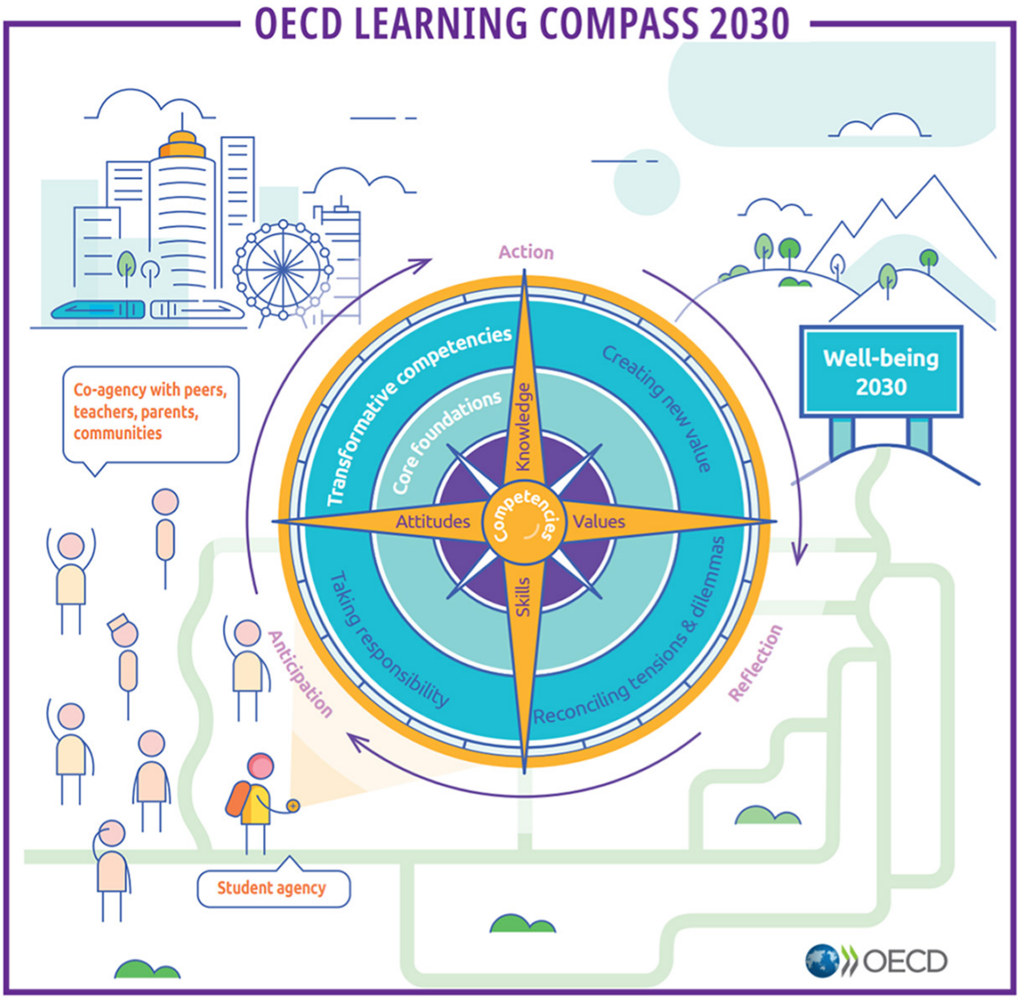

Fig. 1. The OECD's learning compass 2030

Navigating the educational landscape with the compass of well-being is crucial in the era of Education 6.0. As we integrate technology into curricula and address challenges, we must ensure equitable access to quality education, foster innovation, and prepare students for the future. By creating a balanced learning environment that combines technology and human interaction, find the elements from the compass that technology can only support, not replace, or overtake. We support the development of diverse skills while adapting to ever-changing global demands. In this context, understanding students' responses to various learning inputs and incorporating insights from past technologies becomes vital to optimizing their educational experiences and fostering well-being for individuals and communities alike.

3.2 Addressing key skills on smart systems and technologies

In collaborative Problem-Based Learning (PBL), students encounter challenges that equip them for academic and professional achievements. Artificial intelligence can transform higher education to ensure accessibility and accommodate diverse learning abilities, finding objective assessment methods. It is imperative to identify objective methods of assessing learning outcomes. Relying solely on techno-pedagogical methods must be updated and more adequate for 21st-century education. The contemporary educational landscape emphasizes the need for sustainable learning environments wherein transversal learning thrives. Just as we discuss abilities, our perspective might shift to consider the narrowing space of factorization in terms of attitudes, especially the emphasis on caring for individuals irrespective of various sectional factors [42] [43] [44]. Facing and addressing the hurdles of imparting new digital skills [45] is crucial, especially in a world that is becoming increasingly interconnected. There is a pressing need for education to align with the OECD's recommendations, which emphasize fostering innovation using technology and collaborative means [46]. While components of the educational compass might be augmented by technology, they should be kept from being replaced or overshadowed by AI. The goal is to leverage AI to bolster with an appliance of ethics. Technologies with integrated AI capabilities can enhance analytics, offering real-time feedback on learning. This can be observed in tools focused on student-facing learning analytics [47]. With AI becoming a staple in various industries [48]; [49], educators must integrate these concepts into their curricula, ensuring students are future-ready. However, it is crucial to recognize the potential pitfalls of AI in education: the risk of causing harm, fostering undue dependence, or even the possibility of it supplanting human roles. Such challenges demand that educational programs double down on ethical considerations. By embracing more interactive technologies, the content of pedagogy can be enriched, guaranteeing that students gain a holistic understanding of AI applications across diverse domains. Curricular designs should evolve to foster more collaborative, problem-based learning experiences.

Educators should equally incorporate PBL topics into the curriculum to equip all students with practical skills for the future rather than differentiating between those taught innovation and those not. Teachers must promote equity, equality, and justice in individual teaching-studying-learning processes. Providing students with foundations in AI applications for beginning at non-engineering, lower levels [50] and preparing students to work in well-developed supply chain-forming economies are examples that will help prepare students for future careers until at least 2030 in rapidly advancing fields of technology use. While perspectives may emerge as challenges for research, practice, and policy in metaverse adoption [51], different science fiction leads the way with believing in continuous learning every-second [52].

Problem-based learning and critical thinking are effective in teaching students to apply their experiences and knowledge to new project research topics. Incorporating teaching autonomous systems-based data science and high-performance computing [53], for instance, enables the incorporation of different insights and views of blended learning that could be based on augmented simulations. For mastery of future developers, the more hands-on experiences the student gets, the better efficient data processing applications use and advancement become [54]. Data processing abilities contribute to the challenges in terms of developable skills. Addressing challenges to opportunities in teaching from a database-compliant perspective creation to practical use in curricula will equip students with the necessary skills to excel in data-driven industries, enabling them to contribute to the development of advanced computing solutions. While pedagogics and lecturing have a place, considering subject curricular changes within PBL becomes essential in facilitating students' mastery.

3.3 Preparing students for collaboration and fostering innovation

Acknowledging the complexity of societal systems and PBL, we next turn to NLP and LLMs that continue to evolve rapidly. NLP and LLMs are enablers for various application development [55]. Teaching enablers are vital for educators to include topics in their curricula, preparing students for careers in cutting-edge fields. Teaching that harnesses the power of language and communication technologies concepts merely acts as a successful messenger for real-world scenarios. PBL can be based on the consideration of teaching incorporating emerging technologies and applications, such as autonomous systems [56], acoustics [57], and graphics [58]. New technology learning and adoption can also be enhanced through curricula. Structural lines ensure that students are well-versed to pursue careers with the latest advancements for future careers in today's fast-paced, dynamic fields; introducing autonomous systems and real-world simulation environments [59] enables students to develop practical skills in robotics and automation. Encouraging cross-disciplinary collaboration and innovation in education, as exemplified by projects integrating autonomous, acoustics, and graphics, can integrate complex datasets and formulate simulations for systems to be utilized differently [60]. Ensuring students' integration naturally using multidisciplinary technologies, the formation of national integrative AI research center networks [61] will ensure students develop a holistic understanding of the interconnected nature of technology and its applications across diverse industries, ultimately fostering a more innovative and collaborative workforce for sectors.

3.4 Refining guided curriculum topics

Technology-supported learning equips STEM leaders with a diverse skill set that delves into quantum physics and transcends quantum operations, sparking global innovation. The ongoing commitment to safety and quality in education demands rigorous assessments and continuous improvement within institutions. This commitment to quality is evident in the rise of virtual training certifications, such as those curated in Finland. These certifications cater to the escalating demands of society, reflecting the growing concerns in areas like health, logistics, and business. Addressing these concerns is paramount, especially as we advance towards automating supply chains, ensuring sustainability in space orbits. Even renowned educational systems might need re-evaluation through experimental designs [62]. For curricula to be impactful, they must resonate with the cultural nuances of the learners. Enhancements in curricula that bolster students' awareness of safety across various subjects are invaluable. The crux of any curriculum lies not just in the imparted knowledge but also in how this knowledge shapes the organizational frameworks. Integrating a culturally sensitive approach and data-driven insights enriches the content [63]. Topics embedded in the curriculum must align with prevailing trends and advancements, such as the E6.0 initiative, which emphasizes fostering well-being. As AI-driven technologies gain prominence, especially in providing real-time feedback, embedding competencies related to smart systems in collaborative PBL becomes indispensable. Practical AI applications, especially in logistics and vision tasks, underline the significance of their integration into project-based learning. Leveraging data science within the pedagogy of autonomous systems results in a hybrid learning experience enriched further by augmented simulations.

4 DISCUSSION

Is AI necessarily usable for innovating new technologies and solutions in academia? It has great impact in educational setting: by integrating AI, this provides a significant technological advantage by fostering skill development with future demand, enabling adaptive learning through AI-generated student-models and establishes education as the creator of advanced digital capability [52]. This governing function supports regional STEAM leadership [64]. To address declining well-being, future curricula should be optimized [65]. Education can counter mainstream media's effects. With fast technological growth, collaboration between industries, academia, and governments is vital, from political issues to climate change concerns. Beginning from promoting the development of sustainable education and manufacturing technologies [66], it might be interesting also to delve into the development of new mobility metrics [67] and the necessity for incorporating generative stochastic systems [68]. The discussion advocates for holistic, inclusive, and culturally sensitive technology-supported learning, as showcased by [69], underlining, project opportunities. Keeping the discussion short raises stress on modulating the metaverse to create a sustainable educative form of culture of value and circularity [70] [71] to which of interest might arise using lean strategies [72] [73]. The implications of preparing individuals for future careers are of significant importance. Therefore, incorporating AI into curricula and research could wield considerable influence. One could draw parallels between how learning outcomes greatly impact the skills and competencies students develop and how these outcomes can be further shaped for holistic student growth [74].

5 CONCLUSION

In conclusion, the preparation of students for the rapidly changing advancements in technology, particularly in the fields of AI, can make a profound impact on various industries, revolutionizing processes, driving innovation, and expanding the horizons of perspective of human potential [75] [76] [77]. As we continue to integrate these cutting-edge technologies into our daily lives for problem-based and project learning, it is essential to address the challenges associated with adoption, such as data security, compliance, and the need for continuous learning of students into supporting the build of metaverse of the circular economy [78] [1] [79] [80]. By fostering collaboration, sharing knowledge, and leveraging resources, we can ensure the effective and responsible application of AI technologies across various sectors. We see the integration of the technologies teaching in both ways, creating more innovative and interconnected learning opportunities and significant opportunities in posing problem- and project-solving. Educational institutions would contribute to allocating ample opportunities for educators to form new understandings of these technologies. For future research, we may elaborate on organizations' learning culture by surveying specific technologies that interest them [80].

6 FUTURE RESEARCH GUIDELINES AND APPLICATIONS

Future research should aim to develop and structure sustainable spaces between sentences within higher education curricula that bolster STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning. This involves addressing the learning needs of educators and facilitators who are key to the successful implementation of STEAM programs. The creation of comprehensive training initiatives and resources can empower educators to guide students through project-based learning. Furthermore, fostering a culture of peer support and mentorship can enhance the professional development of educators. To foster an inclusive, ethical, and sustainable educational environment, future research should focus on the following areas:

a) Evaluating the present state of STEAM integration in education and pinpointing areas that need enhancement.
b) Highlighting the advantages of interdisciplinary collaboration within STEAM.
c) Assessing the effectiveness of action studies in STEAM teaching applications.
d) Studying the impact of AI on industrial migration patterns and new work practices, particularly in sustainable manufacturing systems.
e) Determining the role of culturally appropriate curricula in fostering global collaboration and addressing migration challenges.

Exploring these areas will enable a better understanding of AI's integration into curricula and its impact on the industrial workforce. Future research should also focus on radically reimagining STEAM curricula and learning environments that nurture creativity, innovation, and interdisciplinary collaboration. This would involve advancing technology-based teaching methods that integrate PBL, project-based learning, and AI-based virtual work. An effective approach could involve setting up Innovation Hubs and outsourcing development to agile organizations for specific contexts such as autonomous systems, music technology, and sound engineering. These hubs could provide a platform for interdisciplinary, project-based learning, promoting collaboration, and fostering valuable skills such as teamwork, critical thinking, and communication. Community engagement and informal learning opportunities can be integrated into this new educational model. Higher education institutions can collaborate with local schools, community centers, and non-profit organizations to extend their reach and challenge existing inequities in STEAM education access. Future research should also focus on promoting individual metacognition and fostering a growth mindset that values learning and creativity. This could be facilitated through interventions aimed at encouraging incremental mindset transfer. It's also important to understand the ethical implications of medical-in-human-attached technologies. It's also important to secure the pedagogies [81]. Ensuring that these technologies are ethically used and implemented is crucial to preventing discrimination and ensuring social justice [82] [83] [84]. Additionally, the subjective state of immersion requires specialized curricula adjustments. Preregistrations to ensure the certification of the virtual training with quality management systems that promote the pedagogical attunement from applying sciences learning into new technology learning together [85]. This can be measured using flow prediction metrics, which can help guide the development of technology-supported learning experiences. Finally, it is important to explore the potential of cognitive robotics and autonomous systems in enhancing STEAM education [86]. This can contribute to the digital transformation of education, enhancing the learning experience for students in STEAM fields. By proper organizational leadership [87], taking future considerations into developing augmented learning environments to engage students reasoning [88], mental intelligence [89], and healthy lifestyles [90].

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