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Artificial intelligence and human behavioral development: A perspective on new skills and competences acquisition for the educational context

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ABSTRACT

Despite the significant emphasis placed on incorporating 21st century skills into the educational framework, particularly at the primary level, recent scholarly works indicate considerable variation in the implementation of these skills across different countries and regions, suggesting a demand for further research specifically focusing on primary education. The indications of the Digicomp framework and 21st-century skills in Europe have outlined the key competences for lifelong learning needed for all citizens, including teachers and students. In this perspective, Education plays a fundamental role in ensuring that citizens acquire the required skills. The objective in the common European framework is clear: to initiate a transition from the culture of knowledge to the culture of competence. Nowadays, technological advancement allows the researchers to create and combine different frameworks with the perspective of an even more tailored, and engaged education, some examples derived from the implementation of Virtual Reality (VR) and Augmented Reality (AR), in the combination of Gamification and AI, or the development of Intelligent Tutoring Systems (ITS) to foster and create an even more personalized learning and teaching. Following these premises, in this paper, we want to point out new research reflections and perspectives that could help researchers, teachers, educators (and consequently students) to reflect on the introduction of new technologies (e.g., artificial intelligence, robot tutors) and on how these can affect on human behavioral development and on the acquisition of new skills and competences (Specifically: Creativity, Critical Thinking, Problem Solving, and Computational Thinking) for the educational context. The analysis carried on, suggests a perspective on how creativity, critical thinking, and problem-solving can be effective in promoting computational thinking, and how Artificial Intelligence (AI) could be an aid instrument to teachers in the fostering of creativity, critical thinking, and problem-solving in schools and educational contexts.

1. Introduction

Information and Communication Technologies (ICTs) play a relevant role in how European societies perceive, discuss, and approach global challenges, including the COVID-19 pandemic, political destabilization, and climate change. Emerging technologies could be key to understanding and overcoming such challenges but are simultaneously perceived as threats to how we live together in a different social context[1].

Artificial intelligence (AI), for example, has accelerated the development of medical breakthroughs, but the threats to humanity are well known if AI is left unchecked, for example AI used in educational or vocational training, that may determine the access to education and professional course of someone's life (e.g., scoring of exams). In this regard, EU proposed a regulation on AI[2] and the regulatory framework on artificial intelligence.[3] The proposed AI regulations are a first step in

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[1] https://joint-research-centre.ec.europa.eu/digcomp/digcomp-framework_en
[2] https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence.
[3] https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai.

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the direction to a trustworthy AI. While most AI systems pose limited to no risk and can contribute to solving many societal challenges, certain AI systems have to treat in a more cautious way to avoid undesirable outcomes. Implementing AI algorithms in the field of learning require to the developers consider various factors, ranging from the sensitivity of the data utilized for training the algorithms to the reliability and trustworthiness of these algorithms. In line with this trajectory, a novel and burgeoning field of research known as Explainable Artificial Intelligence (XAI) has emerged. The primary aim of researchers in this field is to furnish comprehensive explanations and interpretations for the decision-making processes employed by AI systems (Gohel, Singh, & Mohanty, 2021). Nevertheless, it is essential to note that examining how these AI systems function in real-world contexts and assessing their alignment with the intended purposes under expert supervision is another crucial perspective that merits significant attention by researchers and practitioners in the field (Orsoni, Pögelt, et al., 2023). These challenges continue yet learning and working online has sustained societies during a pandemic, overcoming time and space limits and barriers. Artificial Intelligence systems will continue to have a tremendous impact on how we address major challenges, as well as how we live our daily lives and learn, changing our behavior (Gillath et al., 2021). Thus, schools need to provide an appropriate education in a ubiquitously digitalized world and within an accordingly complex and changing career landscape. Some research has highlighted that the worker of the future (student of today) is expected to develop critical thinking, problem-solving, communication, and teamwork since these qualities have significant impacts on the development of innovation (and the use of AI systems) (Chen, Chen, & Lin, 2020; Goksel & Bozkurt, 2019). Hence, current, and future generation of workers need to be prepared for the functional use of emerging technologies (i.e., a use that sustains personal and social development, but also the development of knowledge and skills), preventing the risks of the dysfunctional one (i.e., a use that doesn't sustain human development and could also determine problems in many aspects of human life[4]). Using and reflecting on AI in schools, often subsumed as "digitalization of education", is neither systematically addressed in the European educational context, nor is it subject of standardized let alone technology-enhanced, automatized assessment, which would provide instant feedback to stakeholders such as (head) teachers, parents, school boards, and policymakers.

An important reflection follows from the ethical point of view about what behaviors can or cannot develop such a system (e.g., schools), especially now in which those behaviors have an impact on individuals (Langer & Landers, 2021). For these reasons, the European Union has proposed guidelines and ethics to guide the interaction between humans and the AI system. The goal is to ensure that people develop trust towards this technology and can use it feeling safe, including in school contexts. To all that has been said so far, we must add the robot side which, currently, is the ideal match for artificial intelligence. Considering the perspective of Developmental Robotics, if we want to create artificial intelligence systems that expand following the same dynamics and phases of human development, it is necessary to equip them with a body side that allows them to build knowledge based on environmental interaction. Without the physical-social environment with which to interact, it would be impossible to hypothesize that artificial intelligence could follow, in its development, the dynamics of the human one. For example, an interesting aspect to consider is the use of AI systems, applied to robotics, to create robots sustaining human development in knowledge and skills. Interacting with humans in different periods of development, AI robots could adapt their interactive behavior to act in the human zone of proximal development. This Vygotskian concept defines humans' development potential when they operate with more experienced partners than alone. Studies building on socio-cognitive conflict (Benvenuti & Mazzoni, 2020; Mazzoni & Benvenuti, 2015) have also highlighted the importance of interactions and, particularly, the relevance of sharing different points of view and negotiating them to join more advanced solutions in complex tasks. These studies, together with those conducted in the field of divergent thinking, social creativity, and networked flow dynamics, advanced a perspective of robot/AI systems that evolve in a way that could sustain human cognitive development, improving the human knowledge and skills in the same way, or in a better way, than a human partner could do.

In the workplace, robots can prevent humans from many heavy and tiring activities, safeguarding their physical and mental health. There are currently many experiences with promising results in which robots are used for the education of children, but there is a lack of a shared perspective and plan on what skills should be developed in the school environment to cope with and use AI in educational contexts. This perspective and reflective paper brings together different views and concepts of developmental and educational psychology (starting from a literature review) but also explores more technical fields to offer a perspective on the lines of research that could be taken to offer tools to teachers and students, to prepare them for the challenges of the future (and for the future labor market).

2. State of the art

In response to the pandemic emergency, Information and Communication Technologies (ICT) have highlighted their potential in many fields, particularly in educational contexts. On the one hand, ICT-enabled distance learning and classes were carried on without interruption; on the other, the isolation of pupils, particularly of adolescents, was undoubtedly a negative influence on the ICT-enhanced educational context. The lack of social interactions and motivation leads to feelings of loneliness and dejection (Martisone et al., 2022). Additionally, it strongly limited the ability to learn in a social context. This indicates a clear need to exploit novel technologies to promote a way of learning that is grounded in interactions and sociality.

From a piagetian constructivist perspective (Piaget, 1962; Ackerman, 2001), the process of understanding the world is the result of the relationship established between a thinking and acting subject and the object of his own experience. In addition, Papert (1980; 1993) underlined the importance of technological artifacts in learning, not as supporting this process but as in simulating reality. From Papert's point of view, knowledge cannot simply be transmitted as it is from one person to another, but each subject reconstructs information in a personal and original way. According to this, the use of technological devices (e.g., computers, tablets, and robots) represents an effective method for building knowledge, allowing students to apply theoretical knowledge to practice. Even more, the use of a physical artifact (e.g., a robot tutor) determines an effective learning process as it makes students reflect on the knowledge they possess and how to apply it to the reality on which they are acting (Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013). In his researches and works Papert highlights how the use of robotics kits, far from transmitting computer skills, generates curiosity and stimulates creativity and motivation to learn, allowing one to build and enter in touch with powerful new ideas (Papert, 1980, 1993). Moreover, following the idea that learning is an active process based on experience and that social interactions can facilitate it, learners might make understanding more effective by working together. This means that technological innovation in education should be able to expand teachers/learners' opportunities for collaborative interaction and let them explore new strategies for teaching/learning (Braun, März, Mertens, & Braun, 2020). Moreover, schools need to provide an appropriate education in a ubiquitously digitalized world within complex and changing training needs and career landscapes.

The actual digital transformation is deeply changing most human sectors and the importance of transversal knowledge, skills, and competencies training is growing both in the labor market and as essential abilities for participating in European society. It has been highlighted

[4] https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai.

that the citizens of the future are expected to develop critical thinking, problem-solving, communication, and teamwork since these qualities have a significant impact on the development of innovation (Trilling & Fadel, 2009). Communication, cooperation, and problem-solving are, almost by definition, the future skills demanded. Together with ICT literacy, content creation abilities and safety constitute the so-called 21st-century skills (Ferrari, Punie, & Redecker, 2012). Novel technological tools are key for the construction of 21st-century skills, but how can they develop uniformly for all students in educational contexts?

This can be better understood within the Activity Theory approach applied to an education system (Batiibwe, 2019; Engeström, 2014; Zhang & Bai, 2005), in which emerging technologies mediate the relationship between the actors and the knowledge construction. A strong tenet of Activity Theory is that cognitive development and learning happen first at the social level, thanks to dynamics such as interaction, points of view sharing, socio-cognitive conflict dynamics, and negotiation, and then, it is interiorized by individuals (Fig. 1) (see Fig. 2).

Contradictions (e.g., the use of digital technologies and distance education during the pandemic situation) are the motor of change, in as much as needs go beyond the solutions adopted to date and promote the so-called "learning by expanding" (Engeström, 2015) based on Piagetian processes of assimilation and accommodation, to find a new balance in the system (e.g., schools).

In this panorama, European Union addressed new strategy for high quality, inclusive, and future-oriented education, aiming to "contributing to the development of quality education by encouraging cooperation between Member States and, if necessary, by supporting and supplementing their actions (Treaty of the Functioning of the European Union Article 165)".[5] Despite this, the use of emerging technologies in schools and educational context, often subsumed as "digitalization of education", is not "equally addressed" in Europe, as deepen outline in PISA-OECD data.[6] In this regard, building on promising approaches to learning analytics, progress in this area is bound to the definition of recommendations and methodological approaches that will guide teachers to develop didactic and educational activities based on technological tools (e.g., educational robotics, CT platforms, etc.) and support the schools' journey towards digital readiness.

For all these reasons, following the recommendation of the European Commission's Digital Education Action Plan (2021–2027),[7] this paper supports the fostering of the development of a high-performing digital education ecosystem, and encourages teachers in promoting 21st-century skills through digitalization (e.g. the use of technologies and robot tutor) during their didactic activities, particularly proposing ideas that can favor the development of those skills that were particularly addressed as fundamental: Creativity, Critical Thinking, Problem Solving, and Computational Thinking. Two principal questions guide this perspective paper: a) how creativity, critical thinking, and problem-solving can be effective in promoting computational thinking, and b) how Artificial Intelligence can be an aid instrument to teachers to foster creativity, critical thinking, and problem-solving in schools and educational contexts.

3. Methods

To better understand how to start building shared tools to develop the skills described above, starting from the EU indications, we addressed a review of the existing literature.

This work was arranged using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher et al., 2015). We pursued a systematic literature search across three academic databases (PsycINFO, Scopus, and WOS) searching for keywords 'Artificial Intelligence AND Problem Solving OR Critical Thinking OR Creativity OR Computational Thinking AND (Education OR School OR Learning OR Teaching OR Classroom OR Education system). During the revision process, we filtered only articles, reviews, systematic reviews, and meta-analyses published in English in the last five years (2018–2023), we excluded papers published before 2018, books, chapters book, commentary, keynote presentations, panel discussions, dissertations, work-in-progress articles and works that were not conducted within the context of learning, and education. The revision has been conducted by using Rayyan software (Ouzzani, Hammady, Fedorowicz, & Elmagarmid, 2016). Additional records have been found by using the software Connected Papers (Tarnavsky Eitan, Smolyansky, & Knaan Harpaz, 2020).

95 studies have been established as eligible for further investigation. 917 have been evaluated as duplicates, and then excluded in the next steps. 822 articles were excluded after title screening. The remaining 83 were processed for abstract and full text evaluation. After that, only 20 articles were considered relevant. Moreover, we carried out a bibliographic investigation from some recent meta-analysis and perspective articles by using the Software Connected Papers (Connected Papers, s. d.), then, we mainly focused on those articles found aiming to suggest educational model indication for developing Critical Thinking, Problem Solving and Creativity using AI and Computational Thinking (Alam, 2022; Bocconi et al., 2022; Chassignol, Khoroshavin, Klimova, & Bilyatdinova, 2018; Van Laar, van Deursen, van Dijk, & de Haan, 2020).

The development of these skills is also an important issue of the Digital Education Action Plan 2021–2027 of the European Commission, where quality Computing Education is addressed as a key element under the priority "Enhancing digital skills and competencies for the digital transformation". Relevant to this work is digital competence, which concerns the responsible use of digital technologies for learning, at work, and participation in society. It consists of eight points: information and data literacy, communication and collaboration, digital content creation (including programming), safety (digital well-being and competencies related to cybersecurity), problem-solving and Critical Thinking. In this vision, the skills acquired in one domain could support competencies developed in another. This is the case with the skills related to Critical Thinking, and Creativity, which are embedded throughout the key competencies (Mubin et al., 2013). From this perspective, the necessity to introduce Computer Science (CS) practices, particularly Computational Thinking (CT), coding, and programming already in compulsory education has arisen. Nowadays Critical Thinking, Creativity, collaboration, communication, and CT are the core skills that must be learned by students (Digicomp Framework[8]). This would meet the needs of growing young people that could be creators and not just consumers of technology (Papert, 1993). However, activities that include AI systems that could help teachers and educators to develop didactical activity in schools and educational contexts is still not complete in the literature (and not uniform). In this regard, the following sections (Results of the review) will try to answer to the two review questions, giving a more extensive overview of different activities on how Creativity, Critical Thinking, Problem Solving, could be foster developed, and implemented with Computational Thinking and AI (with e.g., robot tutor) in educational and didactic teaching. First, the paper will discuss about Computational Thinking, Programming and Coding in Schools' Curriculum. Second, the connection between Creativity, Computational Thinking and Programming and how to foster it by means of AI, will be analyzed. Finally, will be the turn of Critical Thinking, Problem Solving, and their connection to Computational Thinking and Programming, and how to foster them by using AI.

[5] https://ec.europa.eu/commission/presscorner/detail/nl/MEMO_17_1402.

[6] https://www.oecd.org/pisa/publications/.

[7] https://education.ec.europa.eu/focus-topics/digital-education/action-plan.

[8] https://joint-research-centre.ec.europa.eu/digcomp/digcomp-framework_en.

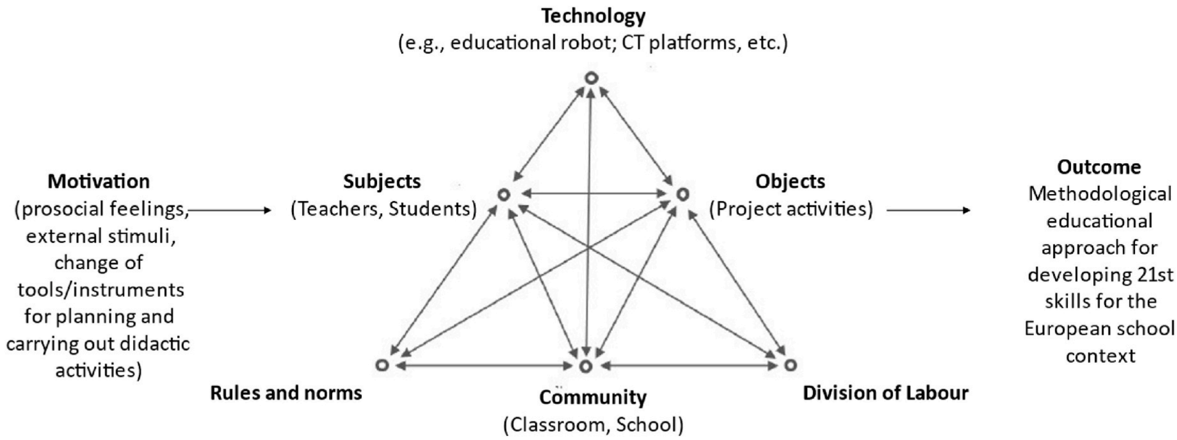

Fig. 1. Activity theory applied to educational context.

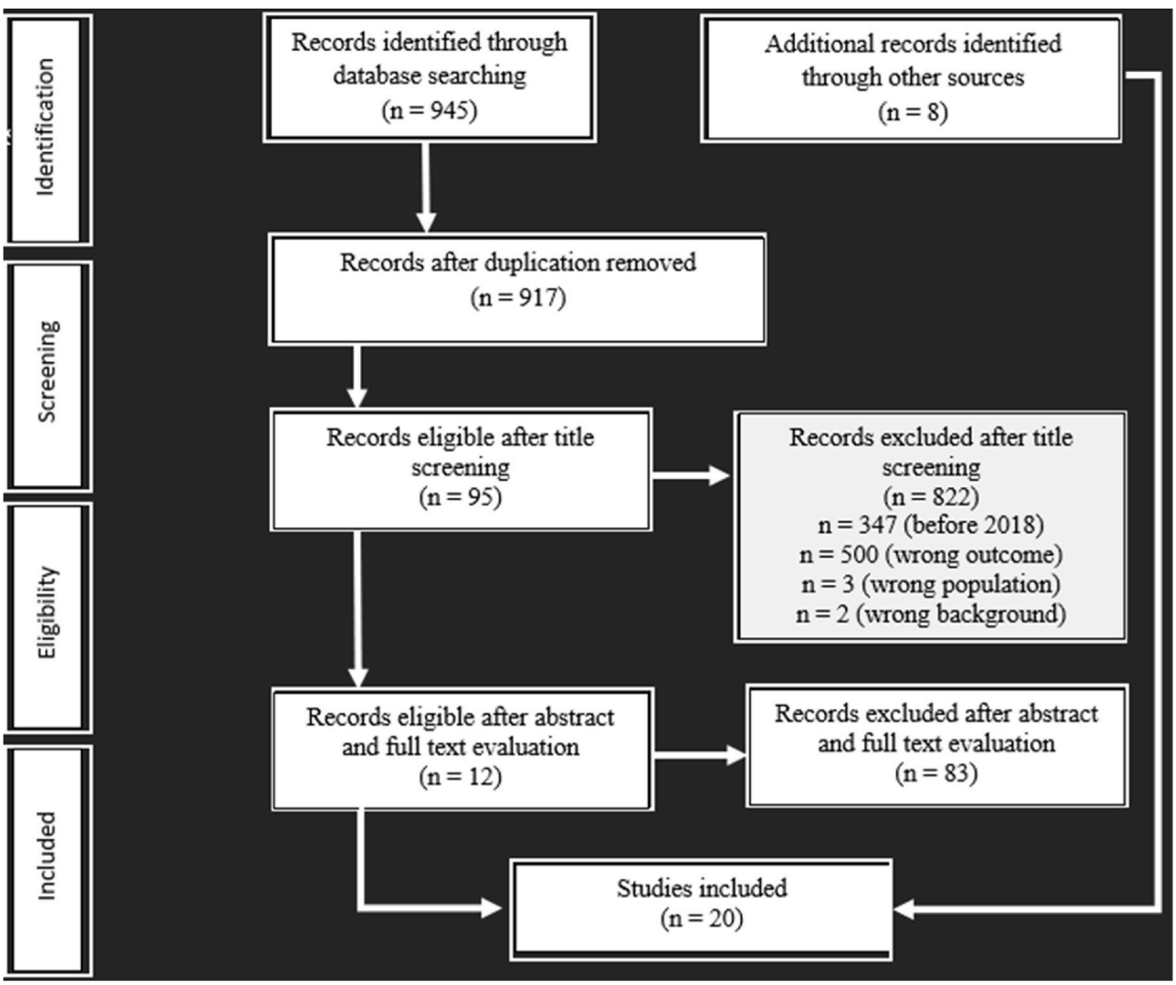

Fig. 2. Summarizes the PRISMA flowchart of the present study process.

4. Results of the review

4.1. Computational thinking, programming, coding in schools' curriculum

Computational Thinking (CT) has been defined in several works by Wing (2006; 2011; 2017) and nowadays Wing's definition is considered the reference point in the discussion on CT. To Wing, "Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer – human or machine – can effectively carry out" (Wing, 2017). Then, CT is a set of concepts and skills involving abstraction, algorithmic thinking, automation, decomposition, debugging, and generalization (Bocconi, Chioccariello, Dettori, Ferrari, & Engelhardt, 2016; Bocconi et al., 2022). These skills are suitable in compulsory education, allowing students to move beyond operable and technical skills, creating problem solvers than just beneficiaries of the technology, developing creativity, and problem-solving capabilities (Yadav, Mayfield, Zhou, & Hambrusch, 2014). Moreover, CT allows approaching problem-solving in a manner that results in solutions that can be reusable in different contexts (Shute, Sun, & Asbell-clarke, 2017).

One of the constituents of CT is programming (Bocconi et al., 2016; Bocconi et al., 2022). We could define programming as the activity of analyzing a problem, designing a solution, and implementing it. This has been indicated by DigComp, the European framework for digital competencies, as one of the constituents for EU citizens (Ferrari, Punie, & Bre, 2013). Differently, coding is the step of implementing solutions in a particular programming language. According to Bers et al. (2019), "coding is a playground", a new literacy for the 21st century, and a new language for children. Through coding, children can learn to code via fun, play, and creativity (Bers et al., 2019). Literature suggests programming as an efficient framework for fostering CT skills (Sun, Hu, & Zhou, 2022; Angeli & Giannakos, 2020).

In recent years, computational thinking and programming/coding are a reality of compulsory education in different EU countries (Bers et al., 2019; Bocconi et al., 2016; Bocconi et al., 2022). The United Kingdom, in 2013, has incorporated computer science in the early years of its school curriculum (National curriculum in England: primary curriculum, 2013). Moreover, an interesting report promoted and funded by the Nordic@BETT2018 Steering Group (Bocconi, Chioccariello, & Earp, 2018), e.g., shows that in Finland, Sweden, Denmark, and Norway, CT and programming are already included in the primary and secondary schools' curricula (but not all over Europe, specifically in the south), sometimes as transversal competencies and within existing subject matter (e.g., in Finland and Sweden) or as a new (elective) subject (e.g., in Denmark and Norway). A deep reading of the report highlights the relevance of two key transversal competencies to foster computational thinking and programming in compulsory schools: critical thinking and creativity (Bocconi et al., 2018).

4.2. Creativity and its connection to computational thinking and programming and how to foster it by using AI

Creativity consists of a core skill for promoting personal growth (Papadakis & Kalogiannakis, 2019) and is embedded throughout the key competencies for lifelong learning (Mazzoni, Benvenuti, & Orsoni, 2022). However, there is still debate about what is creativity. Over the years, researchers developed different conceptualizations and definitions of this term, even if it is possible to find a certain consensus in the simplest definition of creativity. Kaufman & Glăveanu (2019) refer to creativity as something both new and task appropriate. In addition, it is possible to focus on three mental operations that underlie creativity (Antonietti & Molteni, 2014). The first one is related to broadening the mental field, linked to the subject's ability to conceive unique and different ideas e.g. divergent thinking concept (Guilford, 1950), to generate solutions of which at least one survives the judgment (Johnson-Laird, 1998), or the subject's capability of holding a mental wealth of information able to enhance the probability to find elements related to each other for creating something new. In the second mental operation, creativity allows connecting usually conceived antithetical and distant mental fields (Rothenberg, 1979). Lastly, about the third mental operation, a creative act is present when there is a reorganization of the mental field. Only in recent years, creativity has been embraced as a relevant element in computer science for its importance in supplying motivation and interest in the field, but also in improving performance and knowledge acquisition (Israel-Fishelson & Hershkovitz, 2022). Although the literature suggests a bidirectional link between creativity, computer science, and CT, in this work we mainly focus on how creativity can influence CT. Moreover, we present a possible perspective in which AI has been implemented to improve the creativity of participants.

Israel-Fishelson and Hershkovitz (2022) highlighted as creativity may facilitate the resolution of algorithmic problems, the development of computational products, and new knowledge. Liu and Lu (2002) found how standardized creativity tests allow for prediction creativity in solving programming problems among undergraduate students. Similar results have been found in the work of Perez-Poch, González, and López (2016). The authors found a significant positive correlation between the levels of creativity and programming skills among engineering students. In detail, a high level of creativity predicted achieving excellence in programming. These results have been corroborated by Hodgets and colleagues (2013). The idea behind this work was to improve CT by fostering creative thinking. Creative thinking is personalized thinking leading to creative results (Hodges et al., 2013). They found that the implementation of creative thinking exercises in CS courses improved computational knowledge and skills (Miller et al., 2013).

In general, these pieces of evidence suggest a relevant role of creativity and give value to its integration into compulsory education that would foster CT and programming skills. Thus, it is important to explore whether and how Artificial Intelligence can be a valuable tool in fostering human creativity, and consequently CT. The idea of AI helping humans to achieve better creative performances is undoubtedly fascinating. The branch of Computer Science that deals with this aspect is called computational creativity. Wingström, Hautala, and Lundman (2022), observed how nowadays computational creativity focuses on two lines of research. The first explores the capabilities of AI algorithms to recreate human-level creativity while the second is merging the creativity of humans and AI in a reciprocal course. Concerning co-creativity, Maher, Brady, and Fisher (2013) suggested three roles of computers: 1) as supporters of the human creative process by giving tools and procedures; 2) as enhancers of human creative ability by providing knowledge and promising creative cognition; 3) as generators, by offering to the user, creative elements to interpret, evaluate and integrate as creative products.

Unfortunately, the approach to co-creativity is young and most of the co-creative AI is in the arts domains (Wingström et al., 2022). According to this line, one recent work (Rong, Lian, & Tang, 2022), explored how fine art training based on Virtual Reality and Artificial Intelligence can enhance the creativity and concentration of middle school students. The study was done by comparing the students' creativity, distraction, and anxiety levels before and after AI and VR course training. The results showed significant improvement in creativity levels (assessed with the "Creative Thinking Test for Middle School Students"), and significantly reduced distraction and anxiety levels. The authors claim that the training proposed can adequately improve students' creativity and concentration, and at the same time, reduce students' test anxiety.

Another work by Liapis, Yannakakis, Alexopoulos, and Lopes (2016), presented a computational approach by using mixed-initiative tools aiming to support and foster human creativity by improving lateral thinking with educational activities. In this work, four mixed-initiative tools or games were presented. The goal of fostering lateral thinking was carried out by the computer supported by AI that proactively contributes to the design process by creating suggestions for the human user to consider. In this perspective, human and computers do affect each other; the action done by the computer reformulate the human's mental associations, but also the action taken by the human constrains the search space of the algorithm, enabling it to focus on specific possible solutions to a problem (Liapis et al., 2016). Authors suggested in their results how this co-creative approach was able to foster human creativity by improving the lateral thinking of humans. Unfortunately, the work considers only qualitative and observational data limiting the generalizability of results.

4.3. Critical thinking, problem solving, their connection to computational thinking and programming, and how to foster them by using AI

The other transversal competence considered is critical thinking. Critical thinking is merely the ability to think critically and is a key to individual civic engagement and economic success (Willingham, 2019).

As for creativity, there is no general definition for critical thinking, but researchers highlighted some agreement about the characteristics inherent to it, like analysis and synthesis, making judgments, decision-making, drawing warranted conclusions, and generalizations (Buckley, 2012).

According to Fagin and colleagues (Fagin, Harper, Baird, Hadfield, & Sward, 2006), three are the key parts of critical thinking: clarity (the ability to understand the information received), accuracy (the ability to investigate the distance between the information and factual reality), and relevance (the ability to evaluate if the information received is pertinent).

The suggestion is that critical thinking might be considered a prerequisite to problem-solving (Buckley, 2012). Even if the literature did not deeply explore yet the relationship between critical thinking and CT, an interesting work of Buckley (2012), pointed to a connection between these two forms of thinking. The idea formulated, focused on perceiving a problem as an obstacle. The author claimed that to overcome the obstacle was possible to apply a linear problem-solving strategy or a 3-D problem-solving model. Both models consider critical thinking as a non-algorithmic higher order of thinking that directly affects knowledge acquisition. Then, critical thinking becomes a prerequisite for knowledge acquisition. By using critical thinking, the subject becomes aware of the problem and then the information is extrapolated and critically analyzed. Starting from the relevant knowledge extracted in this way, it is possible to apply CT and then solve the problem.

How Artificial Intelligence could be a valuable tool in fostering human critical thinking, and problem-solving? Critical thinking and problem-solving, are the key element in the decision-making process and all these three elements are interconnected to achieve the best solution given a problem (Özgenel, 2018). Starting from this point, a recent line of research focused on the use of AI and metacognition in the learning process to enhance students' problem-solving capabilities. Metacognition is the ability to think about one's cognition (Cortese, 2022). According to Molin, Haelermans, Cabus, and Groot (2020), students with a higher level of metacognitive skills are mainly prone to self-regulated learning, which is an approach linked to learning where students set their goals, and track, regulate and control actions, cognition, and motivation to achieve these goals.

Confidence is the measure by which metacognition is measured in the field of psychology and neuroscience (Cortese, 2022). According to Cortese (2022), is possible to bring together the aspect of confidence with the mathematical formalism of Reinforcement Learning that fits well with the question of how to explain learning and how confidence can affect learning and vice-versa.

The focus on metacognition as an element to enhance students' problem-solving and decision-making capabilities, and how AI can be beneficial for this purpose, has been investigated in a recent work by Callaway et al. (2022). The objective of this work was to improve the planning strategies of students facing different problems. By adopting the Mouselab-MDP paradigm (Callaway, Lieder, Krueger, & Griffiths, 2017), the authors developed an intelligent cognitive tutor that employs metacognitive feedback to teach planning. The idea of metacognitive feedback is to give people feedback on how instead of what they decide to do. The authors based on the theory of metacognitive reinforcement learning developed a system able to discover the optimal cognitive strategies and accelerate metacognitive learning in people by suggesting optimal feedback signals. The presented approach was validated by the authors in six different experiments. The results showed how practicing with this system allowed people to be more effective than traditional methods. In more detail, the group that used the metacognitive feedback showed significantly better results than the other groups (feedback related to action and no feedback). In addition, by applying this method the authors found how improvements were also transferred in new situations, and retained over time (Callaway, 2022).

5. Conclusion

To be a citizen of the 21st century requires one to master different skills and competencies to be an effective worker, for personal realization and development. The school and the teachers are the key elements to educating students in this transformation process where computational thinking, critical thinking, problem-solving, creativity, and the remaining skills are taking a leading role in this even more digitalized world. With this paper we try to propose a perspective on how creativity, critical thinking, and problem-solving can be effective in promoting computational thinking, and how Artificial Intelligence can be an aid instrument to teachers in the fostering of creativity, critical thinking, and problem-solving in schools and educational contexts.

Literature suggests how AI is used in education with different applications like chatbots, intelligent tutoring, automated grading systems, and recommended systems, but its application in the field is still limited compared to others, like medicine and business (Celik, 2022). This aspect is also reflected in this study, where very few articles have been considered eligible for the aim of the article itself. One possible reason has been presented in the work of Celik, Dindar, Muukkonen, and Järvelä (2022), where there was evidence of the resistance of decision-makers such as teachers, educators, and traditional textbook publishers to the use of AI, but also the knowledge of stakeholders, including students, about AI plays a relevant role in its application.

According to this line, Marrone, Taddeo, and Hill (2022) investigated how students perceived AI in fostering creativity in the school context. They found four key factors describing the relationship between AI and creativity: social, affective, technological, and learning. Concerning the affective one, the authors observed an effective response in students based on their degree of familiarity with AI; students who were more familiar with AI concepts or applications reported being more comfortable in using AI technologies compared to the students who were not.

6. Future directions

Considering the precious aspects, to be able to implement new technologies, as a driving force for change in teaching activities, it is necessary to keep in mind that the school is a cornerstone for promoting the skills of the 21st century. Even if the dissemination of these technologies and activities in school curricula in Europe is not uniform, it is necessary to continue to disseminate (also through scientific research in this field) the dissemination of techniques that teachers and educators can use. In this regard, our invitation is to follow the indications of the Digital Education Action Plan (2021–2027), however enhancing collaboration between schools (e.g., using eTwinning[9]) throughout Europe in order to reduce the existing gap in the development of skills that currently exists between north and south (Bocconi, et al., 2022). Additionally, evidence has suggested few studies have implemented AI as a method to help students and individuals foster creativity and problem solving (e.g., Alam, 2022; Callaway et al., 2022; Chen, 2020). This depends a lot on finding resources and on the skills that teachers have in being able to use such technological tools. In this regard, it would be necessary to promote lifelong learning, with a view to a lifelong learning programme[10], also for teachers.[11] Always taking advantage of the networks of connections existing throughout Europe. Teaching and awareness of what AI can and cannot do as a tool is a key step in making it more familiar in the educational context. A tool you can rely on.

[9] https://school-education.ec.europa.eu/en/etwinning.
[10] https://lllplatform.eu/.
[11] https://school-education.ec.europa.eu/en/about/etwinning-future-teachers.

7. Limits

One of the most important limits of this paper is that it doesn't consider the ethical aspects (considering also GDPR's data protection) of the use of AI in many fields. Indeed, one of the most relevant paper's aims are primarily focused on the functional use of AI in fostering the so-called soft skills or life skills, without forgetting the dysfunctional or critical effects of its use (although not central). Thus, future studies, more focused on ethical effects of the use of AI to develop and foster soft skills, should deepen the critical aspects related, e.g., to data protection, data collection, and awareness to interact with non-human agents.

Credit author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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