Project title	Augmented Intelligence for Pedagogically Sustained Training and Education
Project acronym	augMENTOR
Grant agreement No.	101061509
Start date of project	01/01/2023
Duration of project	36 months
Project website	https://augmentor-project.eu/

D4.1 Creative Pedagogy in the AUGMENTOR solution Interim

Related work package	WP4
Document reference	D4.1
Related deliverables	D3.1, D4.2, D4.3
Status	Final
Version	1.0
Due date	30/06/2024
Submission date	29/06/2024
Lead partner	UCA
Contributing partners	UPATRAS, UDE, EASD, KTU
Reviewers	ACP, UDE
Keywords	creativity, critical thinking, design thinking

Dissemination level	
✔	Public
	PP: Restricted to other programme participants (including the Commission)
	RE: Restricted to a group specified by the consortium (including the Commission)
	CO: Confidential, only for members of the consortium (including the Commission)

Funded by the European Union

The augMENTOR project (GA No. 101061509) is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. The European Union cannot be held responsible for them.

Document information

List of contributors	
Name	Partner (short name)
Margarida Romero	UCA
Dea Puspita Septiani	UCA
Alex Urmeneta	UCA
Panos Kostakos	KTU
Donia Trad	UCA
Oksana Strutynska	UCA
Andromahi Filippidi	UPATRAS

Document History			
Version	Date	Change editors	Changes
0.1	01/02/2023	Margarida Romero (UCA)	Table of Contents
0.2	01/06/2023	Margarida Romero (UCA)	Draft version (Executive summary, Transversal competencies, Creativity)
0.3	11/07/2023	Margarida Romero (UCA) Dea Puspita Septiani (UCA) Panos Kostakos (KT)	Updated draft version with the information related to the MIS4TEL study
0.4	20/10/2023	Margarida Romero (UCA) Donia Trad (UCA)	Improvement of the literature review, Reference integration and 4Cs development
0.6	23/01/2024	Donia TRAD (UCA)	Revision
0.7	03/06/2024	Margarida Romero (UCA)	Revision
0.8	11/06/2024	Oksana Strutynska (UCA) Margarida Romero (UCA)	Draft ready for internal review
0.9	16/06/2024	Margarida Romero (UCA) Alex Urmeneta (UCA)	Reviewed version
0.10	28/06/2024	Eleftheria Tsourlidaki (UNIGR)	Pre-final check
1.0	29/06/2024	George Garofalakis (UNI)	Final check, release and submission

Quality control		
Role	Partner (short name)	Approval date
Internal reviewers	ACP, UDE	14/06/2024
Deliverable leader	UCA	27/06/2024
Quality manager	UNIGR	28/06/2024
Project coordinator	UNI	29/06/2024

Funded by
the European Union

Table of contents

Funded by
the European Union

List of figures

List of acronyms

Acronym	Description
AI	Artificial Intelligence
AIED	Artificial Intelligence in Education
AR	Augmented Reality
augMENTOR	Augmented Intelligence for Pedagogically Sustained Training and Education
CFP	Carbon Footprint
CSDP	Common Security and Defense Policy
CSO	Civil Society Organisation
DFG	German Research Foundation
EBSCO	Elton. B. Stephens. CO (company): leading provider of research databases
EU	European Union
HE	Higher Education
ICT	Information and Communications Technology
ITS	Intelligent Tutoring System
ML	Machine-Learning
MSc-level	Master's Level Course
NLP	Natural Language Processing
NGO	Non Governmental Organisation
PF	Pedagogical Framework
R&D	Research & Development
RRI	Responsible Research and Innovation
SMART	Specific, Measurable, Achievable, Relevant, and Time-bound
SLR	Systematic Literature Review
TPACK	Technological Pedagogical Content Knowledge
UNPD	United Nations Development Programme
USA	United States of America
VR	Virtual Reality
WoS	Web of Science

Funded by
the European Union

Executive summary

The Horizon augMENTOR project aims to support the development of transversal competencies, focusing primarily on creativity but also including critical thinking, collaboration, and communication. According to different 21st century frameworks, as well as the Organisation for Economic Co-operation and Development, these competencies are essential to prepare individuals for success in various aspects of life, including education, the workplace, and personal agency for participation in a society in which artificial intelligence (AI) technologies and services are increasing. Thus, in educational settings, it is imperative that educators have at their disposal effective frameworks that properly monitor and assess the development of these competencies.

In augMENTOR, we recognise that to effectively assess these competencies, a one-size-fits-all evaluation model is insufficient. Our objective in the present deliverable is two-fold. We first present the current state-of-the-art in 21st-century competencies with a core focus on creativity, critical thinking, and design thinking. We are acutely aware of the dynamic nature of these competencies and the need for a multifaceted and ongoing evaluation process to ensure their effective development and assessment. Our review was done in the framework of T4.1- Fostering Creativity, critical thinking and design thinking.

Our second objective is to present the first version of a multifaceted approach designed using a combination of methods developed in T4.2 - Integration of creative pedagogy in the augMENTOR solution.

Transversal competencies, such as creativity, critical thinking, collaboration, and communication, are multifaceted and dynamic in nature, and they largely depend on the relevant social context. They encompass a range of skills, behaviours, and qualities that individuals need to navigate an ever-evolving world effectively. The dynamic nature of these competencies presents a unique challenge when it comes to their evaluation.

Evaluating transversal competencies is not a straightforward or linear process. These skills are not static; they evolve and adapt to different contexts and challenges. Therefore, traditional assessment methods may fall short of capturing the full spectrum of an individual's transversal competencies.

1 Introduction

1.1 Objectives

The main objective is to advance the study of 21st century competencies in relation to AI-augmented Educational Resources and, more precisely, competencies related to critical thinking, design thinking, and creativity, and to show how these can be developed in a supportive context of emerging technologies. This deliverable has two main objectives.

(i) describe the augMENTOR's transversal competencies (**Objective 1**);

(ii) report the literature review on transversal competencies (**Objective 2**);

The objectives outlined for the augMENTOR project are crucial to support the pedagogical framework of augMENTOR in coherence with the WP3 objectives. Objective 1 aims to describe augMENTOR's creative pedagogy approaches and the 4Cs competencies of augMENTOR . D4.1's second objective is to report the literature review on the 4Cs in relation to the augMENTOR pedagogical objectives.

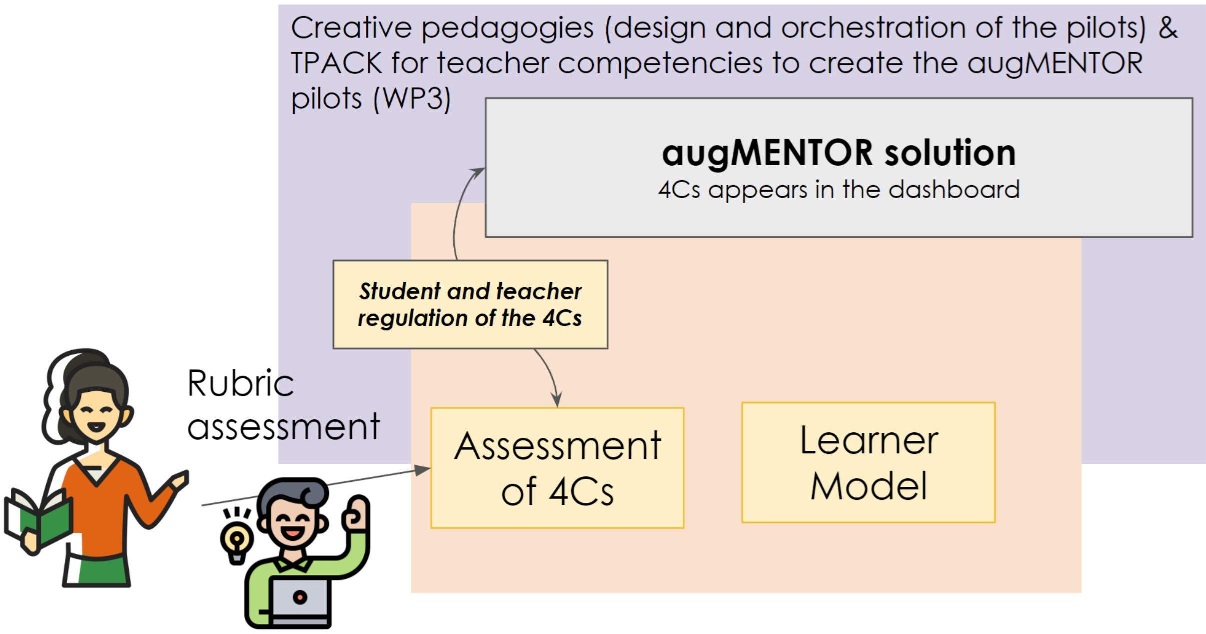

Figure 1. *Overview of the WP4 objectives in relation to WP3*

In augMENTOR, we recognise that to effectively assess the 4Cs competencies, a one-size-fits-all evaluation model is insufficient. Our objective in the present deliverable is two-fold. We first present the current state-of-the-art in 21st-century competencies with a core focus on creativity, critical thinking, communication and collaboration as the 4Cs of augMENTOR project. We are acutely aware of the dynamic nature of these competencies and the need for a multifaceted and ongoing evaluation process to ensure their effective development and assessment. Our review was done in the framework of *T4.1 - Fostering Creativity, Critical Thinking, and Design Thinking*.

The figure below illustrates the alignment and integration of the 4Cs (Creativity, Critical Thinking, Collaboration, Communication) within the augMENTOR project. It outlines the steps taken to ensure the operationalization and assessment of these competencies through rubrics, which will serve to inform the augMENTOR dashboard.

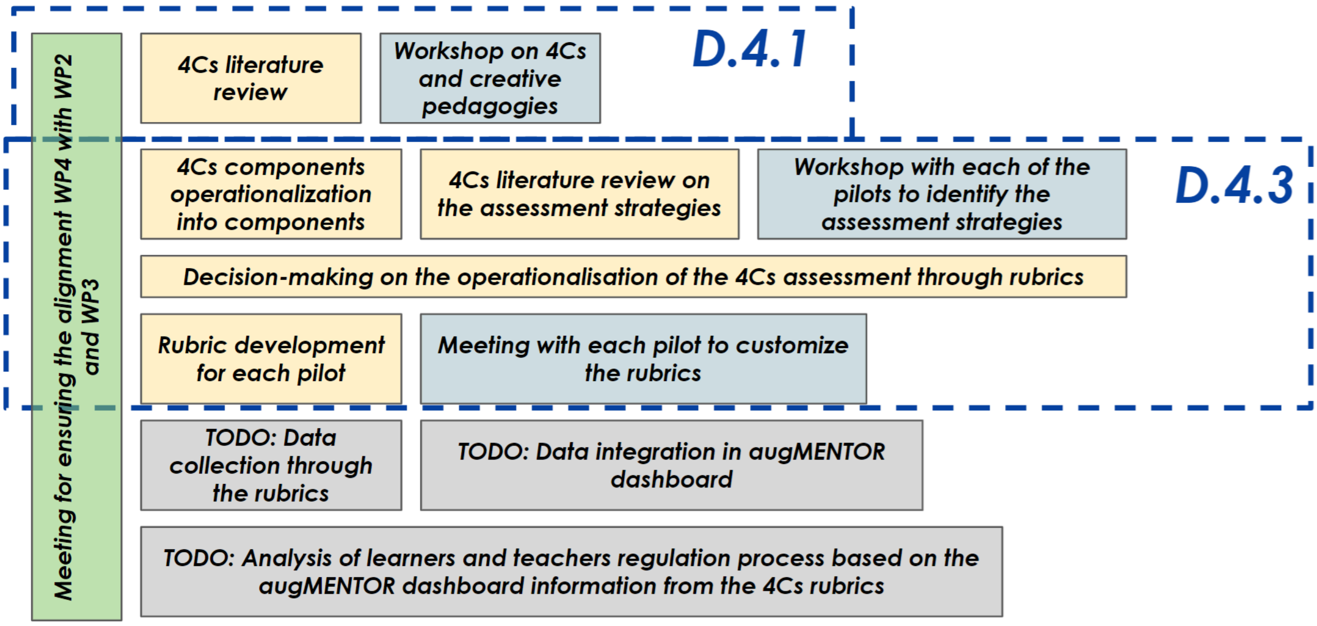

Figure 2. *Process developed in the WP4 in relation to the 4Cs evaluation*

The different tasks developed for these objectives and represented in the figure are described below:

1. **Alignment of WP4 with WP2 and WP3** to ensure consistency and coherence across different work packages within the project. This alignment is facilitated through meetings and continuous collaboration among the teams.
2. **Workshop on 4Cs and Creative Pedagogies**: Workshops are conducted to explore creative pedagogies and how they can be integrated with the 4Cs (based on the continuous task of alignment and the workshops, we have developed the first two sections of this document).

3. **4Cs Literature Review**: A comprehensive literature review was conducted to establish a theoretical foundation for the use of the 4Cs in learning environments and to establish the state-of-the-art in relation to the integration of 21st century skills in creative pedagogies (see chapter 3 - State-of-the-art of the 4Cs). Our findings helped us better understand how the augMENTOR project can leverage AI and design thinking principles to develop more impactful synergies around the creative applications of emerging technologies. The outcome of these findings are expressed in both the shared dependencies of WP2, WP3 and WP5 and more directly in the future deliverables D4.2, D4.3, and D4.4
4. **4Cs Components Operationalization into Components**: This involves breaking down each of the 4Cs into actionable components that can be assessed.
5. **4Cs Literature Review on the Assessment Strategies**: A review focusing on how the 4Cs can be effectively assessed.
6. **Workshop with Each of the Pilots to Identify the Assessment Strategies**: Individual workshops with pilot groups to tailor assessment strategies specific to their needs.
7. **Decision-Making on the Operationalisation of the 4Cs Assessment through Rubrics**: A decision-making process to finalise how the 4Cs will be assessed using rubrics.
8. **Rubric Development for Each Pilot**: Creating specific rubrics for each pilot group to assess the 4Cs.
9. Meeting with Each Pilot to Customise the Rubrics: Iterating the rubrics based on feedback from each pilot group.
10. Data Collection through the Rubrics: Collecting data using the developed rubrics.
11. Data Integration in augMENTOR Dashboard: Integrating the collected data into the augMENTOR dashboard for analysis.

Analysis of Learners and Teachers Regulation Process Based on the augMENTOR Dashboard Information from the 4Cs Rubrics: Analysing the data to understand how learners and teachers regulate their processes based on the feedback from the rubrics.

Funded by
the European Union

1.2 Alignment ofWP4 with WP2, WP3 and WP5

The alignment of WP4 with WP2 and WP5 ensures that the augMENTOR project not only advances educational methodologies but also implements them effectively to enhance the educational experiences and outcomes for learners, making a significant impact in the field of AI-augmented education.

The D4.1 deliverable's dual objectives are to describe the 4Cs within the augMENTOR project and to conduct a thorough literature review on these competencies.

- **Objective 1 of D4.1** introduces the 4Cs and its application as both a framework and a strategy within the augMENTOR project. As a framework, we utilise the 4Cs to provide a structured approach to designing, implementing, and assessing learning activities. Whereas, when applied as a strategy, the 4Cs act as a guide for the specific actions and methodologies employed to foster creativity within physical and digital learning environments.
- **Objective 2 of D4.1** incorporates a comprehensive literature review to define the use and current understanding of the 4Cs in education and to establish the state-of-the-art of technology-enhanced creative competencies. The review grounds the work of WP4 by identifying the efforts made to-date to integrate technology-enhanced learning (TEL) in support of the 4Cs. It also supports the work of WP2 and WP3 by furthering augMENTOR's understanding of what constitutes 21st century competencies and how these cross-disciplinary skills can be made more impactful and inclusive through acculturation efforts and the creation of novel pedagogical frameworks.

WP3 and WP4 are grounded in the pedagogical synergies operationalized through data-driven indicators of the learning aspects in WP3 and the rubric based assessment of the 4Cs that will be further developed in the D4.3 deliverable. Furthermore, while WP3 owns the overarching pedagogical approach of the augMENTOR program through the Pedagogical Design Model with Emerging Technologies (PeDeMET) and Technology Augmented Scenarios and e-Activities (TESA) initiatives, WP4 supports those efforts by focusing on strategies that bolster the development, integration and assessment of 21st century skills (4Cs) within those pedagogical frameworks. The collaboration between these work packages ensures a cohesive approach to creating a learner-centric educational AI-based environment (Romero et al., 2024) that leverages emerging technologies to foster skill development, engagement, and continuous improvement.

Funded by the European Union

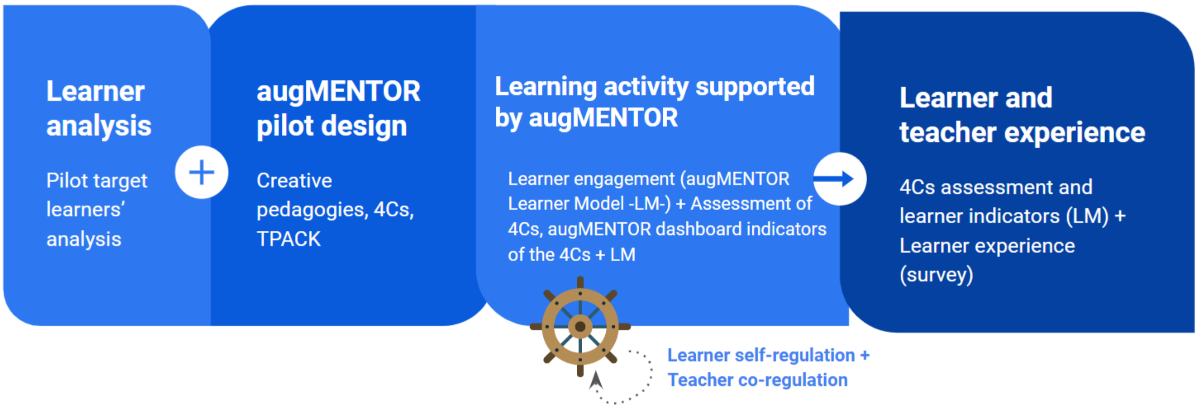

Figure 3. *The 4Cs within the augMENTOR project*

1.3 The 4Cs in augMENTOR

In the Horizon augMENTOR project we select to stick to the "Four Cs" - Collaboration, Communication, Critical Thinking, and Creativity- as a common denominator agreed with all the partners of the project in the moment of designing the proposal, and during all the project advancement towards the integration, support, and assessment of these four Cs competencies. The context of competency-based education and the different frameworks of the transversal competencies that have been considered are described in Annex 1.

In order to characterise and develop the strategy for the assessment of 4Cs in augMENTOR we develop the following methodology:

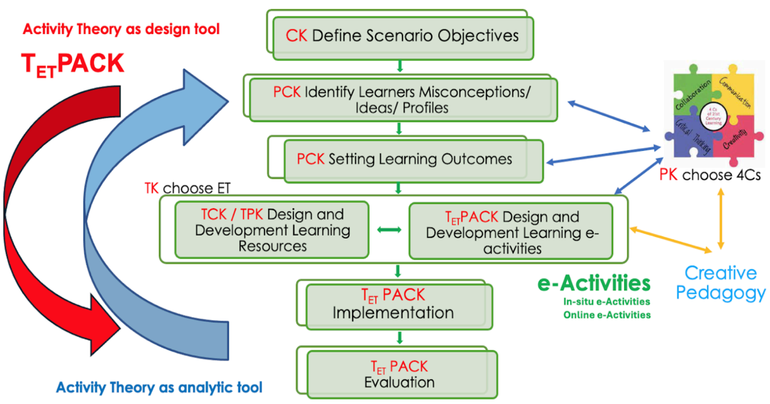

Figure 4. *Technology augmented Educational Scenarios and e-Activities (from D3.1, Figure 9)*

Funded by the European Union

2 Creative pedagogies to support the augMENTOR project

Within the augMENTOR project, we aim to support a creative pedagogy perspective based on Lin's (2011) work. Lin's study introduces a triangular model of creative pedagogy, encompassing creative teaching, teaching for creativity, and creative learning. Lin (2011). Our study encompasses these three interconnected elements.

The collaborative work of WP3 and WP4 is directed towards a shared objective of promoting creative pedagogies, with a specific focus on supporting it through the augMENTOR process of designing the pilots and developing a solution to support the teaching and learning processes. In tandem with WP3, we delve into a comprehensive study of the key competencies essential for the 21st century across diverse educational contexts.

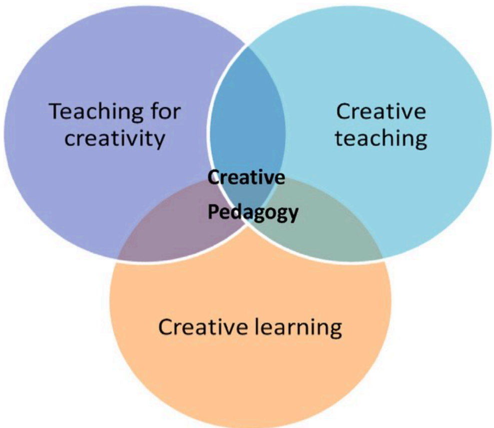

Figure 5. *The three elements of creative pedagogy (Lin 2011)*

2.1 Creative teaching, teaching for creativity, and creative learning

In order to support a creative pedagogy approach, we developed a participatory approach in the process of defining the way transversal competencies, focusing on creativity and critical thinking, are supported in the four pilots of the augMENTOR project. The four pilots have adopted a creative pedagogy approach, incorporating creative teaching, teaching for creativity, and creative learning. The commitment of the augMENTOR project to pedagogical innovation is implemented through the way the pilots are designed to support different transversal competencies focusing on creativity and critical thinking.

According to Banaji et al. (2010), increased interest in creativity in education and creative pedagogies, accompanied by a growth in educational research in this area, marked the turn of the twenty-first century. Further emphasising the international significance attributed to creativity, the Organisation for Economic Co-operation and Development (OECD, 2018) positions creativity and creative thinking as key skills for learners in the 2030s. The upcoming Programme for International Student Assessment (PISA) test of young people's creative thinking (2021) further supports this perspective.

Craft et al. (1997) distinguished between creative teaching and teaching for creativity during the 1990s. Their research has focused on the orientations of both teachers and learners towards 'creative teaching' and 'teaching for creativity. According to Sefton-Green (2008), creative learning, a term that gained prominence more through policy than research in the early 21st century, largely continues to be a concept seeking definition. Jeffrey and Craft (2006) describe it as a "middle ground" between creative teaching and teaching for creativity. Teachers now recognise creative teaching for its emphasis on stimulating, groundbreaking, captivating, and frequently memorable teaching methods, while teaching for creativity focuses more explicitly on fostering the learner's creative abilities. Although creativity and creative learning are expansive notions, it is essential to tailor their definitions to align with the perspectives of practitioners and educators (Lucas & Anderson, 2015).

In competency-based education (Argyris & Schon, 1974; Romero et al., 2015; Voorhees, 2001), competence refers to one's actions and competency evaluates one's performance. The shift to competency-based education prioritises a learner-centred, outcome-based approach over traditional knowledge transmission. Competence involves knowledge, beliefs, and skills, particularly in the context of digital games. Skills are defined as effective task performance. Identifying core skills is a major challenge for educational policymakers in the 21st-century knowledge society.

2.2 Design thinking and creative pedagogies

Design researchers have ingrained 'Design Thinking' into their collective consciousness since Rowe introduced the term in his 1987 book. Design thinking is a collaborative problem solving process that focuses on finding human-centred solutions through a multidisciplinary, iterative approach (Schmidberger & Wippermann, 2023). Embraced commercially in the 1990s by companies such as IDEO and institutionally in the 2000s by Stanford's d.school amongst others, design thinking has become well known for its ability to foster critical thinking, creative problem solving and innovative solutions. As a function of its human-centred perspective, prioritising empathy as a way of understanding the needs of end-users, design thinking supports a creative pedagogical approach that engages learners through the different aspects of the augMENTOR project. Accordingly, each aspect of the creative pedagogical approach presented within D4.1 is viewed through the different stages of design thinking: empathy, define, ideate, prototype, test, and iterate. For example, the prioritisation of learning activities that encourage divergent thinking aligns well with the ideation process, whereas the development of novel ways of assessing 21st century competencies models design thinking's test phase. These integrations, amongst others, can be found in figure below, showing how the augMENTOR project has leveraged design thinking in support of creative pedagogies and the learner and teacher experience.

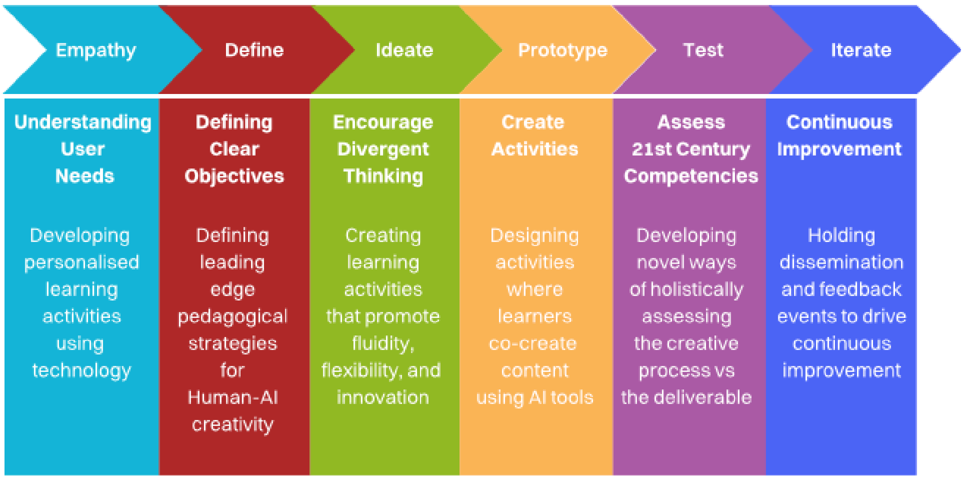

Figure 6. *Integration of design thinking principles within the augMENTOR program*

The pilots employ a specific approach within the augMENTOR project, utilising some of the design thinking principles. The augMENTOR project incorporates the design thinking approach into the participatory co-creation of its pilots, articularly in enhancing the support for transversal competencies, which prioritise creativity and critical thinking, and in evaluating these pilots. This approach involves engaging all stakeholders in the design process and fostering collaboration and innovation. In the context

of creative pedagogies, design thinking acts as a catalyst, providing a structured framework to ideate, prototype, and iterate. The pilot creation within the project takes into account some of the principles of design thinking. This methodological approach aims to play a central role in the design process, guiding each step with a user-centric focus. The integration of the design thinking process can help to create design pilots that are not only functional but also tailored to the specific challenges of the project, resulting in effective educational solutions. The project follows a creative pedagogy approach (Lin, 2011) by using design thinking principles in the development of the augMENTOR pilots. This makes sure that the solutions not only address the targeted transversal competencies but also meet the needs of the diverse educational community involved in the augMENTOR pilots.

Funded by
the European Union

3 State-of-the-art of the 4Cs

Competence is often considered what you do, and competency is how well you do it. Skills are considered part of competence in competency-based education (Argyris & Schon, 1974; Romero et al., 2015; Voorhees, 2001). As an example, we can imagine a school science teacher deploying the augMENTOR solution to support her teaching. Her expertise includes using technology to facilitate education. Her competency is displayed in how effectively she adapts teaching methods based on the augMENTOR dashboard information. The specific skills underpinning her competence include technical proficiency with augMENTOR, data interpretation, and adaptive instructional design. For a further analysis of competencies, please see Annex 1.

The late 20th century popularised the concept of 21st century skills, which now forms part of the transversal competencies framework. Within augMENTOR, we aim to develop a practical perspective on the support of the so-called 21st century skills by considering four of them. To emphasise their cross-cutting nature across various domains and time periods, we will refer to these skills as transversal competencies rather than 21st-century skills from a research perspective. However, in this section, we describe the frameworks (most of them related to 21st century skills) that have permitted the identification of these four main transversal competencies. The concept of the "Four Cs" - Collaboration, Communication, Critical Thinking, and Creativity - has emerged as a vital framework for the essential skills needed by 21st-century learners. Traditional education systems, primarily designed for past industrial and agrarian societies, no longer suffice in the rapidly evolving landscape. The historical emphasis on mastering the "Three Rs" - reading, writing, and arithmetic—has given way to a new imperative. In today's interconnected and globalised society, students must not only excel in the foundational skills of the past but also be proficient in the "Four Cs."

- **Collaboration**, the first of the Four Cs, underscores the significance of working together in a harmonious and productive manner.
- **Communication**, the second C, goes beyond mere language proficiency. It encompasses the capacity to convey ideas clearly, engage in active listening, and navigate diverse forms of communication, including digital platforms.
- **Critical thinking**, the third C, is essential for problem-solving and decision-making. It involves the skill of evaluating information critically, analysing complex situations, and making well-informed judgments.
- **Creativity**, the fourth C, highlights the need for individuals to think innovatively, explore new ideas, and envision novel solutions to emerging challenges.

Funded by
the European Union

The "Four Cs" provide learners with a holistic skill set that equips them to thrive in a world where adaptability, innovation, and the ability to collaborate across diverse and global contexts are paramount. These skills are not just valuable for success in the 21st century; they are becoming increasingly indispensable for navigating the complexities of a society where both societal and technological challenges, such as the rise of generative AIs, present new challenges.

3.1 Literature review for the state-of-the-art of the 4Cs

The methodology followed for the literature review has been developed in a three-step process. First, the research perimeter of the literature was defined in relation to the topics (4Cs in education) and the scientific databases and journals considered for the literature review. We analysed the papers in the second step to determine if they meet the selection criteria. In the first step, the title and abstract of all the initial selections (n=550) were reviewed to select the ones that fit the criteria (N=241). In the second step, the full papers were analysed to select those fitting the criteria (N=92, creativity N=39; critical thinking N=18; collaboration N=21; communication= 14). When a paper addressed two competencies or more in an empirical way, we evaluated each competency separately. Within this process, we do not only provide a literature review as a mere summary of sources; we develop an analytical, synthetic, and critical evaluation of existing knowledge to present a comprehensive understanding of the subject's current state of knowledge.

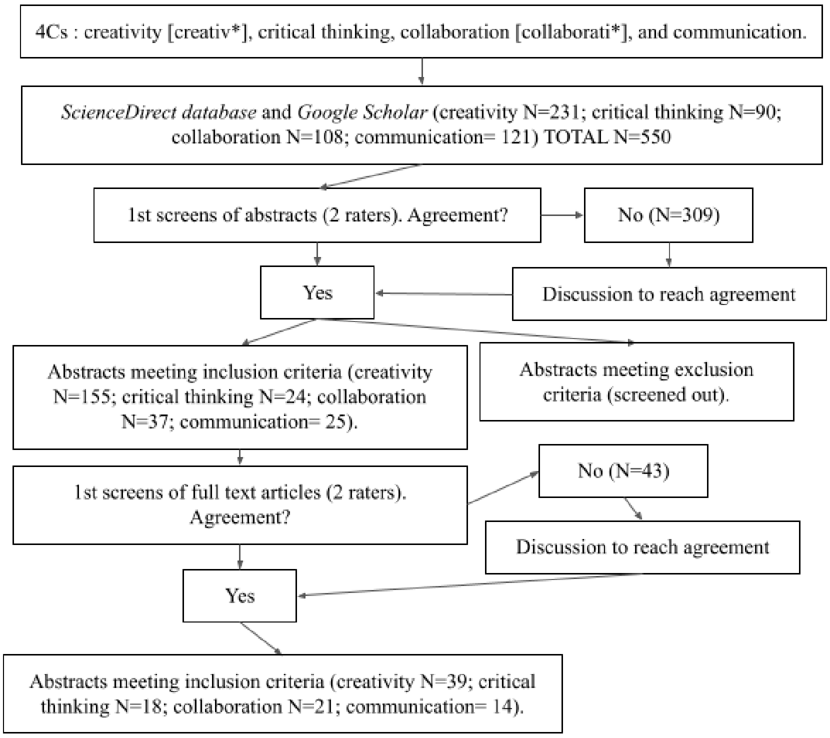

Figure 7. *Literature review methodology*

3.2 State-of-the-art of creativity

We conducted a systematic literature review to document the state-of-the-art of creativity competence in Artificial Intelligence in Education (AIED) with a focus on technological perspectives[1]. In this section, we first introduce AIED's current challenges related to the support of creative pedagogies (Urmeneta & Romero, 2024), followed by an introduction to creativity as a research competency and creative engagement in AIED.

AI tools have been developed over the last five decades for a variety of educational purposes. However, these tools were mostly used in limited situations, often for research purposes. The review by Feng and Law (2021) on the studies developed during 2010–2019 has permitted two main educational technologies to be supported by AI for educational purposes: intelligent tutoring systems (ITSs) and Massive Open Online Courses (MOOCs). The popularisation of the use of AI tools for education has benefited over the past year from the public availability of ChatGPT. In 2022, 242 papers were published on ChatGPT, and 1470 were published in the first three months of 2023. The media's coverage of ChatGPT's effects has made more people aware of how this tool could be used in education. However, it has

[1] The following work has been peer-reviewed and presented in the MIS4TEL conference of 2023.

also raised some concerns about the effects of this type of tool on academic integrity and the ability of teachers and students to be creative in their educational activities. We look at an emergent approach to technology-enhanced learning (TEL) in this paper. AI tools are part of activity systems that are defined not only by the technology tools but also by how they guide human activity systems towards a goal (Engestrom, 2000; Isaac et al., 2022). While some educators are concerned about how AI tools can hinder learners' creative processes by delegating part of the process to AI tools, we should also consider how these tools can support AI-human collaboration for individual, group-based, and large-group collaboration. Annex 2 contains a comprehensive literature review on creative engagement in AI education.

Beyond the creative integration of AI tools in education, AI tools cannot be considered as creative as humans at the current stage. Consider a more robust cognitive architecture that will allow AI models to better support certain human activities, allowing them to process cultural contexts, interpersonal relationships, and long-term memory more effectively. Adding a strong cognitive architecture to AI models could completely change how we do collaborative, open-ended learning activities. This is especially true in collaborative teaching situations at the fifth level, which are all about co-creating content with other people. Such an architecture would enhance AI's capability to contextualise and historically inform decision-making and problem-solving processes. This would be especially valuable in settings where understanding the nuances of context and history is crucial. Moreover, a more sophisticated cognitive architecture could significantly address prevailing challenges such as biases, ethics, and transparency in AI systems. By enabling AI to make decisions that reflect a deeper comprehension of intergroup dynamics and human values, we can foster more ethical and transparent AI interactions.

3.3 State-of-the-art of critical thinking

For authors such as Black et al. (2008), Critical Thinking (CT) is the "analytical thinking that underlies all rational discourse and inquiry. It is characterised by a meticulous and rigorous approach" (p. 30). Most educational frameworks of the current century agree that critical thinking (CT), which involves the capacity to have a critical perspective on information, is an important competency. CT is a competency that has been a linchpin for improved problem-solving, intelligence, adaptability, and academic achievement, making it a vital skill for success in contemporary society. In today's information-rich world, the ability to discern truth from misinformation, differentiate personal opinions from substantiated facts, and effectively process extensive data has become essential. Contemporary educational paradigms recognise CT as a crucial competency. Nevertheless, there isn't a single, accepted definition of CT. According to authors like Black et al. (2008), CT can be defined as "analytical thinking that forms the basis of rational discourse and inquiry. It is characterised by a thorough and rigorous approach" (p. 30), emphasising the importance of a systematic method for enhancing CT comprehension. This skill has long held a prominent position in global education priorities, garnering significant attention from researchers, educators, employers, and policymakers. It serves as a foundation for enhancing problem-solving abilities, intelligence, adaptability, and academic performance, making it an indispensable skill for success in today's rapidly evolving society. In the information-saturated landscape of the present day, the capacity to differentiate between truth and misinformation, distinguish personal beliefs from well-supported facts, and efficiently process large amounts of data has become indispensable. According to Altun and Yildirim (2023), critical thinking is one of the competencies that are essential for both academic and professional success. It plays a critical role in rational thinking, decision-making, and problem solving, making it an essential skill for success in a variety of fields. Halpern (1998) also made similar arguments, defining CT as the outcome of individual thought processes that involve critical thinking to evaluate the effectiveness of decisions or problem-solving abilities.

The multidimensionality of CT and its application across various domains make its definition a challenging process. CT integrates various cognitive functions that are specific to different domains. Having developed CT in a certain domain does not guarantee that it will be applicable in other domains or have effective CT engagement (Facione, 2011). It encompasses a wide range of fields and skills, making it difficult to formulate a concise definition that all parties can agree upon. It is not sufficient to only have CT skills in a specific topic; one must also have the metacognitive ability to figure out which aspects to use when, as well as the mindset required for engaging in effective CT (Facione, 2011). The American Philosophical Association defines an optimal "critical thinker" as one who is curious, open-minded, receptive to new ideas, adaptable, impartial, and knowledgeable—qualities also linked to creativity (Facione, 1990; Lai, 2011). Altun and Ebru (2023) assert a close link between critical thinking and analytical thinking, asserting that critical thinking is an inherent part of any rational discourse or inquiry.

Creativity and CT, two transversal competencies included in the 4Cs, frequently come together to provide well-reasoned arguments. It is best to teach them concurrently because of their related and simultaneous development (Paul & Elder, 2006). Pasquinelli et al. (2021) consider CT as the capacity to assess information's epistemic quality.

Funded by
the European Union

The definition of CT of Pasquinelli et al. (2021) emphasises its capacity to assess the epistemic quality of data and then modify confidence levels for well-informed decision-making. This definition has the benefit of being well recognised and precise, which has immediate implications for assessment and instruction. It lays the groundwork for CT's ability to assess the veracity of information, which includes determining the strength of arguments and the authority of sources. Furthermore, CT is vital for identifying and mitigating cognitive biases, which can hinder rational thinking. While some cognitive biases are inherent to human thinking, the application of critical reasoning can help overcome them and improve logical decision-making.

Critical thinking highlights the capacity to grasp issues and suggest innovative and practical solutions (Yüce, 2023). The age-specific elements of CT are another important aspect of its development. While most higher education competencies include CT, studies also indicate that primary education children have the capacity to develop this skill. Young children can detect false information, and teenagers have the cognitive functions required to develop higher-order critical thinking skills. A model by Facione outlines six measurable CT skills: interpreting information, analysing information, making inferences, evaluating information's strength, providing explanations, and self-regulation (Facione, 1990, 2011). Studies suggest that although young children can distinguish between true and false information, late adolescence is usually when executive functions fully mature and become necessary for questioning biassed reasoning and other sophisticated critical thinking skills. According to Facione (1990), there was a unanimous agreement among experts regarding the following skills: (a) interpretation, (b) analysis, (c) evaluation, (d) inference, (e) explanation, and (f) self-regulation. These skills collectively form the foundation of effective critical thinking.

3.4 State-of-the-art of collaboration

Collaboration stands as a crucial competency, not only in contemporary times but throughout the entirety of human history. Anthropologists and evolutionary psychologists have consistently underscored the ability to collaborate as a pivotal factor in the development of our civilization, arguably in symbiosis with competitive processes (Bertness, 2020). Blomqvist and Levy (200, p. 39) describe collaboration competency as one's "ability to build and manage network relationships based on mutual trust, communication, and commitment". According to Salas et al. (2005), three coordinating mechanisms—mutual trust, closed-loop communication, and shared mental models—support effective teamwork.

Collaboration and communication competencies are considered in some studies to be complementary, with interaction being a key aspect of collaborating to achieve a common goal. The capacity of a collective of individuals to work together towards a goal and overcome the challenges during the process is considered "teamwork" (Williams et al., 2006). The OECD characterises collaborative problem-solving as the ability to interact with others by exchanging knowledge and skills, with the aim of merging ideas and generating a solution to a problem (OECD, 2017). Interaction is a key component of productive teamwork towards a common goal, and cooperation and communication skills are interdependent. "Teamwork" is the collective ability of individuals to collaborate and overcome obstacles in order to achieve a goal (Williams et al., 2006). According to the OECD (2017), collaborative problem-solving is defined as the ability to interact with others through the sharing of knowledge and skills, with the goal of combining concepts and devising a solution for an issue.

Marttunen and Laurinen (2009) identified six characteristics of conversational turns that indicate collaborative engagement in discussions: (a) achieving completion through collaboration; (b) communication between individuals; (c) argumentative actions; (d) questions frequently used to oversee and update the shared understanding among participants; (e) indications of collaboration between individuals are evident in the responses to questions; and (f) providing concise positive feedback during the discussion. The encouragement of behaviours that facilitate smooth communication among team members is fundamental to team success (Beaubien & Baker, 2004). To properly manage the collaborative process, group awareness is required (Chavez & Romero, 2012). Dourish and Bellotti (1992, p. 107) define group awareness (GA) as "an understanding of the activities of others, which provides a context for your own activity". Teams that encompass a variety of skills and abilities tend to yield more creative outcomes (Knowlton, 2003). Jaramillo-Vazquez (2019), Norris et al. (2023), and Pirola-Merlo and Mann (2004) reported similar findings.

3.5 State-of-the-art of communication

Essentially, communication is the exchange of information to influence others' perceptions. Its purpose in collaborative settings is to facilitate information sharing, which will help to achieve particular objectives (Bosse et al., 2010). Human communication is a complex process that includes both verbal and non-verbal elements. It frequently involves managing large volumes of data with a variety of goals and intentions. According to Henly (2016), communication is a reciprocal process that involves exchanging information through speech or other means. It includes elements such as avoiding interruptions, clarifying questions, attentive listening, and expressing understandings, thoughts, and information.

Communication plays a critical role within the 4C competencies spectrum. It involves more than just being adept at verbal and written expression or mastering a language (linguistic competences). It encompasses the discerning use of communication systems (pragmatic skills) and social competencies that are deeply grounded in an understanding of societal norms. Moreover, it encompasses the ability to connect with others, grasp their intentions, and appreciate diverse viewpoints, emphasising the paramount importance of communication in this comprehensive set of skills (Tomasello et al., 2005). According to O'Hagan et al. (2014), word choice, facial expression, attitude, and respectful communication encompass a dynamic interaction of appropriate and empathetic verbal and non-verbal signals.

Like the other 4Cs, communication skills are very important to educators and students. Experts also view them as a crucial element of workforce readiness for 2030. One of the biggest challenges facing educational institutions today is giving students the tools they need to communicate effectively and efficiently in the constantly changing world of information exchange (Morreale et al., 2017). Although school curricula cover all aspects of communication (linguistic, pragmatic, and social) at different levels, it is still uncommon to explicitly teach pragmatic and social competencies. The field of social and emotional intelligence research is progressing, with implications for the creation of evidence-based practices and their effect on students' success both personally and professionally (Humphrey et al., 2007; Keefer et al., 2018).

Educators are discovering that their roles are evolving. In addition to teaching traditional communication skills, their current responsibilities include assisting students in adjusting to and learning new information and communication technologies for efficient information transfer (Zlatić et al., 2014). The other 3Cs are equally dependent on communication. Particularly in educational and professional settings, effective communication fosters collaborative exchanges aimed at shared goals, usually based on a fair assessment of reality (Pornpitakpan, 2004). Trust among group members and high-quality knowledge sharing, intrinsically linked to communication, are essential for effective collaboration. Furthermore, communicating ideas to an audience is a common component of creativity, and in the context of a team, effective communication plays a critical role in fostering creative endeavours.

Funded by
the European Union

4 Conclusion

The augMENTOR project aims to support future-ready learners and to support the teachers through a creative pedagogy approach to the use of AI in education. Through the pilots, we aim to support the development of the 4Cs – creativity, critical thinking, collaboration, and communication – which serve as the cornerstone for success in the dynamic world of the 21st century. In order to support this objectives the D4.1 deliverable introduces the creative pedagogies within the augMENTOR project in relation to the WP3 pedagogical framework and provides the results of a literature review on the 4Cs that serves to support the pilot design and assessment strategy that will be introduced in the D4.2.

The augMENTOR project approach encompasses a creative pedagogy framework – creative teaching, teaching for creativity, and creative learning – following Lin (2011) and the creative uses of artificial intelligence in education (Septiani et al., 2023; Urmeneta & Romero, 2024). Within this approach, learners are empowered to explore their unique creative potential and hone their critical thinking skills through engaging activities and thought-provoking challenges proposed in each of the pilots. By weaving together creative teaching practices, design thinking principles, and a component oriented evaluation of the 4Cs, the D4.1 delivery introduces the 4Cs in relation to the augMENTOR pedagogical framework.

Funded by
the European Union

References

Altun, E., & Yildirim, N. (2023). What does critical thinking mean? Examination of pre-service teachers' cognitive structures and definitions for critical thinking. *Thinking Skills and Creativity*, *49*, 101367. https://doi.org/10.1016/j.tsc.2023.101367

Argyris, C., & Schon, D. A. (1974). *Theory in practice: Increasing professional effectiveness.* Jossey-Bass.

augMENTOR. (2023, January 1). *Augmented Intelligence for Pedagogically Sustained Training and Education (augMENTOR)*. https://cordis.europa.eu/project/id/101061509

Bajis, D., Chaar, B., & Moles, R. (2020). Rethinking Competence: A Nexus of Educational Models in the Context of Lifelong Learning. *Pharmacy*, *8*, 81. https://doi.org/10.3390/pharmacy8020081

Banaji, D. S., Cranmer, D. S., Perrotta, D. C., Ferrari, A., Cachia, R., & Punie, Y. (n.d.). *Expert Perspectives on Creativity and Innovation in European Schools and Teacher Training*.

Bertness, M. (2020). *A Brief Natural History of Civilization: Why a Balance Between Cooperation & Competition Is Vital to Humanity*. Yale University Press.

Biggs, J. (2003). Aligning teaching for constructing learning. *Higher Education Academy*, *1*(4).

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012a). Defining Twenty-First Century Skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 17–66). Springer Netherlands. https://doi.org/10.1007/978-94-007-2324-5_2

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012b). Defining Twenty-First Century Skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 17–66). Springer Netherlands. https://doi.org/10.1007/978-94-007-2324-5_2

Black, B., Chislett, J., & Thwaites, J. (2008). *Critical Thinking – a definition and taxonomy for Cambridge Assessment: Supporting validity arguments about Critical Thinking assessments administered by Cambridge Assessment.*

Borrowski, T. (2019). *The battelle for kids p21 framework for 21st century learning*. University of Illinois at Chicago.

Bosse, H. M., Nickel, M., Huwendiek, S., Jünger, J., Schultz, J. H., & Nikendei, C. (2010). Peer role-play and standardised patients in communication training: A comparative study on the student perspective on acceptability, realism, and perceived effect. *BMC Medical Education*, *10*(1), 27. https://doi.org/10.1186/1472-6920-10-27

Carmeli, A., & Tishler, A. (2006). The relative importance of the top management team's managerial skills. *International Journal of Manpower*, *27*. https://doi.org/10.1108/01437720610652817

Chavez, J., & Romero, M. (2012). Group Awareness, Learning, and Participation in Computer Supported Collaborative Learning (CSCL). *Procedia-Social and Behavioral Sciences*, *46*, 3068–3073.

Che Pee, N. (2011). *Computer games use in an educational system* [PhD Thesis, University of Nottingham]. http://eprints.nottingham.ac.uk/12297

Chen, H., & Chang, W. (2010). The essence of the competence concept: Adopting an organization's sustained competitive advantage viewpoint. *Journal of Management & Organization*, *16*, 677–699. https://doi.org/10.5172/jmo.2010.16.5.677

Chi, M. T. H., & Wylie, R. (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. *Educational Psychologist*, *49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823

Chiu, T. K. F. (2022). Applying the self-determination theory (SDT) to explain student engagement in online learning during the COVID-19 pandemic. *Journal of Research on Technology in Education*, *54*(sup1), S14–S30. https://doi.org/10.1080/15391523.2021.1891998

Chomsky, N., Roberts, I., & Watumull, J. (2023, March 8). *The False Promise of ChatGPT*. The New York Times. https://www.nytimes.com/2023/03/08/opinion/noam-chomsky-chatgpt-ai.html

Craft, A., Dugal, J., Dyer, G., Jeffrey, B., & Lyons, T. (1997). *Can you teach creativity?* (A. Craft, J. Dugal, G. Dyer, B. Jeffrey, & T. Lyons, Eds.). Education Now. https://oro.open.ac.uk/20308/

Cucinelli, G., Davidson, A.-L., Romero, M., & Matheson, T. (2018). Intergenerational Learning Through a Participatory Video Game Design Workshop. *Journal of Intergenerational Relationships*, *16*(1–2), 146–165.

De Bono, E. (2015). *Serious creativity: Using the power of lateral thinking to create new ideas*. Penguin Random House.

Dede, C. (2010). Comparing frameworks for 21st century skills. *21st Century Skills: Rethinking How Students Learn*, *20*, 51–76.

Dourish, P., & Bellotti, V. (1992). Awareness and coordination in shared workspaces. *Proceedings of the 1992 ACM Conference on Computer-Supported Cooperative Work - CSCW '92*, 107–114. https://doi.org/10.1145/143457.143468

Dreyfus, H. L., & Dreyfus, S. E. (2005). Peripheral Vision: Expertise in Real World Contexts. *Organization Studies*, *26*(5), 779–792. https://doi.org/10.1177/0170840605053102

Engestrom, Y. (2000). Activity theory as a framework for analyzing and redesigning work. *Ergonomics*, *43*(7), 960–974. https://doi.org/10.1080/001401300409143

Facione, P. A. (1990). *A STATEMENT OF EXPERT CONSENSUS FOR PURPOSES OF EDUCATIONAL ASSESSMENT AND INSTRUCTION*.

Facione, P. A. (2011). Critical Thinking: What It Is and Why It Counts. *Critical Thinking*.

Feng, S., & Law, N. (2021). Mapping Artificial Intelligence in Education Research: A Network-based Keyword Analysis. *International Journal of Artificial Intelligence in Education*, *31*(2), 277–303. https://doi.org/10.1007/s40593-021-00244-4

Florida, R. L. (2006). *The rise of the creative class: And how it's transforming work, leisure, community and everyday life* (Nachdr.). Basic Books.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring. *American Psychologist*, *53*(4), 449–455. https://doi.org/10.1037/0003-066X.53.4.449

Hayton, J. C., & Kelley, D. J. (2006). A competency-based framework for promoting corporate entrepreneurship. *Human Resource Management*, *45*(3), 407–427. https://doi.org/10.1002/hrm.20118

Henly, S. J. (2016). Health Communication Research for Nursing Science and Practice. *Nursing Research*, *65*(4), 257–258. https://doi.org/10.1097/NNR.0000000000000171

Humphrey, N., Curran, A., Morris, E., Farrell, P., & Woods, K. (2007). Emotional Intelligence and Education: A critical review. *Educational Psychology*, *27*(2), 235–254.

https://doi.org/10.1080/01443410601066735

Hutchins, N. M., Biswas, G., Zhang, N., Snyder, C., Lédeczi, Á., & Maróti, M. (2020). Domain-Specific Modeling Languages in Computer-Based Learning Environments: A Systematic Approach to Support Science Learning through Computational Modeling. *International Journal of Artificial Intelligence in Education*, *30*(4), 537–580. https://doi.org/10.1007/s40593-020-00209-z

Isaac, G., Romero, M., & Barma, S. (2022). Understanding co-creativity in real-world problem solving in project-based learning in higher education. *Revue Internationale Du CRIRES : Innover Dans La Tradition de Vygotsky / CRI_SAS International Journal: Vygotsky's Heritage: Innovation in Education*, *6*(3), 86–99. https://doi.org/10.51657/ric.v6i2.51585

Jaramillo-Vazquez, A. (2019). Creativity as collaboration: Personal ideas, experiences and solidarity in an arts organisation in Mexico City. *Journal of Organizational Ethnography*, *8*(2), 130–145. https://doi.org/10.1108/JOE-10-2017-0048

Käser, T., & Schwartz, D. L. (2020). Modeling and Analyzing Inquiry Strategies in Open-Ended Learning Environments. *International Journal of Artificial Intelligence in Education*, *30*(3), 504–535. https://doi.org/10.1007/s40593-020-00199-y

Keefer, K. V., Parker, J. D. A., & Saklofske, D. H. (2018). Three Decades of Emotional Intelligence Research: Perennial Issues, Emerging Trends, and Lessons Learned in Education: Introduction to Emotional Intelligence in Education. In K. V. Keefer, J. D. A. Parker, & D. H. Saklofske (Eds.), *Emotional Intelligence in Education: Integrating Research with Practice* (pp. 1–19). Springer International Publishing. https://doi.org/10.1007/978-3-319-90633-1_1

Lai, E. R. (2011). Critical thinking: A literature review. *CRITICAL THINKING*.

Lajoie, S. P. (2021). Student Modeling for Individuals and Groups: The BioWorld and HOWARD Platforms. *International Journal of Artificial Intelligence in Education*, *31*(3), 460–475. https://doi.org/10.1007/s40593-020-00219-x

Lawson, A. P., Mayer, R. E., Adamo-Villani, N., Benes, B., Lei, X., & Cheng, J. (2021). Do Learners Recognize and Relate to the Emotions Displayed By Virtual Instructors? *International Journal of Artificial Intelligence in Education*, *31*(1), 134–153. https://doi.org/10.1007/s40593-021-00238-2

Lin, Y.-S. (2011). Fostering creativity through education–a conceptual framework of creative pedagogy. *Creative Education*, *2*(03), 149.

Lucas, B., & Anderson, M. (2015). *Creative Learning in Schools: What it is and why it matters A Rapid Evidence Scan*.

Lukyanenko, R., & Parsons, J. (2015). *Extending Participatory Design Principles to Structured User-generated Content*. Scandinavian Conference on Information Systems, Oulu, Finland.

Marttunen, M. J., & Laurinen, L. I. (2009). Secondary school students' collaboration during dyadic debates face-to-face and through computer chat. *Computers in Human Behavior*, *25*(4), 961–969. https://doi.org/10.1016/j.chb.2009.04.005

Miller, G. E. (1990). The assessment of clinical skills/competence/performance. *Academic Medicine*, *65*(9), S63-7. https://journals.lww.com/academicmedicine/Abstract/1990/09000/The_assessment_of_clinical.45.asp

Morreale, S. P., Valenzano, J. M., & Bauer, J. A. (2017). Why communication education is important: A third study on the centrality of the discipline's content and pedagogy. *Communication Education*, *66*(4), 402–422. https://doi.org/10.1080/03634523.2016.1265136

Moruzzi, C. (2021). Measuring creativity: An account of natural and artificial creativity. *European Journal for Philosophy of Science*, *11*(1), 1. https://doi.org/10.1007/s13194-020-00313-w

Norris, C. M., Taylor, T. A., & Lummis, G. W. (2023). Fostering collaboration and creative thinking through extra-curricular challenges with primary and secondary students. *Thinking Skills and Creativity*, *48*, 101296. https://doi.org/10.1016/j.tsc.2023.101296

OECD. (2017). *PISA 2015 Results (Volume V): Collaborative Problem Solving*. OECD. https://doi.org/10.1787/9789264285521-en

OECD. (2018). *Education at a Glance 2018: OECD Indicators*. Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/fr/education/education-at-a-glance-2018_eag-2018-en

O'Hagan, S., Manias, E., Elder, C., Pill, J., Woodward-Kron, R., McNamara, T., Webb, G., & McColl, G. (2014). What counts as effective communication in nursing? Evidence from nurse educators' and clinicians' feedback on nurse interactions with simulated patients. *Journal of Advanced Nursing*, *70*(6), 1344–1355. https://doi.org/10.1111/jan.12296

Pasquinelli, E., Farina, M., Bedel, A., & Casati, R. (2021). Naturalizing Critical Thinking:

Consequences for Education, Blueprint for Future Research in Cognitive Science. *Mind, Brain, and Education*, *15*(2), 168–176. https://doi.org/10.1111/mbe.12286

Paul, R., & Elder, L. (2006). *Critical Thinking Competency Standards*.

Pirola-Merlo, A., & Mann, L. (2004). The relationship between individual creativity and team creativity: Aggregating across people and time. *Journal of Organizational Behavior*, *25*(2), 235–257. https://doi.org/10.1002/job.240

Pornpitakpan, C. (2004). The Persuasiveness of Source Credibility: A Critical Review of Five Decades' Evidence. *Journal of Applied Social Psychology*, *34*(2), 243–281. https://doi.org/10.1111/j.1559-1816.2004.tb02547.x

Redeker, C., Leis, M., Leendertse, M., Punie, Y., Gijsbers, G., Kirschner, P. A., Stoyanov, S., & Hoogveld, B. (2012). *The future of learning: Preparing for change*. Publications Office of the European Union. https://doi.org/10.2791/64117

Robinson, K. A., Saldanha, I. J., & Mckoy, N. A. (2011). Development of a framework to identify research gaps from systematic reviews. *Journal of Clinical Epidemiology*, *64*(12), 1325–1330. https://doi.org/10.1016/j.jclinepi.2011.06.009

Romero, M. (2018). Développer la pensée informatique pour démystier l'intelligence artificielle. *1024 – Bulletin de La Société Informatique de France*, *12*, 67–75.

Romero, M., & Barma, S. (2022). Analysing an Interactive Problem-Solving Task Through the Lens of Double Stimulation. *Canadian Journal of Learning and Technology*, *48*(1), Article 1. https://doi.org/10.21432/cjlt28170

Romero, M., Duguay, S., Guillaume, I., Sylvie, B., Caroline, D., Laurent, H., & Vivien, L. (2023). Creative engagement in #AIed: From the passive AI content consumer to expansive learning supported by AI (#PPai6). *Creative Uses of Technology*. https://margaridaromero.blog/2023/04/28/expansive-learning-supported-by-ai/

Romero, M., Laferriere, T., & Power, T. M. (2016). The Move is On! From the Passive Multimedia Learner to the Engaged Co-creator. *eLearn*, *2016*(3), 1. https://doi.org/10.1145/2904374.2893358

Romero, M., Lille, B., & Patino, A. (Eds.). (2017). *Usages créatifs du numérique pour l'apprentissage au XXIe siècle* (Vol. 1). Presses de l'Université du Québec.

Romero, M., Usart, M., & Ott, M. (2015). Can Serious Games Contribute to Developing and

Sustaining 21st-Century Skills? *Games and Culture: A Journal of Interactive Media*, *10*(2), 148–177.

Romero, M., Frosig, T., Taylor-Beswick, A. M., Laru, J., Bernasco, B., Urmeneta, A., ... & Girard, M. A. (2024). Manifesto in Defence of Human-Centred Education in the Age of Artificial Intelligence. In *Creative Applications of Artificial Intelligence in Education* (pp. 157-178). Cham: Springer Nature Switzerland.

Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a "Big Five" in Teamwork? *Small Group Research*, *36*(5), 555–599. https://doi.org/10.1177/1046496405277134

Schmidberger, I., & Wippermann, S. (2023). Innovation in Education by Design Thinking (p.

1178). https://doi.org/10.4995/HEAd23.2023.16097

Sefton-Green, J. (Ed.). (2008). *Creative learning*. Arts Council Engand.

Shute, V. J., Smith, G., Kuba, R., Dai, C.-P., Rahimi, S., Liu, Z., & Almond, R. (2021). The Design, Development, and Testing of Learning Supports for the Physics Playground Game. *International Journal of Artificial Intelligence in Education*, *31*(3), 357–379. https://doi.org/10.1007/s40593-020-00196-1

Spady, W. G. (1977). Competency Based Education: A Bandwagon in Search of a Definition. *Educational Researcher*, *6*(1), 9–14. https://doi.org/10.3102/0013189X006001009

Sternberg, R. J., & Frensch, P. A. (2014). *Complex problem solving: Principles and mechanisms*. Psychology Press.

Sue, D. W., Arredondo, P., & McDAVIS, R. J. (1992). Multicultural Counseling Competencies and Standards: A Call to the Profession. *Journal of Counseling & Development*, *70*(4), 477–486. https://doi.org/10.1002/j.1556-6676.1992.tb01642.x

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, *28*(5), 675–691. https://doi.org/10.1017/S0140525X05000129

Tricot, A. (2017). *L'innovation pédagogique: Mythes et réalités*. http://www.cafepedagogique.net/LEXPRESSO/Pages/2017/09/05092017Article636401937485284884.aspx

Tsai, Y.-C. (2023). *Empowering Learner-Centered Instruction: Integrating ChatGPT Python API and Tinker Learning for Enhanced Creativity and Problem-Solving Skills*.

VanLehn, K., Banerjee, C., Milner, F., & Wetzel, J. (2020). Teaching Algebraic Model Construction: A Tutoring System, Lessons Learned and an Evaluation. *International Journal of Artificial Intelligence in Education*, *30*(3), 459–480. https://doi.org/10.1007/s40593-020-00205-3

Varma, S. (2011). Criteria for the Design and Evaluation of Cognitive Architectures. *Cognitive Science*, *35*(7), 1329–1351. https://doi.org/10.1111/j.1551-6709.2011.01190.x

Voorhees, R. A. (2001). Competency-Based Learning Models: A Necessary Future. *New Directions for Institutional Research*, *2001*(110), 5–13. https://doi.org/10.1002/ir.7

Westera, W. (2001). Competences in education: A confusion of tongues. *Journal of Curriculum Studies*, *33*(1), 75–88. https://doi.org/10.1080/00220270120625

Williams, E. A., Duray, R., & Reddy, V. (2006). Teamwork Orientation, Group Cohesiveness, and Student Learning: A Study of the Use of Teams in Online Distance Education. *Journal of Management Education*, *30*(4), 592–616. https://doi.org/10.1177/1052562905276740

Wilson, J., Huang, Y., Palermo, C., Beard, G., & MacArthur, C. A. (2021). Automated Feedback and Automated Scoring in the Elementary Grades: Usage, Attitudes, and Associations with Writing Outcomes in a Districtwide Implementation of MI Write. *International Journal of Artificial Intelligence in Education*, *31*(2), 234–276. https://doi.org/10.1007/s40593-020-00236-w

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35.

Yannier, N., Hudson, S. E., & Koedinger, K. R. (2020). Active Learning is About More Than Hands-On: A Mixed-Reality AI System to Support STEM Education. *International Journal of Artificial Intelligence in Education*, *30*(1), 74–96. https://doi.org/10.1007/s40593-020-00194-3

Yüce, E. (2023). Critical thinking, autonomous learning, and academic grit among preservice EFL teachers. *Thinking Skills and Creativity*, *50*, 101382. https://doi.org/10.1016/j.tsc.2023.101382

Zapata-Rivera, D. (2021). Open Student Modeling Research and its Connections to Educational Assessment. *International Journal of Artificial Intelligence in Education*, *31*(3), 380–396. https://doi.org/10.1007/s40593-020-00206-2

Zhang, J., Scardamalia, M., Lamon, M., Messina, R., & Reeve, R. (2007). Socio-cognitive dynamics of knowledge building in the work of 9-and 10-year-olds. *Educational Technology Research and Development*, *55*(2), 117–145.

Zlatić, L., Bjekić, D., Marinković, S., & Bojović, M. (2014). Development of Teacher Communication Competence. *Procedia - Social and Behavioral Sciences*, *116*, 606–610. https://doi.org/10.1016/j.sbspro.2014.01.265

Funded by
the European Union

Annex 1 - Competencies

For Westera (2001), « competence is no more than a descriptive term that could easily be substituted with other terms like conditions for successful performance » (p. 7). Education has traditionally been focused on knowledge transmission in formal educational settings. In the final decades of the 20th century, a learner-centred approach to education enabled competency-based education (Spady, 1977). In this approach, the emphasis is not on the curriculum and domain-specific knowledge but on a learner-centred and outcome-based approach. Sue et al., (1992) characterise competence as a set of knowledge (K), beliefs and attitudes (A), and skills (S). In the context of digital games, (Che Pee, 2011) considers competence as a "combination of knowledge, skills, and behaviour leading to an individual being able to perform a certain task at a given level" (p. 22). Accordingly, skill is the part of competence related to the ability to behave effectively and engage certain attitudes and knowledge in action-oriented situations. Carmeli and Thistle (2006) define skills as the « ability to do something in an effective manner » (p. 13). The characterization of the core or key skills in each educational system and society is one of the main challenges for educational policymakers. The knowledge society requires a new set of skills to cope with the knowledge-based economy and uncertain worldwide changes. This has led to the definition of the so-called 21st century skills and their respective frameworks of reference (Binkley et al., 2012a; Dede, 2010; Redeker et al., 2012; Romero et al., 2015). In augMENTOR, we focus on the 4Cs: creativity, critical thinking, collaboration and communication.

Westera (2001) challenges the idea of skills as part of competences and proposes to restrict competence to « a class of cognitive sub skills that are involved in coping with complex problems » (p. 12).

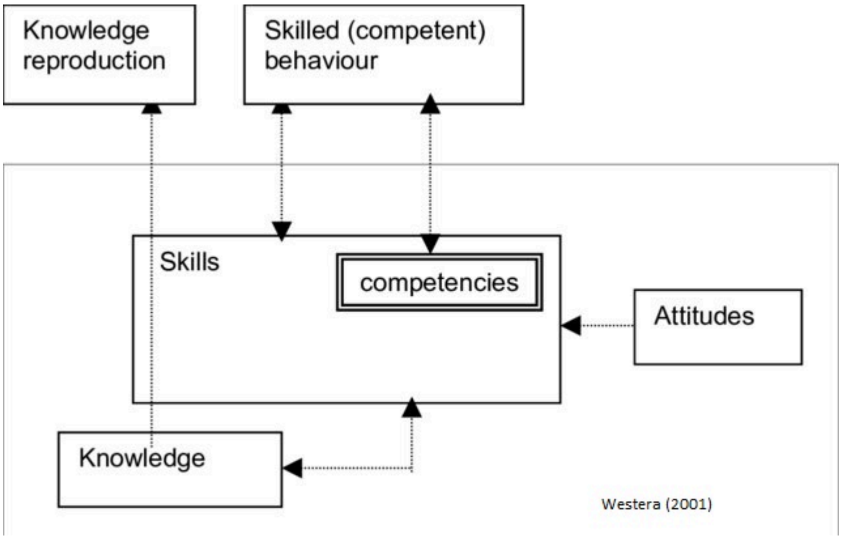

Figure 1. *Competences as subskills (Westera, 2001)*

Competence and competencies are dynamic!

Competence (what you do) and thus competency (how well you do it) can be understood as an interactive 'process' between a person and a specific (dynamic) activity system (Hayton & Kelley, 2006). The dynamic and systemic nature of human activity systems may aid in understanding the "*chicken-and-egg paradox*" in skill/competency hierarchy. It is not the sequential or hierarchical relationship of the elements that is important in dynamic systems, but the systemic constraints in the enactment of all the different (meta)cognitive processes, (prior or in-task) knowledge, affordances, and socio-cultural settings that are entangled in the activity system.

In order to better support a competency-based education, we need to develop integrative learning experiences or real-world problem-solving activities while skills can be potentially developed in the learning process, as represented in the figure below.

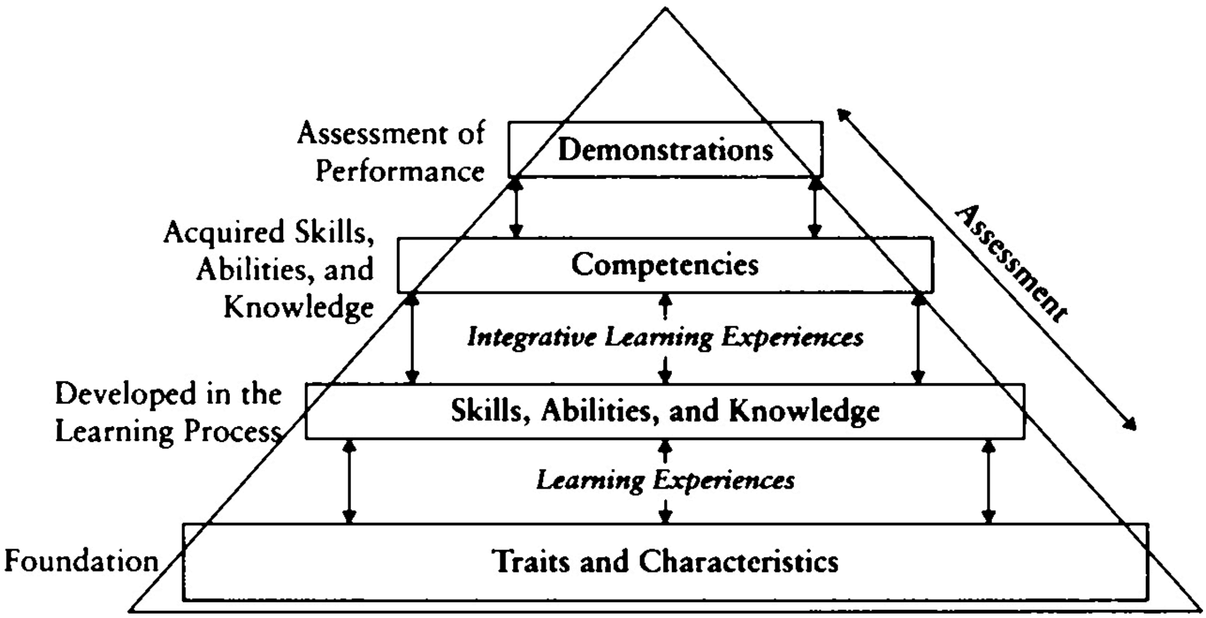

Figure 2. *U.S. Department of Education Competency Model Source: U.S. Department of Education (2002); (Voorhees, 2001).*

In workplace competence studies, Cheng and Chang (2010) also distinguish the visible and hidden aspects of the competencies at the individual and organisational level.

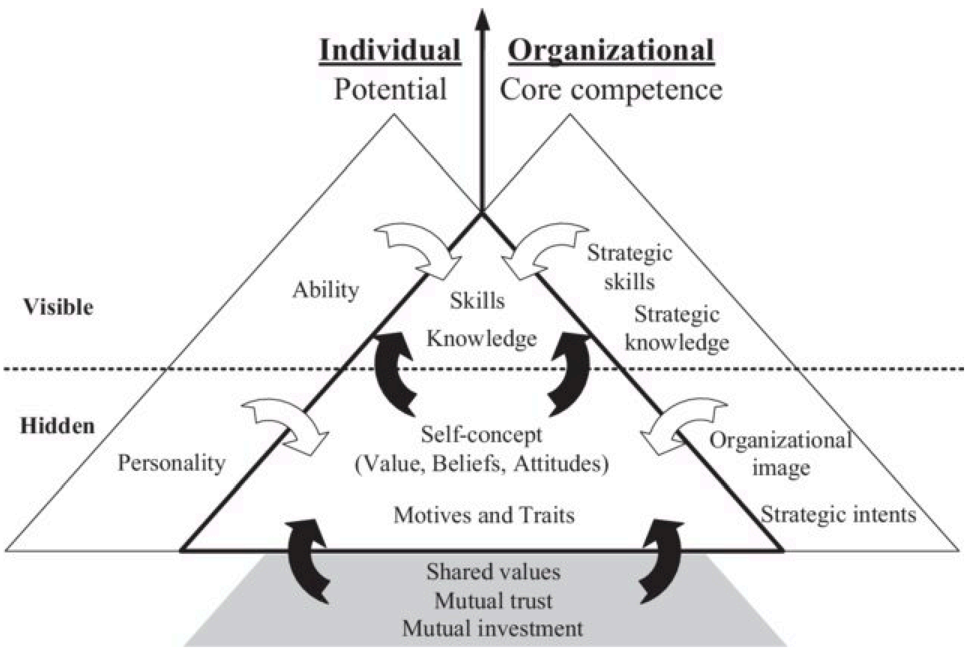

Figure 3. *Competence framework by (Chen & Chang, 2010)*

There are different levels of competencies. Following (Bajis et al., 2020), we can distinguish four levels as represented in figure 4.

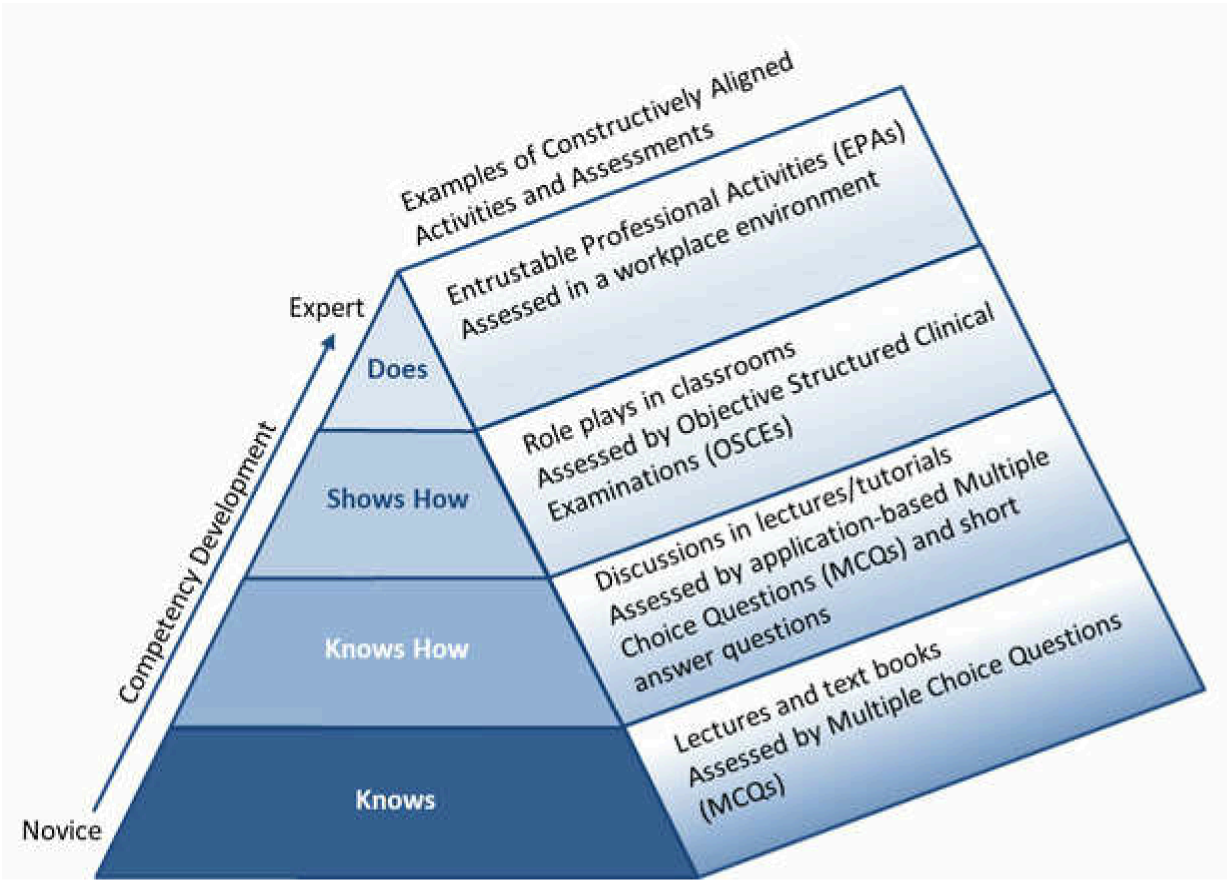

Figure 4. *Constructively alighted tent of competency assessment by (Bajis et al., 2020)*

The model of (Bajis et al., 2020) is adapted from Miller's prism of clinical competence(Miller, 1990) , Biggs' constructive alignment (Biggs, 2003), and Dreyfus & Dreyfus' development of expertise model (Dreyfus & Dreyfus, 2005).

21st-century skills

Binkley et al. (2012) define 21st-century skills as encompassing the ability to think, work, and live in interconnected, media-rich environments. Their perspective emphasises the dynamic nature of these skills, aligning them with a rapidly changing world. Redeker et al. (2012) took a holistic approach by categorising 21st-century skills into three general domains. Firstly, there are personal skills, which include attributes like initiative, resilience, responsibility, risk-taking, and creativity. Secondly, social skills involve team collaboration, networking, empathy, compassion, and co-construction of knowledge. Lastly, learning skills encompass competencies in managing, organising, metacognition, and the ability to learn from failures. This classification highlights the importance of both individual and interpersonal skills in the 21st century. From an information and communication technology (ICT) perspective, Dede (2010) underscores the need for new abilities. These include "information problem-solving," which involves the capacity to swiftly filter vast volumes of data, extracting valuable information for informed decision-making. Additionally, it involves the skill to distinguish meaningful signals from the noise in an overwhelming influx of data.

The concept of 21st century skills encompasses a broad set of abilities that individuals need to thrive in the current society. It goes beyond traditional academic knowledge and emphasises the development of skills related to critical thinking, adaptability, digital literacy, creativity, collaboration, and effective communication. These skills are essential in navigating the complexities of our interconnected, information-rich, and rapidly evolving world. Therefore, the term 21st century skills represents a popular term that will be sometimes used in the end-user documents of the Horizon augMENTOR project while the term "transversal competency" will be privileged in the research outcomes. The analysis of Romero et al. (2015) have reviewed the different 21st century frameworks leading to the identification of the main skills or competencies identified in the different frameworks.

Table 1. *Skills identified in the different 21st century frameworks (Romero et al., 2015)*

Mentioned in all frameworks	Mentioned in most frameworks	Mentioned in a few frameworks	Mentioned only in one framework
• Communication • Collaboration • ICT literacy • Social and/or cultural skills	• Creativity • Critical thinking • Problem solving • Develop quality products/ productivity	• Learning to learn • Self-direction Planning • Flexibility, and adaptability	• Risk taking • Manage and solve conflicts • Sense of initiative and entrepreneurship

Funded by the European Union

Figure 5. *#5c21 competency framework*

More recent competency frameworks, such as the #5c21 has also integrated computational thinking (Wing, 2006) as a key competency for overcoming the consumer perspective of AI and permit the learners to become citizens able to solve problems with the use of digital technologies. For the Horizon augMENTOR project we do not integrate computational thinking directly, but we encompass it in certain activities that will be evaluated through creativity competency. In the Horizon augMENTOR project, we selected to stick to the "Four Cs" - Collaboration, Communication, Critical Thinking, and Creativity- as a common denominator agreed with all the partners of the project in the moment of designing the proposal and during all the project advancement towards the integration, support and assessment of these four Cs competencies.

Funded by
the European Union

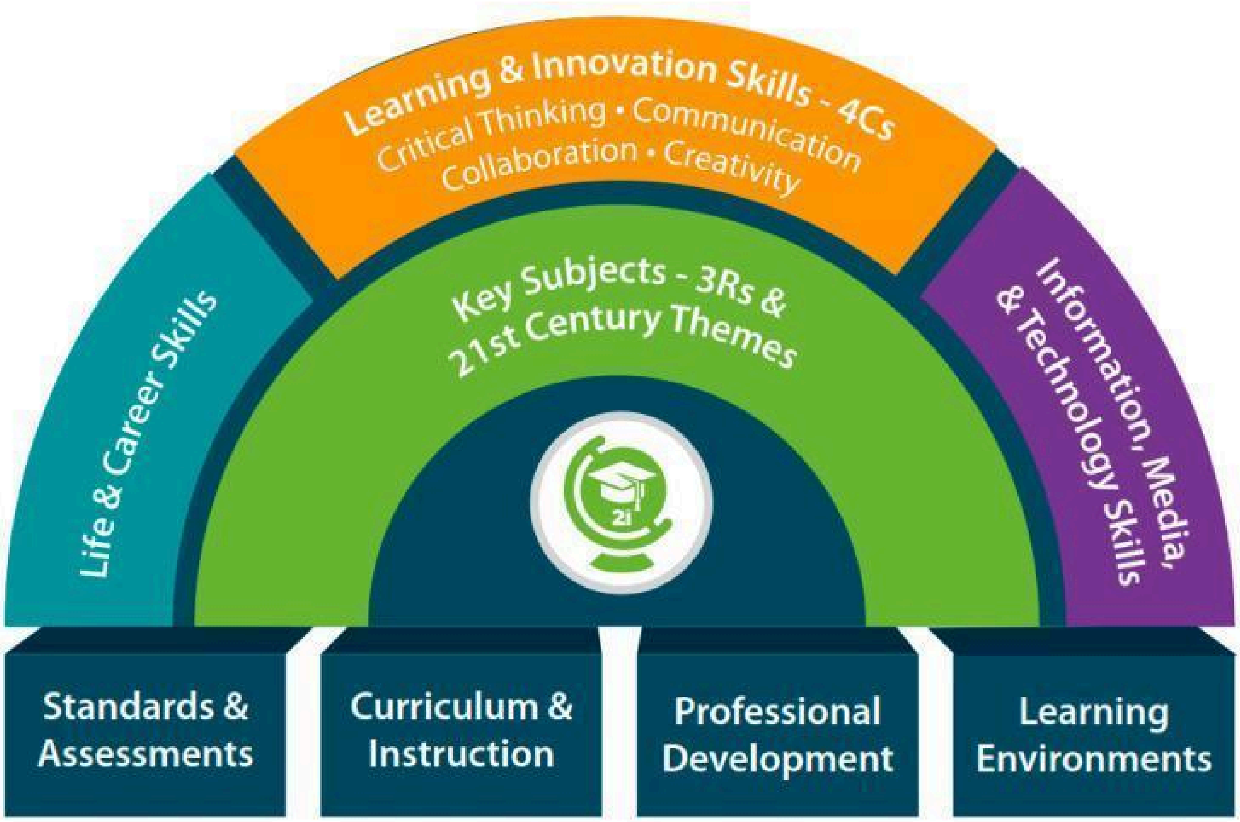

Figure 6. *The P21 Framework for 21st Century Learning (Borrowski, 2019)*

Annex 2 - Creative engagement in AIED

Creativity as one of the 21st-century skills to be supported in AI-human learning activities

Creativity is now widely acknowledged as a crucial skill that distinguishes human labour from that performed by robots in an environment where automatization and artificial intelligence are having an increasing effect (De Bono, 2015; Florida, 2006; Sternberg & Frensch, 2014). According to (Florida, 2006), creativity is a factor in the social division of modern societies into "creative classes," who establish professions where creativity is a decisive element in their sophisticated problem-solving activities, and "creative workers," and those who do not. In post-industrial knowledge societies, different types of jobs increasingly depend on the “creative class”, and those who work in it "engage in complex problem-solving that involves a great deal of independent judgement and requires high levels of education or human capital" (p. 8). For this reason, supporting creative processes is essential in 21st-century education. AI tools should be part of the efforts to support human creativity development, not only at the school, but also in creative professions. Teachers are among the professionals who face challenges related to the need to support learners' 21st-century competencies as well as a better understanding of how AI technologies operate and can support the teaching and learning process. The emergence of generative AI tools such as ChatGPT has raised awareness among educators about the need to better understand AI and how to regulate or integrate their use for educational purposes.

Creativity is one of the six key transversal competencies for the 21st century education #5c21 model (Romero et al., 2017), in which critical thinking is the ability to develop independent, critical thought in order to analyse ideas, knowledge, and processes based on a human-based value system and judgement. While creativity can be considered either human or "artificial creativity" when an AI system develops useful, novel, and original ideas or artefacts (Moruzzi, 2021); critical thinking can only be performed by humans because this competency relies on human criteria and takes into account factors such as the cultural context and interpersonal relationships in a certain socio-cultural context (Romero, 2018). In the Horizon augMENTOR project (augMENTOR, 2023), we aim to support learners’ creativity by developing a pedagogical framework, permitting the use of LMS AI tools, to support learners and teachers in their creative processes.

Funded by
the European Union

The limits of AI tools for supporting cognitive architecture to support creativity

While creativity can manifest as either human or "artificial creativity" when an AI system generates useful, novel, and original ideas or artefacts, critical thinking is inherently human. It depends on human criteria and factors such as cultural context and interpersonal relationships within a specific socio-cultural environment. Human cognitive architecture allows for the incorporation of cultural context and interpersonal relationships within a specific socio-cultural environment.

Presently, large language models (LLMs) like OpenAI's ChatGPT are incapable of engaging in critical thinking and human-like creativity because they do not possess a cognitive architecture capable of self-reflection and metacognitive judgments. In short, as Chomsky explains (Chomsky, N. et al., 2023). Cognitive architectures are based on different theories of cognition that are developed as a form of computational formalisms (Varma, 2011). These cognitive architectures have been considered as one of the elements to support the development of artificial intelligence through trying to implement some of the characteristics of human cognitive architectures. AI models like ChatGPT struggle to strike a balance between creativity and constraint, leading to excessive or minimal output with ethical ambiguity and linguistic inaccuracies, making their widespread acceptance a matter of amusement and desolation. The lack of a cognitive framework and the misalignment with human objectives, preferences, and ethical principles have motivated some GPT3 developers to consider the ethical considerations to align with human objectives (Oster & Mishra, 2023). A significant hurdle in the future advancement of conversational AI is establishing a cognitive architecture that could also support improved critical thinking. To address these limitations, OpenAI has also opted to develop a short memory (e.g., GPT4), which better supports the integration of socio-cultural prompts and creates results that are perceived by the end-user as more creative than prior releases.

Despite their shortcomings, conversational AI models such as ChatGPT are becoming crucial enablers for Learner-Centred Instruction (LCI) and Tinker Learning. In a recent study of Tsai (2023), forty-one students were given several assignments and a final project to complete, each designed to develop their skills in different areas. ChatGPT was used as a tool to enhance these assignments to analyse and understand datasets, generate insights and recommendations, create natural language descriptions of solutions, and analyse large amounts of text data. The feedback collected from the survey results suggests that the teaching methods utilised in the course were positively received by the majority of the participating students.

Creative engagement: learners' and teachers' perspective

Learners' engagement is a requirement for correctly developing the learning activities designed by the teachers. Engagement is defined as the learners' "involvement in learning activities in terms of attention, participation, effort, intensity, or persistence" (Chiu, 2022, p. S16). Creative engagement is a form of engagement that is not only cognitive but also in which the learner is a creative agent, producing (or making) generative acts or artefacts. Creative engagement as a teacher relies on generating new learning activities, while the learners' creative engagement is related to the acts of artefacts developed by the learners.

For example, the English-ABLE system (Zapata-Rivera, 2021) has the main pedagogical objective of supporting the learners' engagement with three artificial agents based on the Open Students Model (OSM) which are designed to engage the learners' in a teaching process of the OSM. Through the learners' engagement with the OSM agents, they are expected to develop their English as a Second Language (ESL) competencies. The agents have been designed in a way to engage in different objectives, such as grammar feedback. We can consider the learners' engagement in the English-ABLE system as creative because they are producing novel, useful, and original interactions with artificial agents. They are not only selecting pre-established answers (non-creative engagement), but they are also creatively engaged in the interaction with these three artificial agents. For supporting these creative engagements, the system is based on an "adaptive sequencing of activities and adaptive feedback mechanisms" (Zapata-Rivera, 2021, p. 382). So, it's important to model the learner, the activities, and the feedback system while keeping in mind the learner's creative process for this particular task. The external regulation of the teachers can increase learners' creative engagement. In the context of the English-ABLE solution, dynamic recommendations that enable teachers to make decisions about how to support the learners' process, also support the teachers' creative engagement in the supervision process.

#PPai6 levels of creative engagement in AI for education

Technology alone is not sufficient for driving innovation or improvement in education (Romero et al., 2016; Tricot, 2017). The learning activities are complex systems in which technological and cultural artefacts mediate individual and collective activity oriented towards a certain goal and are constrained by the socio-cultural and situational elements within which the learning activity is developed (Romero & Barma, 2022). An important consequence of considering learning activities as an intertwined system in which there is an emergent use of technologies based on the learners' motivations, the task constraints, and the situational aspects of the activity, is that the same technology could be used in a very diverse way. For example, the Teachable Machine[2] for creating machine learning models can be used in a lecture in which the teacher shows an example of its use to a group of learners who are not engaged in the activity. In this context, the learners are "passive consumers" of the lecture on Teachable Machine. But the teacher can also engage the learners in a group-based activity in which the children will create a model for improving the recycling system of their neighbourhood in collaboration with the shop owners around the school. In this participatory solution co-creation, Teachable Machine could be used as a tool to integrate when tinkering with a solution that is possible to develop, thanks to the participatory creative process engaged by the community participating in this objective. Teachable Machine is only a tool with the potential to support the creative engagement process, depending on the pedagogical scenario of the teaching activity proposed by the teacher.

From passive consumption to participatory content co-creation

In the next figure, six levels of creative engagement with AI tools in education are identified, which are on a continuum from simple to complex, and reflect the degree of creative engagement a learner can experience as a socio-cognitive process:

- *Level 1: Passive consumer.* The learner just consults AI-generated content with no creative engagement on their side.
- *Level 2: Interaction*. The learner interacts with an AI system that adapts the feedback and activity progression based on the learners' and task models. In this second level,

[2] https://teachablemachine.withgoogle.com/

the AI system adapts to the learner, but the learner isn't doing anything creative; they're just moving forward based on how the system is set up.

- *Level 3: Individual content creation*. The learner can use creativity to put forth various suggestions for solutions or ideas that the AI system has not already predetermined.
- *Level 4: Collaborative content creation*. A dyad or small group of learners are engaged in a joint creative activity to propose different ideas or solutions which are not pre-determined by the AI system. E.g. A group of learners can engage in creating a poster to raise awareness about food waste in their school and do a joint brainstorming with ChatGPT before engaging in the final design of their poster.
- *Level 5: Participatory knowledge co-creation*. A group of learners, in collaboration with other participants outside their learning group, engage in a creative participatory activity engaged in a complex problem-solving situation.
- *Level 6. Expansive learning supported by AI*. In formative interventions supported by AI, participants' agency may expand or transform problematic situations. AI tools can be used to help identify contradictions in complex problems and help generate concepts or artefacts to regulate conflicting stimuli and foster collective agency and action. AI tools can be used to assist in the modelling of activity systems as well as in the simulation of new actions, facilitating the expansive visualisation process (Romero et al., 2023). Formative interventions A formative intervention approach grounded in activity theory stands out for three key reasons: (1) Learners take the lead in designing formative interventions. (2) The collaborative design process is considered an integral part of a broader learning experience, involving participatory stages. (3) Formative interventions target creative solutions that evolve over relatively extended periods in the activities (Clarke-Midura & Dede, 2009) Fishman & al., 2004.

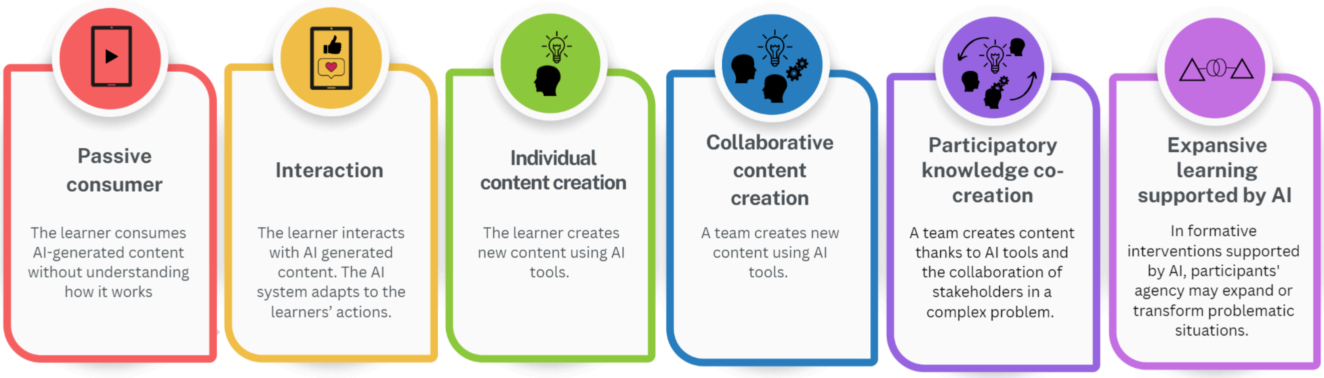

Figure 1. *Six levels of creative engagement in AI in education (#PPai6)*

The third level of the #PPai6 is similar to the highest level of the Blooms' taxonomy (creating). Nevertheless, the other levels of Blooms' taxonomy are not applicable to the #PPai6 model because we do not assume that the passive consumption of AI content or the interaction with AI tools ensures the cognitive processes defined in Blooms' taxonomy (remembering, understanding, applying, analysing, evaluating). The first level of the #PPai6 is similar to the "passive" level of Chi and Wylie's ICAP framework (Chi & Wylie, 2014). The biggest difference between our model and the ICAP is the consideration of interactivity. While "interactive mode of engagement" is the highest level of cognitive engagement within the ICAP framework, our model considers "participatory knowledge co-creation" and "expansive learning" as the most transformative AI-learner situations. Participatory knowledge co-creation engages the participants not only in an interactive and socio-constructive situation, but also engages learners in the identification, understanding, and problem-solving processes of a problematic situation within their learning or neighbourhood community, linking the team-based co-creation process with a participatory process wherein a team of learners engages in their learning community in order to improve a real-world problem or value community initiatives (Isaac et al., 2022; Lukyanenko & Parsons, 2015).

The first two levels do not engage the learners' in a creative activity. In the first level, the learners use what is made available to them without any interaction. In the second level, learners interact with an AI system that responds to their actions based on a model of the learning task and a model of the learner that is built into the AI system. The AI tool has a predefined set of options that lead to interactions governed by a "programmed instruction" approach, harking back to Pressey's teaching machine. ITS are the most common AI tools at this second level of creative engagement.

The third level of creative engagement with AI tools in education is to get the learner to make texts, photos, or videos that are related to a certain learning moment or situation. Whereas the fourth and fifth levels of creative engagement with AI tools engage learners in a co-creation process that supports the knowledge construction process (Zhang et al., 2007). The fifth level gets students involved in finding a problem in their learning or community, understanding it, and coming up with a solution. In this fifth level, the co-creation participatory process is oriented toward the community as well as real-life problem-solving (Isaac et al., 2022). Participatory and community-oriented (or based) knowledge co-creation values local community initiatives, promotes diversity, and regenerates intergenerational and intercultural links that are often missed in our current societies (Cucinelli et al., 2018).

Funded by
the European Union

Annex 3 - Literature review on creative engagement in AI in education

For the analysis of the six levels of creative engagement in AI in education (2023), we reviewed the International Journal of Artificial Intelligence in Education (AIED) within the last three years. We selected all the papers integrating an empirical study focusing on the teacher, the learner or both. The criteria are the six levels of the #PPAI6 model. Based on these criteria, two researchers analysed 41 papers in order to identify the different levels of creative engagement, considering not only the learners' and teachers' perspectives on creative engagement but also the domain of application and the educational level of the study.

For papers integrating more than one AI solution, we evaluate them separately. For example, HOWARD and BioWorld AI-tools in the paper of Lajoie (Lajoie, 2021), we integrated two records in the analysis of creative engagement levels in order to report the specificities of these different AI solutions that were studied.

Studies in which both learner and teacher activity are supported are also integrated as two separate entries in order to consider the level of creative engagement from each of these perspectives.

Results

Levels of creative engagement

The assessment of the six levels of creative engagement across the 41 selected studies has revealed that the majority of creative engagement focuses on the learner perspective (n=32), with only six instances of AI tools supporting teachers' creative engagement (Fig. 3). In three studies, BioWorld & HOWARD Platform (Lajoie, 2021), MiWRITE (Wilson et al., 2021), English-ABLE & CBAL (Zapata-Rivera, 2021), the tool supported both the teacher and the learner's creative engagement process.

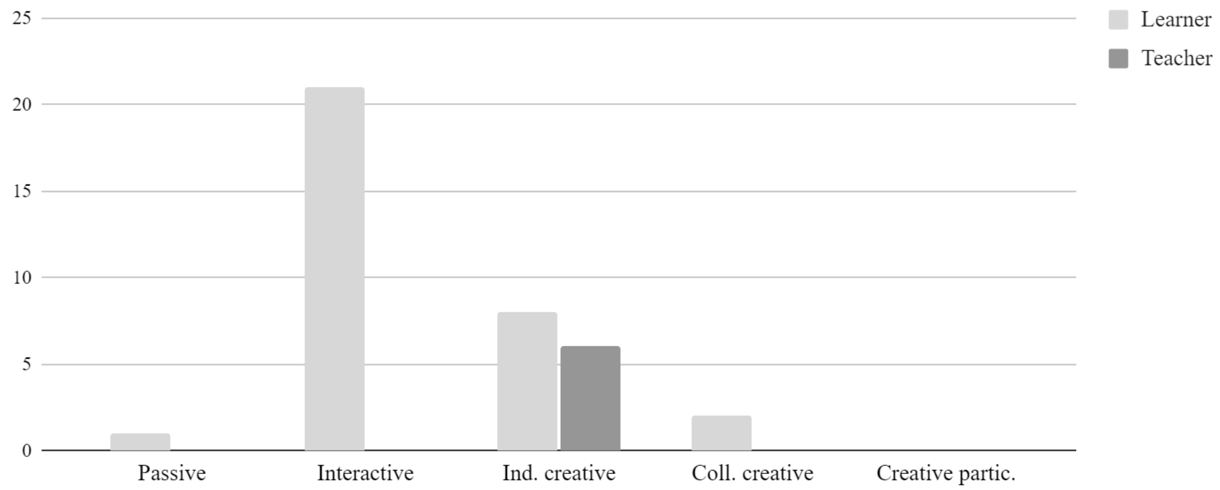

***Figure 1.** Number of papers (y-axis) according to the learners' and teachers' levels of creative engagement (x-axis).*

Only one study has developed a solution in which there is no creative engagement from the learners. The study of Lawson et al. (2021) only looked at learners' emotional expressions to animated instructions during a presentation. This study shows that learners can identify and connect with the emotional tone, whether positive or negative, exhibited by a virtual instructor.

We can observe that the majority of studies (n=21) support the second level of creative engagement, "interactive consuming". In this level, the learner uses an AI tool to help with a well-defined learning activity, and the system adapts to the learner's needs. Most of the systems in this context are self-identified as Intelligent Tutoring Systems (ITS).

Individual creative engagement, the third level of the #PPai6 model, is the only level in which we can observe both the learner's (n=8) and teacher's (n=6) perspectives, which are in some cases supported independently, as in the case of Tuglet (Käser & Schwartz, 2020), Physics Playground (Shute et al., 2021), C2STEM (Hutchins et al., 2020), TopoMath (VanLehn et al., 2020), etc. More interestingly, the BioWorld & HOWARD Platform (Lajoie, 2021), MiWRITE (Wilson et al., 2021), English-ABLE and CBAL (Zapata-Rivera, 2021) tools support both the teachers and the learners in their creative processes.

The fourth level, collective creative engagement, can be observed in two studies. The first one is the study of NoRILLA (Yannier et al., 2020), a specialised Augmented Reality (AR) for STEM education where learners are encouraged to do an exploratory construction together. The learners' using the AI tool NoRILLA are engaged in building blocks that should not fall during a strong motion. First, the learners advance individually, and once they have achieved a certain progression, they are able to engage in teams for an exploratory construction collaboratively with the tool. The second study is using the HOWARD Platform (Lajoie, 2021) where learners and instructors can simultaneously engage in monitoring and responding in a problem-based learning (PBL) environment in which discussion is encouraged.

Participatory content co-creation, the fifth level of the #PPai6 framework, neither the sixth level (expansive learning) are not observed in any of the 41 studies revised.

AI tools can be used in diverse pedagogical scenarios with different degrees of creative engagement for the learner or the teacher. In this study, we have analysed 41 studies in order to identify creative engagement with AI tools. The results show the majority of educational uses of AI are individual (n=33 for the learners, n=6 for the teachers), with only two uses to support the learners' co-creativity. We can observe that most of the uses of AI tools do not engage learners creatively. Most of the studies engage learners in the second level of the #PPai6 framework, "interactive consuming", through intelligent tutoring systems (ITS) which permit the system to adapt to the learners' inputs based on the learner model and the learning task model integrated into the AI-tool. Developing a learner and task model is already a complex process that requires domain-specific expertise and computer modelling efforts. Computer-supported collaborative learning (CSCL) activities are more complex in relation to the group dynamics that are emerging not only at the individual level but at the collective level. The lack of standardisation on these group dynamics ontologies and modes is one of the potential reasons why we observe a limited number of collaborative uses of AI tools in education.

We can observe that some of the AI tools are Digital Game-Based Learning (DGBL) solutions. The characteristics of DGBL as systems engaging the learners' by providing feedback and supporting actions towards a learning objective are aligned with the characteristics of AI tools in education, which share these two characteristics. Most DGBL solutions support the second level of creative engagement. Among the DGBL AI tools, two address STEM education, such as C2STEM (Hutchins et al., 2020) and NoRILLA (Yannier et al., 2020).

None of the studies supports participatory content co-creation, the fifth and sixth level of the #PPai6 framework. We can consider not only the higher degree of complexity of AI systems but also their ability to support users whose' behaviour does not correspond to the teacher-and-learner model. In the context of Maison de l'intelligence artificielle (MIA) in Sophia Antipolis, the types of activities in which the learners are engaged correspond to the fifth level. The learners are engaged to co-create solutions addressing different Sustainable Development Goals (SDGs) in collaboration with the AI experts in the MIA, their teachers, and other learners.

The analysis of the levels of creative engagement will permit the AI community in education to consider the pedagogical integration of AI tools, considering the possibility of engaging teachers and learners in creative processes. Moreover, the results of the study contribute to the Horizon augMENTOR Project by supporting researchers and computer engineers in their understanding of the different types of AI solutions that can better support 21st-century competencies. These results can permit educators to design the AI tools and their integration to better support the learners' creativity.