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To cite this article:

Noroozi, O. (2025). Towards technology-enhanced transformative learning environments. *International Journal of Technology in Education (IJTE), 8*(2), 541-556. https://doi.org/10.46328/ijte.1209

International Journal of Technology in Education
2025, Vol. 8, No. 2, 541-556 https://doi.org/10.46328/ijte.1209

Towards Technology-Enhanced Transformative Learning Environments

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Article Info

Article History

Received:
15 January 2025
Accepted:
17 January 2025

Keywords

Second-order scaffolding
Sustainable education
Technology-enhanced learning
Transformative competences

Abstract

The world currently grapples with ambiguity and uncertainty, facing ongoing challenges that span various aspects of life, from economic fluctuations and political instability to environmental crises and technological advancements. Confronting such ambiguity and uncertainty highlights the critical importance of equipping learners with transformative competences. Such competencies empower individuals to navigate challenges, foster innovation, reconcile conflicting demands, shoulder responsibility collaboratively, and contribute to a more promising future. Learners need to cultivate these competences to help shape a world where well-being and sustainability, for themselves, others, and the planet, can be realized. Creating such a transformative learning ecosystem requires educational institutions to constantly look for embedding competences in their curriculum to provide rich learning settings for their learners to become capable professionals to manage today's complex issues. This, of course, demands for a shift from teaching and learning in the traditional classrooms into learning and collaboration with Technology-Enhanced Learning (TEL) environments to make learning processes more effective, efficient, and engaging and ultimately to enhance learners' transformative competences. This theoretical paper argues for a deep exploration of the indispensable need for a paradigm shift in educational practices. It first sets the stage by elucidating the foundational rationale for such transformation within the educational landscape. Subsequently, it delves into a nuanced exposition of the key constituents comprising this transformative competences. Next, it discusses the need for a shift from providing first-order scaffolding (tools for living) towards providing them with second-order scaffolding (tools for learning) to meet the needs of the society. Subsequently, it discusses the role of TEL environments for second-order scaffolding to nurture learners' transformative competences. Finally, it provides a framework that delineates the multifaceted dimensions of TEL environments for the cultivation and refinement of learners' transformative competences.

Introduction

The world is dealing with ambiguity and uncertainty in many global aspects facing severe challenges such as food security, hunger, poverty, health hazards, inequality, environmental degradation, climate change, conflicts and scarcity of resources. These challenges are complex, ambiguous, controversial, multifaceted and thus the solutions

are not straight-forward and require relevant competences (Wals et al., 2014). The intricacy of these issues demands a nuanced understanding and the application of diverse and relevant competences to navigate and address them effectively. In such a dynamic and interconnected landscape, the ability to contend with ambiguity and uncertainty becomes a crucial skill set, enabling individuals and societies to tackle these challenges and work together towards sustainable and equitable solutions.

To deal with such challenges we need to empower society through sustainable solutions by means of high quality education. Education is a crucial component of this empowerment strategy that can equip individuals and communities with the necessary competences to engage meaningfully with the challenges of the modern world and actively participate in the pursuit of sustainable solutions. By fostering critical thinking, interdisciplinary understanding, and a sense of responsibility, education prepares society to grapple with ambiguity and uncertainty. It cultivates a mindset that embraces the need for continuous learning and adaptation in the face of evolving global challenges (Noroozi & Sahin, 2023).

The Organisation for Economic Co-operation and Development (OECD) identifies three "transformative competences " that learners need to poses in order to deal with these challenges and shape a better future including *creating new value*, *reconciling tensions and dilemmas*, and *taking responsibility* (OECD, 2019). Learners need to acquire these competences to shape a world where well-being and sustainability – for themselves, for others, and for the planet – is achievable. This requires transformation in education to train learners become professionals, who can contribute to sustainable solutions for existing and future complex issues all over the world, and who take their social, personal and ethical responsibilities seriously. This implies that our educational institutions, should not only provide ample opportunities for learners to acquire knowledge for accomplishing complex tasks at hand (*first-order scaffolding: tools for living*) but also provide them with self-regulating their learning experiences to apply and transfer their acquired knowledge for solving new complex tasks in similar situations (*second-order scaffolding: tools for learning*) to meet the needs of the society (Qian & Clark, 2016; Noroozi et al., 2018). To achieve this, our education demands for a shift from teaching and learning in the traditional classrooms into learning and collaboration with Technology-Enhanced Learning (TEL) environments to make learning processes more effective, efficient, and engaging and ultimately to enhance learners' transformative competences.

This theoretical paper advocates a crucial shift in educational practices, emphasizing the necessity of transforming the educational landscape. It begins by introducing the key components of transformative competences. Then, it stresses the crucial need for a move from offering basic life tools (first-order scaffolding) to providing advanced learning tools (second-order scaffolding) to our learners to align with societal needs. Additionally, it highlights the role of TEL environments in fostering learners transformative competences by offering a framework detailing various aspects of TEL environments in relation to various transformative competences. The paper ends with discussions on how these TEL environments could be designed to serve as pivotal arenas for the cultivation and refinement of learners' transformative competences within educational settings, thereby contributing significantly to the holistic development of future-ready individuals poised to thrive in a dynamic and uncertain world.

Transformative Competences

The OECD's framework for transformative competences includes a range of competences and attributes that learners need for navigating the challenges of the 21st century (see Figure 1). These competences go beyond traditional academic knowledge and focus on skills and qualities that are considered essential for success in the rapidly changing and complex modern world. In a broad sense, these competences include *creating new value*, *reconciling tensions and dilemmas*, and *taking responsibility*.

According to OECD (2019), creating new value refers to a person's ability to innovate and act entrepreneurially by taking informed and responsible actions. Individuals with this competence can identify opportunities and generate ideas that contribute positively to their environment. For creating new value, learners need to develop new thinking, ideas and insight, ask questions, collaborate with others, and think "outside the box" in order to find innovative solutions for complex problems. This blends a need for enhancing learners' collaboration, critical and entrepreneurial skills. To reconcile tensions and dilemmas, learners need to be able to balance contradictory or seemingly incompatible logics and demands, and become comfortable with complexity and ambiguity to deal with complex and controversial issues (Noroozi et al., 2012). In other words, learners not only need to learn to navigate conflicting perspectives, interests, and values but also develop capacities to resolve such conflicts or dilemmas in a constructive manner. This blends a need for enhancing learners' argumentation and reasoning skills. Taking responsibility refers to reflection and evaluation upon learner' actions in light of his or her experience, personal and societal goals. Learners who have the capacity to take responsibility for their actions have a strong moral compass that allows for considered reflection, working with others, sharing and engaging in societal debates, and respecting the planet. This goes beyond personal responsibility to include a sense of social responsibility to be aware of the consequences of their actions while taking into account ethical considerations and the well-being of others. This blends a need for enhancing learners' self-regulation, reflection, adaptation, and presentation skills (OECD, 2019).

Over time and depending on the societal needs, some proposed competences may evolve, and the terminology used may vary among different educational and policy contexts. The OECD, along with various other organizations, continues to explore and refine frameworks for transformative competences to ensure that education systems prepare learners for the demands of the contemporary world and provide them with ample opportunities to not only acquire knowledge for accomplishing complex tasks at hand (*first-order scaffolding: tools for living*) but also self-regulating their learning experiences to apply and transfer their acquired knowledge for solving new complex tasks in similar situations (*second-order scaffolding: tools for learning*) (Noroozi et al., 2018).

Second-order Scaffolding in relation to Transformative Competences

Van Merriënboer and Kirschner (2013), in their book "Ten Steps to Complex Learning," demands for two distinct scaffolding types within educational contexts: first-order and second-order scaffolds. First-order scaffolding, synonymous with regular scaffolding, involves providing support and guidance tailored to the acquisition and

execution of domain-specific complex skills. Conversely, second-order scaffolding is designed to assist learners in acquiring self-directed learning for performing similar tasks (see Noroozi et al., 2018).

The first-order scaffolding approach is applicable in situations where learners need to perform recurrent and routine aspects of the learning tasks in order to master on a complex cognitive skill or a professional competency within the domain being taught. For instance, a medical instructor may employ diverse methods, such as workshops, skills-lab exercises, drill-and-practice programs, or intelligent electronic agents, to instruct medical learners in life-saving skills like mouth-to-mouth resuscitation, intubation, and external cardiac massage (Van Merriënboer & Kirschner, 2013). First-order scaffolding is analogous to a class situation in which scaffolding is used as a means to help learners acquire domain-specific knowledge or complex skill aspects of a learning task such as the pros and cons of energy conservation or waste management. For the first-order scaffolding, the distribution of control over task practice and responsibilities is a collaborative effort between the learner and the teacher, or alternatively, a tutor or pedagogical agent within a computer program can assume the role of the teacher. The teacher is tasked with designing and selecting the learning tasks and offering guidance on effective task practice, while the learner assumes responsibility for identifying helpful routines to enhance overall task performance and identifying opportunities for task practice (Van Merriënboer & Kirschner).

First-order scaffolding cannot promote learners' transformative competence development. For promoting such domain-general competences, we not only need to support learners with their domain-specific knowledge acquisition but also help them develop their self-regulated learning competences that will help them become competent professionals who can handle comparable tasks and continue learning in their future professions (Noroozi et al., 2018). Such scaffolds that aim for both teaching a particular complex cognitive skill and stimulating the development of self-directed learning skills are called second-order scaffolding. As an illustration, a teacher might initially convene regular meetings with learners to discuss the problem and the selection of the learning task. Subsequently, the teacher could progressively reduce the frequency of coaching meetings, eventually empowering the learner to schedule such meetings only when necessary (Van Merriënboer & Kirschner, 2013). This approach serves the dual purpose of providing crucial support for specific routines and recurring aspects of the learning task, especially in its early stages, while concurrently fostering self-directed learning skills by granting the learner the autonomy to choose their own learning tasks.

In the context of transformative competences learning, this mirrors a classroom scenario where scaffolding is employed to instruct learners in acquiring higher-order competences such as argumentation and reasoning (Noroozi et al., 2018). This goes beyond addressing the current complex cognitive issue within the taught domain; it also equips learners with the capability to apply such competence in analogous tasks in the future. Within this scaffolding framework, the teacher (or the system or agent) not only facilitates the acquisition of specific transformative competence but also encourages self-directed learning by progressively diminishing support and guidance. This evolution enables learners to independently apply the acquired transformative competence when learning new complex cognitive skills (Noroozi et al., 2018).

To conclude, second-order scaffolding equips learners with tools for learning, as opposed to the tools for living

provided by the first-order scaffolding. This implies that for dealing with global challenges, second-order argument-scaffolding should be given priority above first-order scaffolding by educational institutions to train qualified professionals with appropriate transformative competences to deal with complex and authentic problems (Noroozi et al., 2018). The challenge for educational designers is, thus, how to design and implement tools for second-order argument-scaffolding (i.e., self-regulated acquisition and application of argumentation competence) that can also facilitate the acquisition of the first-order skill (i.e., acquisition of the particular cognitive complex skills). In the subsequent section, I elucidate how can TEL environments, as a form of second-order scaffolds, be designed to make learning processes more effective, efficient, and engaging and ultimately to enhance learners' transformative competences.

Technology-Enhanced Learning (TEL) Environments

TEL refers to learning environments where educational tools are used to enhance learners' learning experiences. Technology, however, is not the focus of the learning process, nor is it all a learner needs to learn in such environments (Cartelli & Palma, 2008). TEL environments allow learners to perform complex learning and develop their higher-order thinking skills in a rich learning environment (Urbina et al., 2021) by offering relevant affordances and scaffolds to make learning more cost-effective, time-effective, sustainable, scalable, and adaptive (Kirkwood & Price, 2014). TEL environments have become a useful arena for knowledge creation activities in such a way that learners can control their learning and discovering knowledge, but the discovery is supported by extra guidance, support, and feedback (Noroozi & Sahin, 2023). TEL environments can enhance learning by understanding how learners learn, providing them with relevant resources and materials, and customizing personalized learning experiences tailored to learners' individual needs (Kirkwood & Price, 2014). This implies that the design of effective TEL environments requires consideration of a learner's ability to interact with and use technological tools and scaffolds for the development of their transformative competences. By directing attention of learners on important task features through procedural and metacognitive scaffolds, TEL environments can guide learners towards engaging in desirable learning activities and can constrain them from engaging in unnecessary, misleading, or unproductive actions through predefined rules, tasks (Noroozi et al., 2018).

To achieve the potential of second-order scaffolding with TEL environments, we need to understand the relations among educational technology, learning, and learners' transformative competence development. Scientific evidence shows that TEL environments such as Computer-Supported Collaborative Learning (CSCL) settings, online learning platforms, Massive Open Online Courses (MOOCs), Artificial Intelligence (AI), Learning Analytics (LA), digital gaming, computer-based simulations, extended reality can be designed in such a way to enhance learners' transformative competences (e.g. argumentation, critical thinking, reasoning, problem-solving, self-regulation, presentation, and entrepreneurial thinking) for solving complex and controversial challenges (see Noroozi & Sahin, 2023). To do so, we need to design TEL environments based on solid theoretical foundations and theories of learning and peer learning to help individual learners acquire transformative competences when they are engaged in *peer learning* processes. There is a strong focus on peer learning because complex problems often need to be tackled and solved in learning groups through inquiry and interaction with peers rather than individuals. This implies that the theoretical foundations and theories of learning in TEL environments need to

target learning groups next to individuals so that all members of a group as a team could acquire transformative competences (Noroozi et al., 2018). Below it is explained how to use these TEL environments as a form of second-order scaffolding approach to enhance and develop learners' transformative competences in educational settings.

Second-order Scaffolding with TEL Environments

Second-order scaffolding with TEL environments demands for integration of solid theoretical foundations and theories of learning. In the following sections, I will elaborate on how to take advantage of the latest developments of TEL environments to design second-order scaffolds (Van Merriënboer & Kirschner, 2013; Noroozi et al., 2018) to not only help learners acquire knowledge for accomplishing complex tasks at hand but also self-regulate their experiences to apply and transfer their acquired knowledge for solving new complex tasks in similar situations.

Second-order scaffolding requires features such as contingency, fading, and transfer of responsibility (see Van de Pol et al., 2010). The first common characteristic of second-order scaffolding is contingency often referred to adapted or tailored support. The support must be adapted to the current level of performance of the learners. This requires diagnosis of learner's current level of competence. Fischer and colleagues (2013) developed the Script Theory of Guidance (SToG) that can be coupled with the conceptual framework of Noroozi and colleagues (2018) to provide learners with adaptive scaffolds. Fading support, i.e. gradual withdrawal of the scaffolding, is the second common characteristic of scaffolding. Based on SToG, fading can only be effective when the design of the components of scaffolds is based on learner's current level of specific competence to secure continuous application of the suggested strategy even after the support components are faded out (Fischer et al., 2013). This can be realized when fading is complemented by an adaptation method tailored to the current needs of each learner (Noroozi et al., 2018). Fading of the scaffolding is strongly related to the third common characteristic of scaffolding, namely the transfer of responsibility. Via contingent fading, responsibility is gradually transferred to the learner so that the learner can apply the acquired competence in comparable non-trained learning situations (Van de Pol et al., 2010). Successful contingent fading depends on the extent to which learners can internalize (acquisition) and externalize (consolidation) the support provided (Noroozi et al., 2018). Internalization happens when learners are continuously exposed to external support to acquire corresponding support components. Consolidation happens if support is no longer needed when learners have already developed their own internal support for solving comparable non-trained tasks. This can best be achieved if and when the learner is aware of the corresponding activities and the underlying reasoning behind the activities (Fischer et al. 2013), otherwise, it will just aid the learner at that moment and will not be transferred (Noroozi et al., 2018). We thus need to ensure that adaptive fading targets both acquisition and consolidation.

To summarize, similar to Van de Pol et al. (2010), I refer to second-order argument scaffolding as a concept that can focus on the development of learners' competence for accomplishing comparable non-trained tasks (tools for living) instead of the first-order scaffolding metaphor for helping learners to accomplish only trained tasks at hand (tools for learning). These second-order scaffolds will: 1) diagnose learners' current level of behaviour, 2) provide them with contingent support, and 3) fade out support depending on learners' performance.

Towards Technology-Enhanced Transformative Learning

Figure 1 depicts a pathway towards sustainable technology-enhanced transformative learning. This figure is built on the conceptual framework of second-order scaffolding offered by Noroozi and colleagues (2018), follow key characteristics of scaffolding including contingency, fading, transfer of responsibility (Van de Pol et al., 2010), and take advantage of complementary educational tools in TEL environments (i.e. learning analytics, multimodalities, AI, automatic analysis systems, natural language processing, adaptive support systems) (see Banihashem et al., 2023; Fiacco, Cotos, & Rosé, 2019). Below I provide various examples of TEL environments that can be used to enhance learners' various transformative competences (e.g. argumentation, critical thinking, reasoning, problem-solving, self-regulation, presentation, and entrepreneurial thinking).

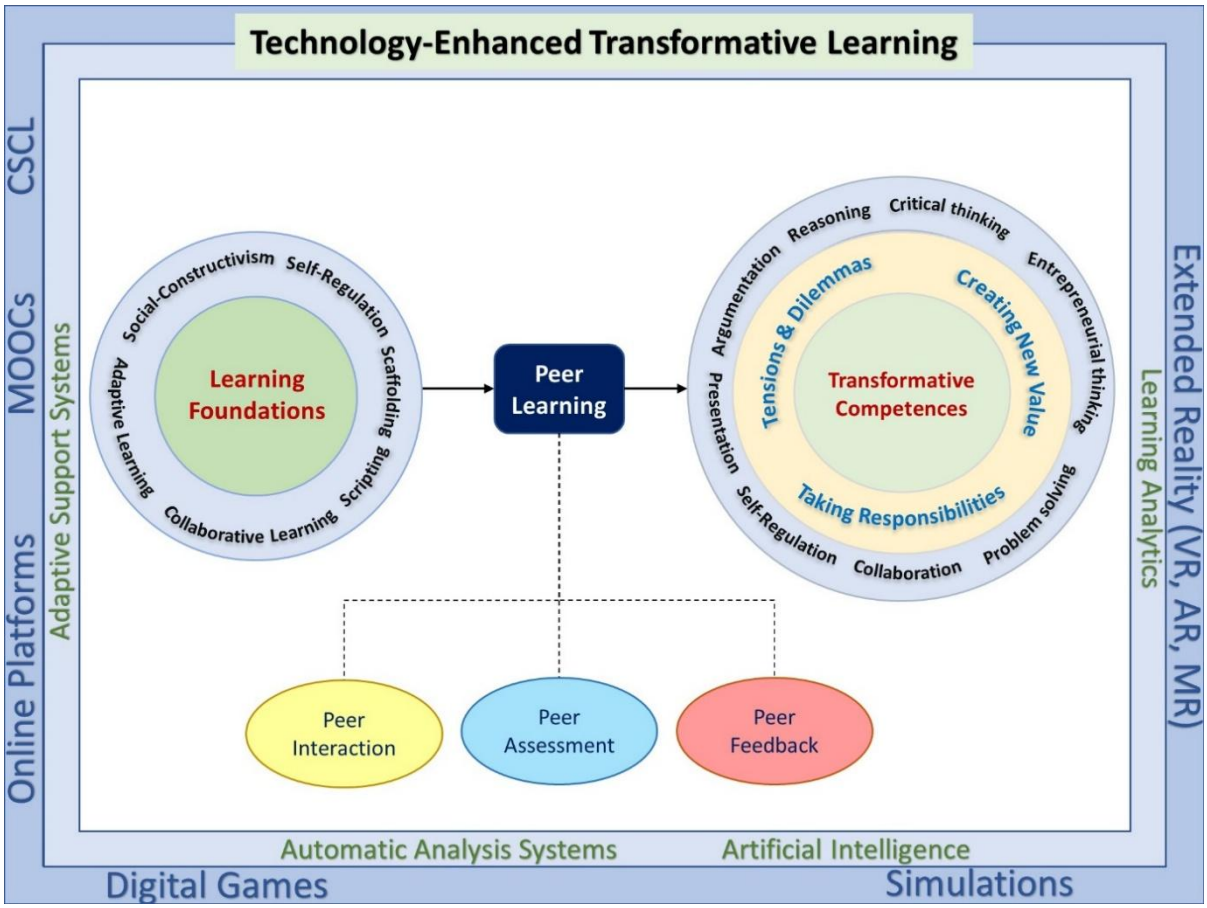

Figure 1. Towards Sustainable Technology-Enhanced Transformative Learning

Digital Games for Enhancing Learners' Transformative Competences

Learning through Game-Based Learning (GBL) is based on a socio-constructivist perspective in which learners acquire various skills by practicing them, rather than reading and thinking, while engaging in active learning processes. In such a combination of learning with fun, GBL provide learners with a pleasant learning environment that can stimulate motivational aspects of learning, whilst the support from the game elements offers the possibility of acquiring targeted skills (Dehghanzadeh et al., 2023). Although the game industry has grown rapidly

in recent years, the use of GBL for enhancing learners' transformative competences is still limited. So far, the potential of these powerful GBL innovations for the practice and accomplishment of learning tasks at hand (first-order scaffolding) has been explored with positive learning outcomes. Upcoming years, we need to explore the role of GBL environments for enhancing learners' transformative competences such as complex problem-solving, collaboration and self-regulated learning in real educational settings. This is important since rapid advances of learning analytics and AI within gaming environments allow for gamified learning environments to dynamically adapt, learn, and evolve its strategies and behaviors in response to changing circumstances and learners interactions. This competency involves the AI's capacity to go beyond pre-programmed responses and actively improve its decision-making processes through experience and feedback (see Banihashem et al., 2023).

Extended Reality for Enhancing Learners' Presentation and Communication Skills

Extended Reality (XR) is the umbrella term for immersive mediums (real-and-virtual combined environments) including virtual reality (VR), augmented reality (AR), mixed reality (MR) (Rauschnabel et al., 2022). Extended reality is a powerful technology that can be used to improve and innovate education, by overcoming limitations associated with time constraints and shortage of teachers in the curriculum (Van Ginkel et al., 2020). Extended reality is rapidly taking off in education with a sharp growing number of institutes adopting this technology. Such technology can provide learners with a rich, memorable, and immersive real-life situation to experience various items/places/destinations from across the world without ever having to leave the classroom. While AR refers to one or more pieces of digital content onto an individual's physical environment, such as a classroom (Rauschnabel et al., 2022), VR refer to a system that uses displays, tracking, and other advanced technologies to immerse learner in a virtual environment (LaViola et al., 2017). MR refers to the use of AR and VR to create immersive experiences based on an individual's physical environment.

Extended reality can be used to provide learners with rich learning opportunities to practice their presentation, communication, and argumentation skills which are needed for higher education learners to actively participate in the knowledge society. For example, VR with virtual audience followed by detailed feedback produced by the system (e.g. performance, body language, anxiety control, self-efficacy, knowledge, and retention) can be used to improve learners' presentation, communication, and argumentation skills (Van Ginkel et al., 2019, 2020). This can be done because VR can promote situated learning and increase motivation (Buttussi & Chittaro, 2018;), deliver detailed (delayed and immediate) feedback to the learner (Van Ginkel et al., 2020) and provide a cost-effective practice for education (Merchant et al., 2014).

In education, extended reality allows students to explore historical events, conduct virtual science experiments, or even step into complex concepts, promoting critical thinking and problem-solving. It also provides realistic simulations and facilitates collaboration, communication, interpersonal and teamwork skills by offering a dynamic platform for cultivating the cognitive, social, and emotional dimensions of transformative competences in a wide range of educational and professional contexts (Van Ginkel et al., 2019). These characteristics fit very well to the trend in educational settings to adopt independent and personalized learning approach, which employs unsupervised training for learners.

Digitally-supported Learning Environments for Enhancing Learners' Entrepreneurial Thinking

Digitally-supported learning environments can be used to foster learners' entrepreneurial thinking which is seen as one of the core learning objectives of the young generation (Obschonka et al., 2017), to deal with the uncertainty and complexity of today's societal issues (Farrokhnia et al., 2022). The first and the most important steps towards entrepreneurial thinking is opportunity identification (OI) among higher education learners. According to scholars, OI is an individual's ability to identify ideas and transfer them to products, processes, or services that have value for customers, end-users, or society (Baggen et al., 2015). From the cognitive psychology perspective, the OI process can be described as a multi-step creative process starting with the generation of an idea which the individual subsequently develops into a feasible opportunity (Dimov, 2007). This creative process involves a sequential application of divergent and convergent thinking to respectively facilitate the generation and evaluation of ideas (Gielnik et al., 2012).

OI can be improved through educational techniques and interventions that encourage divergent and convergent thinking (Sannomiya & Yamaguchi, 2016), such as brainstorming (Ritter & Mostert, 2017). However, research has shown that brainstorming sessions do not always result in a large number of quality ideas and it could be hindered by a cognitive difficulty called "the fixation effect" (Cassotti et al., 2016). This issue can be tackled by designing TEL environments that would provide learners with contingent and adaptive guidance in the forms of procedural steps to help them generate quality business ideas by overcoming the so-called cognitive difficulty. Furthermore, various techniques and methods in TEL environments can be designed for idea evaluation which is also an important step for the entrepreneurial thinking.

Computer-support Systems for Enhancing Learners' Argumentation and Reasoning

Argumentation and reasoning are essential aspects of scientific thinking, which are central to the process by which science advances (Kuhn, 1993). Despite the fact that argumentation and reasoning are shaped in social conversation and also in learners' online exchanges in daily life, learners often struggle to generate, analyze, interpret, and evaluate valid arguments and solid reasoning (see Noroozi et al., 2012).

Scientific evidence shows that not only learning to orally argue and reason is important for learners but also learning to write argumentative essays (see Granado-Peinado et al., 2019; Noroozi et al., 2018). Despite popularity of essay writing tasks for learners in higher education (see Latifi, Noroozi, & Talaee, 2023), teachers often are not happy with regard to the argumentation and reasoning quality of such essays. Learners' essays often lack sound argumentation, reasoning, and depth of elaboration (ValeroHaro et al., 2023) because they are either unaware of the features of a good quality argumentative essay or they have difficulty in transferring their argumentation and reasoning knowledge into applications i.e. writing argumentative essays (Wu & Schunn, 2020). From teachers' point of view, a clear and high quality argumentative essay should encompass a clear claim supported by argumentation, reasoning and evidence, followed by acknowledgment of counter-arguments against the original claim, and integrations of the arguments and counter-arguments which could lead to a final conclusion on the issue. This implies that writing such essays require solid argumentation strategies (Wingate, 2012).

Research on scaffolding argumentation and reasoning has been influenced by developments in educational technologies focusing on the role of computer support systems (see Noroozi & McAlister, 2012). The scaffolds developed, implemented and researched in TEL environments up until now have been meant primarily to stimulate argumentative discourse activities for learning within a particular domain and not to help learners acquire argumentation and reasoning competences for self-regulating their activities for applications in new similar situations. In a recent conceptual article (see Noroozi et al., 2018), it is argued that with adaptive scaffolding of argumentation and reasoning, learners should be able to transfer their acquired argumentation competence to similar situations for dealing with various complex, ill-defined, and controversial issues in that specific discipline. The challenge for course developers, educational designers and researchers is, thus, how to design tools for self-regulated acquisition and application of argumentation and reasoning competences that can also facilitate the acquisition of domain-specific knowledge or professional competency (see Noroozi et al., 2018). Therefore, future research should focus on the design, evaluation, improvement and upgrading of TEL environments with second-order scaffolding to achieve both acquisition and also transfer and application of such competences in new similar situations (self-regulated learning). Such second-order scaffolding could ensure us that learners actually understand, learn, and apply (transfer) targeted argumentation and reasoning activities in new similar situations.

Computer-support Systems for Enhancing Learners' Peer Learning Literacy

Peer learning is the core of research line in TEL environments because complex problems often need to be tackled and solved in learning groups through inquiry and interaction with peers rather than individuals. Peer learning is one of the most prominent instructional strategies that teachers use to enhance both learners' writing skills, their motivation, and also their learning in the particular content domain (Carless & Boud, 2018). By comparing their own writing with peers, learners are enabled to broaden and deepen their reflective thinking (Yang, 2010) and critical thinking and understanding about the topic (see Taghizadeh Kerman et al., 2023). Learners typically vary in terms of their peer learning literacy when it comes to implementation of received feedback from peers (Er et al., 2021; Winstone & Carless, 2019). Peer learning literacy involves learners understanding of received feedback from peers, their willingness and capacity to use feedback, and how they feel about their position in the peer learning. A low level of literacy could decrease the efficiency of peer learning (Carless & Boud, 2018).

Peer learning has the potential to improve learners' writing and learning (Gielen & De Wever, 2015; Nelson & Schunn, 2009). Instructional support can be used to guide learners' peer learning processes towards expected and desirable activities which may in turn enhance learners' peer learning literacy and also their writing and learning. Although peer learning and its effects on various learning outcomes has been studied from a number of perspectives, much questions remains to be answered regarding what leads learners to act (or not) on their peers' comments in revisions. For peer learning processes to positively influence learning outcomes, it must be put into action (Topping, 1998), otherwise peer learning would be useless. Scientific literature suggests that learners often find translating feedback from peers into action and implementation to be complex, multi-dimensional, and challenging (Price et al., 2011).

Learners' implementation of peer comments can be influenced by various factors such as feedback

literacy/content/features (Nelson & Schunn, 2009), individual characteristics (Noroozi, 2018), as well as learners' psychological state of mind such as attitudes and perceptions towards peer feedback (Strijbos et al., 2010). The extent to which learners are hampered in the uptake of peer feedback and peer review is strongly related to their level of peer learning literacy which refers to learners' ability to comprehend, implement, and benefit from peer learning (Winstone & Carless, 2019). As a result of poor perception, comprehension, and interpretation of peer comments, the valuable information from peers will not be fully understood and thus not implemented in the revised works (Wu & Schunn, 2020). Questions remain regarding critical feedback and review features, their mechanisms by which peer learning does or does not result in learners implementing peer comments in revisions. This needs further exploration on how implementation of peer learning processes in revised works are related to peer learning uptake/content/features, their argumentation quality, as well as learners' characteristics and perceptions (Wu & Schunn, 2020; Yu & Wu, 2016).

Furthermore, despite vast scientific research on the importance and the effects of peer learning processes on learners' writing and learning, a crucial issue in peer learning that is left under investigated is how to best enhance learners' peer learning literacy in such a way that also leads to enhancing their transformative competences. Learners with better peer learning literacy engage in higher quality peer learning processes which in turn may result in higher quality learning. By directing attention of learners on important peer learning processes/content/features through relevant procedural and metacognitive scaffolds, computer-support systems can guide learners towards engaging in desirable peer learning activities and can constrain them from engaging in unnecessary, misleading, or unproductive peer interaction (Sharma & Hannafin, 2007; Noroozi et al., 2024). Hence, a promising research stream lies in investigating how best to design second-order scaffolding using computer-support systems in TEL environments for maximizing learners' peer learning processes and its relationship with peer learning uptake/content/features, their perception and individual characteristics to enhance learners' ability to acquire transformative competences.

Artificial Intelligence for Enhancing Learners' Critical Thinking

Artificial intelligence (AI) has emerged as a powerful tool for enhancing learners' critical thinking skills. By providing personalized learning experiences, AI-driven educational platforms can adapt to individual learning styles and paces, ensuring that each student receives the support they need to develop critical thinking abilities (see Gökçearslan et al., 2024). AI systems can analyze vast amounts of data to identify patterns in students' performance, pinpointing areas where they may struggle and offering targeted interventions. For instance, intelligent tutoring systems can present challenging problems that require higher-order thinking, encouraging learners to analyze, evaluate, and create solutions (Giray et al., 2024).

Moreover, AI can provide real-time feedback, a crucial element in fostering critical thinking (Hammoda, 2024). Instant feedback helps learners understand their mistakes and misconceptions, guiding them to reconsider and refine their thought processes. AI can also support collaborative learning by connecting students with peers worldwide, enabling diverse perspectives and problem-solving approaches. Through natural language processing, AI can facilitate discussions and debates, prompting learners to articulate and defend their ideas effectively

(Banihashem et al., 2024). This constant engagement with diverse viewpoints and problem-solving methods nurtures an environment where critical thinking can flourish. As AI technology continues to evolve, its potential to enhance critical thinking in education will only expand, making it an invaluable asset in the modern learning landscape.

Learning Analytics for Enhancing Learners' Self-regulation

Learning analytics plays a crucial role in enhancing self-regulated learning by providing students with actionable insights into their own learning processes. Through the analysis of data collected from learning management systems, educational tools, and other digital platforms, students can gain a deeper understanding of their strengths, weaknesses, and study habits (see Cloude et al., 2022). For example, learning analytics can track how much time students spend on different activities, their performance on various assessments, and their engagement levels throughout a course. By visualizing data through dashboards and reports, students can identify areas where they need to improve, set specific learning goals, and monitor their progress (Moon et al., 2024). This transparency empowers learners to take control of their education, make informed decisions, and develop the skills necessary for effective self-regulation.

Moreover, learning analytics can provide personalized feedback and recommendations that further support self-regulated learning (see Banihashem et al., 2023). For instance, if a student consistently struggles with a particular concept, the system can suggest targeted resources such as additional readings, practice exercises, or multimedia content tailored to their needs. Additionally, learning analytics can help students develop time management and planning skills by offering insights into how they allocate their study time and how it correlates with their academic performance. By understanding these patterns, students can adjust their study schedules to optimize their learning outcomes (see Gašević et al., 2022). This personalized guidance not only helps students stay motivated and on track but also fosters a sense of ownership and accountability for their learning journey. As learning analytics technology continues to advance, it will increasingly enable students to become more self-directed and autonomous learners, ultimately leading to greater academic success and lifelong learning.

Conclusions

Traditional classrooms can no longer meet the needs of the world of work. The new world of work is demanding higher levels of expert thinking and transformative competences (OECD, 2019). These competences include creating new value (collaboration, critical thinking, and entrepreneurial mindset), reconciling tensions and dilemmas (argumentation and reasoning), and taking responsibility (self-regulation, reflection, adaptation, and presentation) (OECD, 2019; Noroozi & Sahin, 2023). Acquiring such transformative competences is relevant for learners in almost any domain and even discipline ranging from soft to hard sciences and from natural to social sciences to actively engaging in societal debates and solving today's complex issues in varied workplace, educational, and community contexts (Han et al., 2021).

In this article, I explained how to use the potential of advanced educational technologies in TEL environments to

support learners' transformative competence development which is a necessity for actively engaging in societal debates and solving today's complex and controversial issues. This is important since by achieving such transformative competences, learners are able to acquire domain-specific knowledge through cognitive processing and epistemic exchange of ideas and interaction with their learning peers (see Noroozi et al., 2018). In other words, this conceptual work helps us understand how to take advantage of the latest developments of TEL environments to design second-order scaffolds to not only help learners acquire knowledge for accomplishing complex tasks at hand but also self-regulate their experiences to apply and transfer their acquired knowledge for solving new complex tasks in similar situations.

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