

TECHNOLOGY-ENHANCED ACTIVE LEARNING IN CONTEMPORARY EDUCATION: A REVIEW OF GAMIFICATION, EDUCATIONAL ESCAPE ROOMS, STE(A)M AND ARTIFICIAL INTELLIGENCE

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Abstract: The rapid development of digital technologies is transforming contemporary educational environments and creating new opportunities for active, engaging and interdisciplinary learning. However, the presence of technology alone does not guarantee improved educational outcomes, as its effectiveness largely depends on the pedagogical approaches through which it is integrated into the learning process. The purpose of this review is to examine the development and intersection of four increasingly important approaches to technology-enhanced education: gamification, educational escape rooms, STE(A)M-based learning and artificial intelligence. A structured literature review was conducted by analysing relevant scientific publications addressing technology-supported active learning, with particular attention to studies published in recent years. The reviewed literature was thematically analysed according to pedagogical application, learner engagement, motivation, collaboration, creativity, problem-solving and learning outcomes. The results indicate that gamification and educational escape rooms can support active participation, motivation and collaborative problem-solving, while STE(A)M approaches contribute to interdisciplinary learning, creativity and the integration of knowledge from different fields. Artificial intelligence introduces additional opportunities for personalisation, adaptive learning and interactive educational experiences, but also raises important questions concerning ethics, digital competence, academic integrity and responsible use. The synthesis further indicates a gradual shift from the simple introduction of digital tools towards the intentional integration of technology, pedagogical design and learner-centred activities. Several research gaps were identified, including the limited availability of longitudinal studies, differences in assessment approaches, insufficient evidence concerning long-term learning outcomes, and the need for research combining gamification, STE(A)M and artificial intelligence within integrated learning models. Based on the findings, an integrated conceptual framework for technology-enhanced active learning is proposed, linking technological affordances with pedagogical design, learner engagement, learning processes and educational outcomes. The review recommends further empirical and longitudinal research, particularly on integrated technology-supported learning environments, as well as the development of pedagogically grounded and ethically responsible approaches to the use of artificial intelligence in education. The proposed framework may support researchers and educators in designing and evaluating innovative, interdisciplinary and learner-centred educational practices.

Keywords: technology-enhanced learning, gamification, educational escape rooms, STE(A)M education, artificial intelligence

1. INTRODUCTION

The rapid development of digital technologies is transforming contemporary education and changing the ways in which knowledge is accessed, presented and applied. Digital platforms, interactive technologies, artificial intelligence and innovative pedagogical approaches increasingly create learning environments that extend beyond the traditional teacher-centred classroom. However, digital transformation should not be understood merely as the introduction of technological tools. Its educational value depends on how technology is integrated into meaningful pedagogical processes that encourage active participation, collaboration, problem solving and the development of transferable competencies. Research on the digitalization of Bulgarian schools similarly emphasizes that technological transformation involves not only infrastructure and platforms, but also the development of digital competencies among teachers, students and other participants in the educational process (Mishkova-Yotova, 2024).

A major development associated with this transformation is the shift towards active and learner-centred learning, in which students are expected to explore, make decisions, solve problems, communicate and collaborate rather than simply receive information. Consequently, approaches that combine clear educational objectives with increased learner engagement have attracted growing research attention, including gamification, game-based learning and experiential learning.

Educational escape rooms represent a particularly relevant example of this development. Designed around explicit learning objectives, they incorporate puzzles, challenges and game elements into structured learning activities. Mishkova-Yotova (2022) demonstrates their potential to support teamwork, communication, time management, critical thinking and creativity, positioning the educational escape room as more than a

motivational technique and as a structured environment for applying knowledge and skills to contextualized problems.

Their potential is particularly relevant when escape rooms are combined with interdisciplinary learning. Mishkova-Yotova and Borisova (2023) demonstrate how an educational escape room can connect visual arts and mathematics within a common problem-solving activity, enabling learners to apply knowledge from different disciplines and collaborate towards a shared outcome. Such characteristics correspond to the principles of STE(A)M education, where interdisciplinary knowledge is applied to meaningful problems. Further research by Aleksieva and Mishkova-Yotova (2025) examines the integration of STEM education and educational escape rooms in primary education, highlighting the potential of this combination for interdisciplinary and engaging learning.

Artificial intelligence introduces a further dimension to technology-enhanced learning. AI can potentially support personalised learning, adaptive feedback, content generation and interactive educational experiences, while also raising questions concerning teacher competencies, academic integrity, privacy, ethical use and the reliability of generated content. Its increasing availability therefore reinforces the need for pedagogically grounded approaches to educational innovation.

Against this background, the present review examines the intersection of four dimensions of technology-enhanced active learning: gamification, educational escape rooms, STE(A)M-based learning and artificial intelligence. The study focuses on their pedagogical applications and their potential relationship with student motivation, engagement, collaboration, creativity, problem-solving and learning outcomes, with particular attention to educational escape rooms as a model connecting game elements, interdisciplinary learning and experiential activities.

The objective of the review is to identify common tendencies, limitations and research gaps and to explore how these approaches can be conceptually integrated into a broader model of technology-enhanced active learning. On this basis, the review proposes a framework that may support future empirical research and the design of innovative, interdisciplinary and learner-centred educational practices.

2. MATERIALS AND METHODS

The present study employs a structured literature review approach to examine research on technology-enhanced active learning, with particular emphasis on gamification, educational escape rooms, STE(A)M education and artificial intelligence. The review was designed to identify major pedagogical applications, reported educational benefits, methodological tendencies and research gaps across these interconnected fields.

The literature search focused on scientific publications addressing technology-supported approaches to active participation, motivation, collaboration, creativity, problem-solving and learning outcomes. Particular attention was given to peer-reviewed studies and review papers published in recent years, while selected earlier publications were retained when they provided important theoretical or conceptual foundations.

The search strategy used combinations of keywords including *technology-enhanced learning*, *active learning*, *gamification*, *educational escape room*, *escape game*, *STEM education*, *STEAM education*, *artificial intelligence in education*, *student engagement*, *student motivation*, *interdisciplinary learning* and *problem solving*. The search focused on studies examining these concepts within formal educational contexts and providing information concerning their pedagogical application or reported educational effects.

The analysis included literature from international and Bulgarian research contexts. The selected studies were subjected to thematic analysis and organized according to five principal analytical dimensions: (1) pedagogical approach and technological environment; (2) learner motivation and engagement; (3) collaboration and communication; (4) creativity and problem-solving; and (5) learning outcomes and educational effectiveness. This classification enabled comparison across different technological and pedagogical approaches and identification of areas of convergence and divergence.

A further analytical dimension concerned the relationship between technological tools and pedagogical design. This distinction was considered important because the educational value of a technology-supported intervention depends not only on the technology itself, but also on its integration with clearly defined learning objectives and meaningful learning activities. The analysis therefore examined the extent to which the reviewed approaches connected technological affordances with active participation, interdisciplinary learning and practical knowledge application.

Finally, the identified findings were synthesized comparatively to develop an integrated conceptual framework connecting technological affordances, strategic pedagogical design, learner engagement, learning processes and educational outcomes. The framework is intended not as a causal model derived from a single empirical dataset, but as an analytical synthesis of the reviewed literature and a basis for identifying directions for future empirical research.

3. RESULTS

The thematic analysis of the reviewed literature indicates that technology-enhanced active learning is developing around several interconnected pedagogical approaches rather than around individual technological tools. Four major dimensions were identified: gamification, educational escape rooms, STE(A)M-based learning and artificial intelligence. Across these dimensions, the most frequently discussed educational effects concern learner motivation and engagement, collaboration, creativity, problem-solving and the application of knowledge in meaningful contexts. At the same time, the reviewed studies indicate that the effects of technology-supported interventions depend strongly on their pedagogical design and the learning context in which they are implemented.

The reviewed literature indicates a strong relationship between gamification, student motivation and engagement. A meta-analysis of 41 studies involving more than 5,000 participants found an overall positive effect of gamification on learning outcomes, while identifying variation according to discipline, intervention duration, design principles and learning environment (Li et al., 2023). Similarly, Li et al. (2024) found that gamification enhanced intrinsic motivation and perceptions of autonomy and relatedness, although its effect on competency was comparatively limited. A systematic review of K–12 education further emphasizes the importance of design and pedagogical context in determining the effectiveness of gamified learning (Dehghanzadeh et al., 2024). Thus, gamification should not be regarded as an automatic mechanism for improving academic achievement, but rather as a means of supporting participation and sustained engagement.

This interpretation is consistent with Mishkova-Yotova (2023), who examines the integration of game elements through the educational escape room. Here, game mechanics are connected to educational objectives within a structured learning activity, linking motivation and active participation with the completion of educational tasks.

The analysis identifies educational escape rooms as a promising form of technology-supported and game-based active learning, combining educational objectives with challenges, puzzles, time constraints, collaboration and contextualized problem solving. A recent meta-analysis found positive effects across several educational outcomes, while indicating that effectiveness varies according to design and implementation conditions (Kim et al., 2024). Similarly, Vorderbermeier et al. (2024) highlight the need for stronger integration of learning theories, didactic design and practical implementation, reinforcing the importance of designing escape rooms around explicit learning objectives rather than primarily as entertaining or motivational activities.

Educational escape rooms can also extend beyond subject-specific knowledge by supporting communication, teamwork, decision-making and practical knowledge application. Mishkova-Yotova (2022) demonstrates their applicability in foreign-language education, where the learning environment is transformed into an interactive and problem-oriented space that encourages collaboration and active participation.

Their interdisciplinary potential is further demonstrated by Mishkova-Yotova and Borisova (2023), who combine art and mathematics within an educational escape room. By requiring knowledge from different subject areas to be applied within a common learning task, this approach illustrates how escape rooms can serve as a bridge between gamification, experiential learning and interdisciplinary education.

The analysis of STE(A)M literature identifies interdisciplinary integration as a central characteristic, although evidence concerning its practical implementation in schools remains uneven (White & Delaney, 2021). Other reviews similarly highlight interdisciplinary integration, creativity and meaningful knowledge application as important dimensions of STEAM education (Sanz-Camarero et al., 2023).

Gamification can complement this interdisciplinary and applied character of STEM education. Mursalin et al. (2024) identify positive associations between game elements and student motivation, engagement and learning outcomes, while also highlighting their potential to support collaborative learning. Their findings emphasize the importance of contextualization and pedagogical design, suggesting that gamification can function as a complementary mechanism within STEM learning rather than as an isolated motivational technique.

STE(A)M activities are particularly compatible with active learning environments in which students investigate, design, create and solve authentic problems. This relationship is reflected in the research of Aleksieva and Mishkova-Yotova (2025), which examines the integration of STEM education and educational escape rooms in primary education. Their work demonstrates the potential of combining interdisciplinary STEM content with the problem-solving and collaborative characteristics of the escape-room format. Educational escape rooms can therefore be viewed not only as gamified activities but also as potential environments for implementing interdisciplinary STE(A)M learning.

Artificial intelligence represents a rapidly developing dimension of technology-enhanced education. Recent research explores its applications in personalised learning, feedback, content generation, assessment and learner support. A systematic review of generative AI in teaching and learning highlights the rapid growth of research and the need for clearer frameworks for its educational integration (Ogunleye et al., 2024). Similarly, empirical research in science education identifies AI as a technology with potential implications for instruction, assessment and learning processes, while emphasizing the need for further investigation (Almasri, 2024).

The educational value of AI, however, depends on its pedagogical integration rather than technological functionality alone. Although generative AI can provide individualized assistance, rapid feedback and

interactive learning opportunities, concerns regarding academic integrity, reliability, student dependence, teacher competencies and responsible use remain significant. AI should therefore be considered a component of a broader pedagogical model rather than a replacement for instructional design or the teacher's role.

Comparison of the four dimensions reveals several common characteristics. Motivation and engagement are most consistently associated with gamification and educational escape rooms, while collaboration and problem-solving are particularly prominent in escape-room and STE(A)M activities. STE(A)M emphasizes creativity and interdisciplinary application of knowledge, whereas artificial intelligence adds opportunities for personalisation and adaptive support alongside new ethical and pedagogical challenges. Overall, the findings suggest that the potential of technology-enhanced active learning lies primarily in the integration of complementary approaches rather than in any single technology or pedagogical technique.

4. DISCUSSIONS

The findings of the present review suggest that technology-enhanced education is increasingly moving from the isolated use of digital tools towards the intentional integration of technology, pedagogical design and learner-centred activities. Although gamification, educational escape rooms, STE(A)M education and artificial intelligence represent distinct approaches, their applications share a common emphasis on active participation, meaningful tasks and the practical application of knowledge.

A central implication of the reviewed literature is that technology should be considered an enabler of pedagogical processes rather than an educational objective in itself. The effects of gamification depend on how game elements are connected with learning objectives and the educational context (Li et al., 2023; Li et al., 2024). Educational escape rooms illustrate this principle by combining game-based activities with structured learning tasks and collaboration. Mishkova-Yotova (2022) demonstrates this approach in foreign-language education, while Mishkova-Yotova (2023) emphasizes the integration of game elements into structured learning activities. Thus, the educational value of escape rooms lies in their pedagogical design rather than in their recreational characteristics.

The interdisciplinary dimension further increases the relevance of educational escape rooms. Mishkova-Yotova and Borisova (2023) demonstrate how an escape-room format can connect art and mathematics within a common learning task, while Aleksieva and Mishkova-Yotova (2025) demonstrate its potential in STEM-oriented primary education. These applications correspond to the broader principles of STE(A)M education, in which knowledge from different disciplines is functionally connected through meaningful problems. Educational escape rooms may therefore provide a practical context for integrating gamification, experiential learning and interdisciplinary education.

The review also indicates that digitalization represents a broader dimension of educational transformation. The study of Mishkova-Yotova (2024) concerning the “Shkolo” educational platform illustrates that digital transformation extends beyond individual classroom activities to the organization of educational processes. Consequently, effective technology-enhanced learning requires alignment between technological infrastructure, teacher competencies, pedagogical practices and institutional support.

Artificial intelligence introduces an additional dimension to this transformation. Generative and adaptive AI systems can potentially support personalisation, differentiated learning materials, feedback and interactive educational experiences. These possibilities create opportunities for combining AI with gamification, educational escape rooms and STE(A)M activities. However, such applications should currently be regarded as emerging opportunities rather than established educational effects. The reviewed literature also highlights significant questions concerning reliability, ethics, academic integrity and the appropriate role of AI in learning (Almasri, 2024; Ogunleye et al., 2024).

An important implication is therefore that the four approaches should not be viewed as competing alternatives, but rather as complementary components of an integrated learning environment. Gamification primarily contributes motivational and engagement mechanisms; educational escape rooms provide a structured experiential and collaborative environment; STE(A)M contributes interdisciplinary content and authentic problem contexts; and artificial intelligence can provide personalisation, adaptive feedback and additional learner support. Based on the synthesis of the reviewed literature, the present review proposes an integrated conceptual framework in which technological affordances constitute the enabling layer, strategic pedagogical design transforms these affordances into meaningful learning activities, and active learner participation supports collaboration, creativity, problem-solving and practical knowledge application. Within this framework, the four approaches are conceptualized as complementary mechanisms within a broader learner-centred system. The proposed pathway from technology to competency development is illustrated in Figure 1.

Figure 1. The Path to Competency: Transforming Technology into Learning Outcomes.



Source: Researched by the author; visualized with Google NotebookLM and subsequently reviewed and adapted by the author.

The proposed framework also highlights several research gaps. Further empirical evidence is needed to determine whether the combined use of these approaches produces stronger learning outcomes than their individual application. Longitudinal research is particularly needed to establish whether increased motivation and engagement translate into sustained learning and competency development. Future studies should also examine how the effectiveness of integrated technology-enhanced environments varies according to learners' age, prior knowledge, digital competence and educational context. The rapid development of artificial intelligence further requires continuous examination of its ethical and pedagogical boundaries.

The Bulgarian research context provides a relevant basis for future investigations. The studies of Mishkova-Yotova and her collaborators demonstrate applications of educational escape rooms in foreign-language, interdisciplinary and STEM-oriented contexts, while her research on digitalization illustrates the broader transformation of the Bulgarian educational environment (Mishkova-Yotova, 2022, 2023, 2024; Mishkova-Yotova & Borisova, 2023; Aleksieva & Mishkova-Yotova, 2025). Together, these contributions illustrate a developing research trajectory in which innovative pedagogical models and digital technologies form part of broader educational transformation.

The evidence should nevertheless be interpreted cautiously, as differences in research designs, samples, educational levels and outcome measures limit direct comparison between studies. Positive effects on motivation or engagement should not automatically be interpreted as evidence of long-term academic achievement. Future research should therefore prioritize comparative and longitudinal designs, standardized outcome measures and transparent reporting.

Overall, the discussion indicates that the central challenge of technology-enhanced education is not whether technology should be used, but how it should be pedagogically designed and integrated. The convergence of gamification, educational escape rooms, STE(A)M and artificial intelligence offers considerable potential, provided that technological innovation remains connected to clearly defined educational purposes.

5. CONCLUSIONS

The present review demonstrates that technology-enhanced active learning should be understood as a pedagogical transformation rather than simply the introduction of new digital tools. Gamification, educational escape rooms, STE(A)M education and artificial intelligence offer complementary opportunities to support learner engagement, collaboration, creativity, problem-solving and the meaningful application of knowledge. Their educational potential depends primarily on the relationship between technological affordances and clearly defined pedagogical objectives.

The Bulgarian research of Mishkova-Yotova and her collaborators provides relevant examples of educational escape rooms in foreign-language, interdisciplinary and STEM-oriented contexts, alongside research on digitalization in Bulgarian schools (Mishkova-Yotova, 2022, 2023, 2024; Mishkova-Yotova & Borisova, 2023; Aleksieva & Mishkova-Yotova, 2025). These contributions form part of the broader development of technology-enhanced and learner-centred education.

The integrated conceptual framework proposed in this review conceptualizes gamification, educational escape rooms, STE(A)M and artificial intelligence as complementary components of a learner-centred environment, connecting technological affordances and strategic pedagogical design with active learner participation, skill

development and competency development. The framework may provide a basis for designing and evaluating future technology-supported educational interventions. In practice, technologies should be selected according to learning objectives rather than technological novelty, while institutions should support innovation through teacher preparation, pedagogical development and digital competencies.

Future research should empirically examine whether the combined use of these approaches produces measurable advantages over their separate implementation. Longitudinal and comparative studies are particularly needed to investigate differences across educational levels and learner characteristics and to determine whether increased engagement translates into sustained learning and competency development. Such research could contribute to evidence-based models of integrated technology-enhanced education.

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