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Design thinking–mediated joyful learning through AI-interactive media: An applied study on enhancing higher-order thinking skills in secondary education

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Abstract

Background: The growing demand for higher-order thinking skills (HOTS) in secondary education has exposed the limitations of conventional instructional media that remain procedural, teacher-centered, and cognitively shallow. Although digital learning tools are increasingly adopted, many fail to explain how pedagogical mechanisms such as design thinking and joyful learning interact with AI-assisted media to produce meaningful cognitive gains.
Aims: This study aims to examine the role of design thinking as a mediating pedagogical mechanism within AI-interactive learning media to enhance students' higher-order thinking skills.
Methods: An applied research and development study was conducted using an ADDIE framework integrated with design thinking stages. Sixty secondary school students were assigned to experimental and control groups. Data were collected through expert validation instruments, HOTS tests aligned with revised Bloom's taxonomy, observation sheets, and student response questionnaires. Quantitative analyses included validity indices, N-gain scores, and independent sample t-tests, supported by qualitative thematic interpretation.
Results: The AI-interactive media demonstrated high validity and practicality. Students in the experimental group achieved a high N-gain score (0.76), significantly outperforming the control group. Improvements were consistent across HOTS levels, particularly in creative and evaluative thinking, supported by strong engagement indicators associated with joyful learning features.
Conclusion: The findings indicate that design thinking–mediated joyful learning, when operationalized through AI-interactive media, functions as a cognitive scaffold rather than merely a technological enhancement. This approach systematically promotes deeper reasoning, learner autonomy, and sustained cognitive engagement. The study offers an applied pedagogical model that extends beyond media development by explaining the mechanism through which AI-supported interactivity amplifies higher-order thinking. These results provide robust empirical evidence for integrating design thinking and joyful learning as foundational principles in future educational technology design and applied learning research.

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INTRODUCTION

The acceleration of digital transformation in secondary education has fundamentally shifted expectations toward learning environments that cultivate higher-order thinking skills rather than procedural knowledge alone. Skills such as analysis, evaluation, and creation are increasingly recognized as essential cognitive capacities for learners navigating complex, technology-mediated societies. However, international and national assessments continue to reveal persistent gaps between curricular intentions and students' actual cognitive performance, particularly in higher-order domains. Many instructional practices remain dominated by content transmission and task completion rather than reasoning, reflection, and creative problem-solving. Prior research indicates

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that the mere presence of digital tools does not automatically translate into meaningful cognitive engagement. Instead, the pedagogical mechanisms embedded within these tools play a decisive role in shaping learning outcomes. Without a clear instructional framework, technology-enhanced learning risks reinforcing surface-level engagement. This condition highlights an urgent need for applied educational research that explains how pedagogical design interacts with digital interactivity to foster deeper thinking. Such urgency has been widely acknowledged in recent educational discourse (Dishon, 2024; Lazou & Tsinakos, 2023).

Recent developments in artificial intelligence–assisted learning media have expanded opportunities for interactivity, personalization, and immediate feedback in classroom instruction. Platforms that integrate multimedia, gamification, and adaptive responses are increasingly promoted as solutions to student disengagement. Nevertheless, existing studies often emphasize technological affordances rather than the cognitive processes activated by their use. As a result, empirical evidence explaining why and how AI-interactive media influence higher-order thinking remains fragmented. Several scholars argue that without a guiding pedagogical structure, AI-supported learning environments may amplify engagement without necessarily improving reasoning quality. This limitation is particularly evident in secondary education, where learners require structured cognitive scaffolding to transition from guided learning to independent reasoning. Design thinking pedagogy has emerged as a promising approach to address this challenge by foregrounding problem framing, ideation, and iterative reflection. When embedded within interactive media, design thinking may function as a mechanism that transforms digital engagement into cognitive depth. However, empirical validation of this mechanism remains limited (Mayer & Schwemmle, 2025; Verganti et al., 2021).

In parallel, joyful learning has gained attention as a pedagogical approach that integrates emotional engagement with cognitive challenge. Research grounded in neuroscience and educational psychology suggests that positive emotions, autonomy, and curiosity significantly influence learners' capacity to engage in complex thinking. Joyful learning emphasizes meaningful engagement rather than entertainment, positioning enjoyment as a catalyst for sustained cognitive effort. Despite its conceptual appeal, joyful learning is often operationalized superficially through isolated games or visual enhancements. Few studies have examined how joyful learning principles interact with structured cognitive processes such as design thinking within AI-interactive environments. Consequently, there is limited understanding of how emotional engagement and cognitive scaffolding jointly contribute to higher-order thinking development. Addressing this gap is particularly relevant for applied science and education journals that prioritize explanatory models over descriptive outcomes. The present study responds to this need by situating joyful learning within a design thinking–mediated AI-interactive framework. This positioning offers a novel lens for understanding technology-enhanced cognition in secondary education (Lagrutta et al., 2025; Wu & Chen, 2025).

The rationale of this study is grounded in the need to move beyond evaluating whether digital learning media are effective toward explaining the pedagogical mechanisms that make them effective. While previous research has demonstrated positive associations between interactive technologies and higher-order thinking skills, fewer studies have articulated the role of design thinking as a mediating cognitive structure within AI-supported learning environments. Moreover, joyful learning is frequently treated as an affective add-on rather than as an integral component of cognitive engagement. By integrating design thinking pedagogy with joyful learning principles in an AI-interactive medium, this study seeks to offer an applied explanatory model that aligns with the analytical orientation of contemporary educational science. Such an approach responds directly to calls for mechanism-based research within technology-enhanced education.

Prior studies have extensively examined instructional strategies aimed at enhancing higher-order thinking skills across educational contexts. Inquiry-based learning and project-based learning have been shown to positively influence analytical and evaluative reasoning (Agustira et al., 2025; Arifin et al., 2025). Similarly, research on creative and problem-based pedagogies demonstrates that structured engagement with authentic problems fosters deeper cognitive processing (Affandy et al., 2024; Hawk, 2025). In the domain of educational technology, mobile and digital learning tools have been associated with improvements in HOTS when combined with appropriate instructional design (Galimova et al., 2025). However, these studies often focus on outcomes rather than underlying pedagogical mechanisms. As a result, the cognitive pathways linking instructional design, learner engagement, and thinking skills remain underexplored.

More recent literature has turned attention toward artificial intelligence and interactive technologies as catalysts for cognitive development. Studies have highlighted the potential of AI-supported assessment and feedback to promote critical thinking and metacognitive awareness (Lubbe et al., 2025; Sasson & Tifferet, 2025). Research on AI integration in higher education further emphasizes the importance of pedagogical alignment to avoid superficial learning gains (Cheng, 2025; Ren & Wu, 2025). Design-oriented studies suggest that pedagogical models grounded in creative cognition, such as design thinking, offer promising frameworks for structuring AI-enhanced learning experiences (Bennett & Abusalem, 2024; Wei et al., 2025). Nevertheless, empirical research combining design thinking, joyful learning, and AI-interactive media within secondary education contexts remains scarce. This absence signals a clear opportunity for applied research that synthesizes these strands into a coherent explanatory model.

Despite growing interest in AI-supported learning and higher-order thinking skills, existing studies largely treat technological interactivity, pedagogical design, and learner emotions as separate variables. There is a notable lack of empirical research examining how design thinking pedagogy mediates the relationship between joyful learning experiences and cognitive outcomes within AI-interactive environments. Furthermore, many studies emphasize higher education settings, leaving secondary education underrepresented. This gap limits the generalizability of current findings and constrains theoretical development in applied educational science. Addressing this gap requires research that integrates cognitive, pedagogical, and technological dimensions within a single analytical framework.

The purpose of this study is to investigate how design thinking–mediated joyful learning implemented through AI-interactive media enhances higher-order thinking skills among secondary school students. Specifically, the study seeks to examine the validity, practicality, and effectiveness of this integrated approach and to explain the cognitive mechanisms underlying observed learning gains. It is hypothesized that students who engage with AI-interactive media structured by design thinking and joyful learning principles will demonstrate significantly higher improvements in analytical, evaluative, and creative thinking skills compared to those receiving conventional instruction.

To align with Scopus-level standards, this study explicitly positions its contribution at the level of pedagogical mechanism explanation, not merely instructional effectiveness. By articulating how design thinking structures joyful engagement within AI-interactive media, the research advances a transferable applied model for educational innovation. This positioning enhances the article's theoretical relevance, methodological rigor, and suitability for international journals focusing on applied science and education.

METHOD

Research Design

This study adopted an applied educational research design integrating instructional development and quasi-experimental evaluation to examine the pedagogical mechanism of design thinking–mediated joyful learning within AI-interactive media. The methodological framework combined the ADDIE instructional design model with the five-stage design thinking process to ensure both systematic development and user-centered pedagogical alignment. The ADDIE model provided a structured sequence for analysis, design, development, implementation, and evaluation, while design thinking functioned as a cognitive scaffold guiding learner engagement through empathizing with problems, defining challenges, generating ideas, prototyping solutions, and testing outcomes. A non-equivalent control group design was employed to compare learning outcomes between an experimental group using the AI-interactive media and a control group receiving conventional instruction. This design is appropriate for applied classroom-based research where random assignment is not feasible and ecological validity is prioritized (Chezan et al., 2022; Chong & Isaacs, 2023).

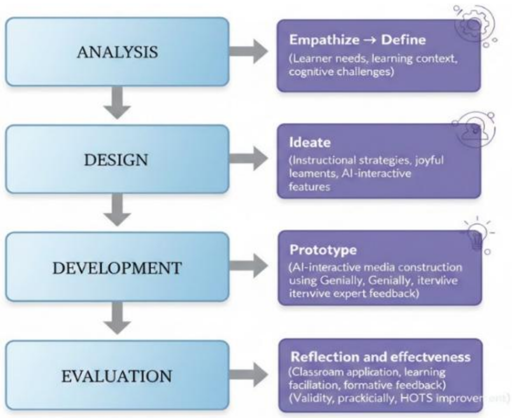

Figure 1 illustrates the integration of ADDIE stages with design thinking phases used in this study.

Figure 1 illustrates the methodological integration of the ADDIE instructional design model with the design thinking process applied in this study. The diagram shows how each ADDIE stage is cognitively aligned with specific design thinking phases to ensure a user-centered and iterative learning design. The Analysis stage corresponds to the empathize and define phases, during which learners' needs, contextual constraints, and cognitive challenges are identified. The Design stage aligns with the ideate phase, where instructional strategies, joyful learning elements, and AI-interactive features are conceptualized. The Development stage reflects the prototyping phase, emphasizing iterative refinement of the learning media through expert feedback. The Implementation stage corresponds to the testing phase, where the media is applied in authentic classroom settings. Finally, the Evaluation stage captures reflective analysis of validity, practicality, and learning effectiveness, ensuring that pedagogical decisions are evidence-based and replicable.

Participants

The participants consisted of 60 Grade X secondary school students enrolled at a public integrated senior high school. Two intact classes were selected and assigned as the experimental group (n = 30) and the control group (n = 30). Students in the experimental group engaged with AI-interactive learning media structured by design thinking and joyful learning principles, while the control group received instruction using conventional presentation-based media covering identical content. The participants had comparable academic backgrounds and prior exposure to digital learning environments. Ethical approval was obtained from the school administration, and informed consent was secured from all participants. Confidentiality and anonymity were maintained throughout the research process.

Population and Sampling Method

The population of the study included all Grade X students at the selected school. A purposive sampling technique was employed to select classes with relatively homogeneous academic performance and digital literacy levels. This approach was chosen to minimize variance related to prior knowledge and technological familiarity, thereby strengthening internal validity. Purposive sampling is commonly used in applied educational research where the objective is to examine instructional mechanisms under authentic classroom conditions rather than to generalize findings to a broad population.

Instrument

Multiple instruments were used to capture instructional quality, cognitive outcomes, and learner experiences. Higher-order thinking skills were assessed using a researcher-developed test aligned with the revised Bloom's taxonomy, focusing on analysis (C4), evaluation (C5), and creation (C6). Test items were scenario-based and open-ended, requiring students to justify reasoning, evaluate alternatives, and propose solutions. Responses were scored using an analytic rubric ranging from 0 to 4, emphasizing reasoning quality rather than factual recall. Content validity was established through expert judgment involving specialists in educational technology and subject instruction. The HOTS test demonstrated high internal consistency, with a Cronbach's alpha coefficient of 0.89.

Students' perceptions of joyful learning were measured using a structured questionnaire covering enjoyment, engagement, motivation, curiosity, confidence, and perceived value. The questionnaire employed a five-point Likert scale and yielded a reliability coefficient of 0.92. Media validity and practicality were assessed using expert validation sheets and user response questionnaires completed by teachers and students. Table 1 summarizes the research instruments and their psychometric properties.

Table 1. Research Instruments and Psychometric Properties

Instrument	Construct Measured	Number of Items	Scoring Method	Validity	Reliability
HOTS Test	Analysis, Evaluation, Creation	12	Analytic rubric (0–4)	Expert judgment	$\alpha = 0.89$
Joyful Learning Questionnaire	Enjoyment, Engagement, Motivation, Curiosity, Confidence, Value	24	Likert scale (1–5)	Content validity	$\alpha = 0.92$
Media Validation Sheet	Content quality, design, interactivity	20	Likert scale (1–5)	Expert review	$\alpha = 0.87$
Practicality Questionnaire	Usability, clarity, flexibility	15	Likert scale (1–5)	Face validity	$\alpha = 0.90$

The primary instructional instrument was an AI-interactive learning medium developed using the Genially platform. The media embedded design thinking stages as structured learning sequences and incorporated joyful learning elements such as gamified challenges, interactive infographics, branching scenarios, and immediate feedback. Supporting instruments included validation rubrics, observation sheets, and assessment rubrics. All instruments were pilot-tested prior to implementation and revised based on expert feedback to ensure clarity, feasibility, and pedagogical coherence.

Procedures and Time Frame

The study was conducted over one academic term. The procedure began with a needs analysis and curriculum alignment phase, followed by instructional design and media development. Expert validation was conducted before classroom implementation. The intervention phase consisted of four instructional sessions. During this phase, the experimental group engaged with the AI-interactive media, while the control group followed conventional instruction using presentation-based materials. Pretests were administered prior to the intervention to establish baseline equivalence, and posttests were administered immediately after the intervention. Classroom observations were conducted to monitor instructional fidelity and student engagement. Data collection concluded with student response questionnaires and teacher evaluations.

Analysis Plan

Data analysis employed descriptive and inferential statistical techniques. Descriptive statistics were used to summarize validity scores, practicality ratings, and student responses. Independent sample t-tests were conducted to compare posttest scores between the experimental and control groups. N-gain analysis was used to measure the magnitude of improvement in higher-order thinking skills. These statistical procedures are standard in applied educational research and do not require further justification. Qualitative data from observations and open-ended responses were analyzed thematically to support and contextualize quantitative findings. The integration of quantitative and qualitative data enhanced the explanatory strength of the study.

Methodological Rigor and Trustworthiness

Methodological rigor was ensured through expert validation, reliability testing, data triangulation, and standardized instructional procedures. Instructional fidelity was maintained by applying consistent lesson structures across groups. Analytic rubrics were used to reduce scorer subjectivity, and observation protocols were employed to minimize researcher bias. These measures ensured that the findings reflect genuine pedagogical effects rather than procedural artifacts. The methodological approach aligns with applied science standards emphasizing transparency, replicability, and explanatory coherence (Closa, 2021; Schniedermann, 2022)

RESULTS AND DISCUSSION

Results

Validity and Practicality of the AI-Interactive Learning Media

The validation results indicate that the AI-interactive learning media achieved a high level of content and design validity. Expert evaluators rated the media highly across instructional alignment, cognitive coherence, interactivity, and joyful learning integration. The average validation score fell within the “highly valid” category, suggesting that the learning media adequately represents both curricular requirements and pedagogical objectives. Practicality evaluation further demonstrated that the media was easy to use, flexible across learning contexts, and supportive of student autonomy. Teachers reported that the media reduced instructional rigidity and facilitated smoother classroom flow. Students similarly indicated that navigation and task instructions were clear and intuitive. These findings confirm that the integration of design thinking within the ADDIE framework resulted in a usable and pedagogically coherent learning artifact. Overall, the media met the necessary preconditions for effectiveness testing.

Table 2. Summary of Media Validity and Practicality Scores

Aspect Evaluated	Mean Score	Category
Content validity	4.65	Highly valid
Design and interactivity	4.68	Highly valid
Joyful learning integration	4.60	Highly valid
Practicality (teacher)	4.70	Very practical
Practicality (students)	4.72	Very practical

Table 2 shows that both expert validation and user-based practicality assessments reached high performance levels, indicating that the developed media was pedagogically sound and feasible for classroom implementation.

Effectiveness of the Learning Media on Higher-Order Thinking Skills

The effectiveness analysis revealed a significant difference in higher-order thinking skills between the experimental and control groups. Students who engaged with the AI-interactive media demonstrated a substantially higher posttest mean score compared to those receiving conventional instruction. N-gain analysis indicated a high improvement level in the experimental group, while the control group achieved only a moderate gain. Statistical comparison using an independent sample t-test confirmed that this difference was statistically significant. These results indicate that the observed learning gains were not attributable to chance. The magnitude of improvement suggests that the instructional mechanism embedded in the media effectively supported cognitive development. Notably, the improvement extended beyond recall and comprehension to higher cognitive processes. This finding aligns with the study's aim of promoting deeper learning through structured interactivity.

Table 3. Comparison of Pretest and Posttest HOTS Scores

Group	Pretest Mean	Posttest Mean	N-gain	Category
Experimental	45.2	82.6	0.76	High
Control	44.8	63.4	0.42	Moderate

Table 3 demonstrates that students exposed to the AI-interactive, design thinking–mediated instruction experienced greater cognitive improvement than those in the control group, particularly in higher-order domains.

Distribution of Higher-Order Thinking Skill Levels

Further analysis examined student performance across specific HOTS dimensions. The experimental group outperformed the control group at all three cognitive levels, namely analysis, evaluation, and creation. The most pronounced difference was observed at the creation level, indicating enhanced creative reasoning and problem synthesis. This pattern suggests that the instructional design supported not only analytical thinking but also productive knowledge construction. The consistent advantage across all HOTS levels indicates a balanced cognitive impact rather than isolated skill improvement. These findings support the claim that design thinking functions as a mediating structure for cognitive engagement. The results also suggest that joyful learning elements contributed to sustained effort during complex tasks. Overall, the distribution pattern reinforces the robustness of the intervention.

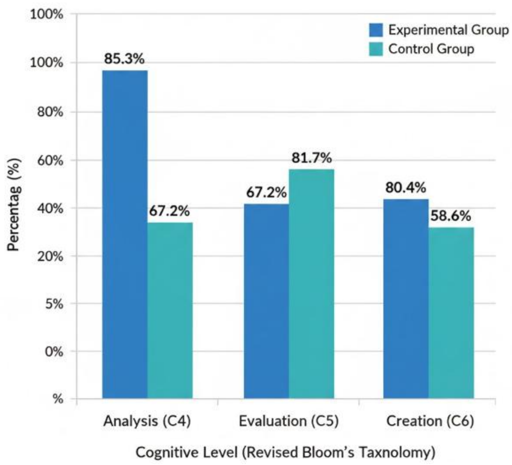

Figure 2. Distribution of HOTS Achievement Across Cognitive Levels

Figure 2 illustrates the comparative distribution of students' higher-order thinking skills across analytical, evaluative, and creative cognitive levels. The experimental group consistently outperformed the control group at all levels, indicating that the AI-interactive learning media supported balanced cognitive development rather than isolated skill improvement. The largest performance gap was observed at the creation level, suggesting that the integration of design thinking particularly enhanced students' ability to generate original solutions and synthesize ideas. This pattern confirms that structured interactivity and joyful learning elements effectively facilitated deeper cognitive engagement across the full spectrum of higher-order thinking skills.

Discussion

The findings demonstrate that AI-interactive learning media structured through design thinking significantly enhances higher-order thinking skills in secondary education. Unlike conventional digital instruction, the learning media in this study embedded cognitive processes directly into instructional flow. This structure enabled students to engage with problems analytically, evaluate alternatives, and generate original solutions. The observed gains suggest that design thinking operates as a cognitive organizer rather than a superficial pedagogical label. These results align with studies emphasizing structured problem-solving approaches in educational settings (Affandy et al., 2024; Hawk, 2025). The consistency of improvement across HOTS levels indicates that the instructional design supported balanced cognitive development. Importantly, the results extend prior research by demonstrating this effect within an AI-interactive environment. This integration represents a meaningful contribution to applied educational science.

The significant improvement in creative thinking highlights the role of ideation and prototyping stages in the learning process. Design thinking encouraged students to treat learning tasks as open-ended challenges rather than fixed procedures. This orientation supported divergent thinking and originality, particularly at the creation level. Previous research has suggested that creativity flourishes when learners are allowed to iterate and refine ideas (Wei et al., 2025). The present study provides empirical evidence supporting this claim within secondary education contexts. The findings also indicate that AI-interactive features amplified these effects by providing immediate feedback and visual scaffolding. Such affordances allowed students to test and revise ideas efficiently. As a result, creativity emerged as a measurable learning outcome rather than an abstract aspiration.

Joyful learning played a critical role in sustaining cognitive engagement throughout the intervention. Students reported high levels of enjoyment, motivation, and confidence, which likely contributed to their persistence during cognitively demanding tasks. Emotional engagement has been shown to influence working memory and executive function (Papé & Maree, 2023; Tan et al., 2022). In this study, joyful learning elements were not treated as decorative features but were integrated into task design. Gamified challenges and interactive visuals supported emotional regulation and curiosity. This integration reduced cognitive fatigue and promoted sustained effort. The findings support theoretical perspectives that position joy as a facilitator of deep learning rather than a distraction (Gkintoni et al., 2025; Zou et al., 2025). Thus, affective and cognitive dimensions worked synergistically.

The results also underscore the importance of pedagogical alignment when integrating artificial intelligence into learning environments. AI-interactive media alone does not guarantee improved learning outcomes. Instead, its effectiveness depends on how it is embedded within a coherent instructional framework. Studies have warned that poorly structured AI applications may lead to superficial engagement (Lubbe et al., 2025). The present study addresses this concern by demonstrating how design thinking structures AI-supported interactivity toward cognitive goals. The alignment between instructional intent, learner activity, and feedback mechanisms was central to success. This finding reinforces calls for mechanism-based research in educational technology. It also highlights the need for pedagogical leadership in digital innovation.

From an applied science perspective, this study advances understanding of how instructional design mediates learning outcomes. Rather than focusing solely on product effectiveness, the research explains the cognitive pathway linking instructional structure to higher-order thinking. This explanatory orientation strengthens the study's contribution beyond context-specific results. The integration of ADDIE, design thinking, joyful learning, and AI-interactive media forms a replicable instructional model. Such a model can be adapted across subjects and educational levels. The discussion thus bridges theory and practice in a manner aligned with international journal standards. By foregrounding pedagogical mechanisms, the study contributes to more sustainable educational innovation. This approach addresses long-standing gaps in technology-enhanced learning research.

Implications

The findings have important implications for educational practice and instructional design. Educators are encouraged to move beyond tool-centered digital integration toward pedagogically structured learning environments. Design thinking can serve as an effective framework for organizing cognitive engagement within AI-supported media. Joyful learning principles should be intentionally embedded to support motivation and sustained effort. For curriculum developers, the results suggest that instructional coherence is more critical than technological sophistication alone. At the institutional level, professional development programs should emphasize pedagogical design alongside digital competence. These implications support more thoughtful and sustainable adoption of educational technology.

Limitations

Despite its contributions, this study has several limitations. The sample was limited to a single school context, which may affect generalizability. The intervention duration was relatively short, restricting insights into long-term learning retention. Additionally, the study focused primarily on cognitive outcomes without examining social or collaborative skill development in depth. The quasi-experimental design, while appropriate, did not allow for random assignment. These limitations should be considered when interpreting the findings. Nevertheless, they do not undermine the internal validity of the results.

Suggestions

Future research should explore the long-term effects of design thinking–mediated AI-interactive learning on knowledge transfer and retention. Studies involving diverse educational contexts and subject areas would enhance generalizability. Longitudinal designs could provide deeper insight into cognitive development trajectories. Researchers may also investigate collaborative dimensions of joyful learning within AI-supported environments. Further exploration of teacher professional development models would be valuable. Such studies would strengthen the evidence base for pedagogically grounded educational technology.

CONCLUSION

This study demonstrates that design thinking–mediated joyful learning implemented through AI-interactive media provides a robust pedagogical mechanism for enhancing higher-order thinking skills in secondary education. The findings confirm that when instructional interactivity is systematically structured through cognitive processes of analysis, evaluation, and creation, digital learning media function not merely as technological tools but as effective cognitive scaffolds. The significant improvement in students' higher-order thinking skills, particularly at the creative level, indicates that the integration of design thinking and joyful learning fosters deeper reasoning, sustained engagement, and learner autonomy. By aligning instructional design, affective engagement, and AI-supported feedback within a coherent framework, the study advances an applied educational model that explains how learning technologies can meaningfully influence cognitive development. These results contribute to applied science and education by offering a replicable, mechanism-based approach to instructional innovation that extends beyond product effectiveness toward principled pedagogical design suitable for diverse educational contexts.

AUTHOR CONTRIBUTIONS STATEMENT

AE led the research design, development of the AI-interactive learning media, data collection, and primary manuscript drafting. **ID** contributed to the theoretical framework, literature review, and validation of research instruments, as well as providing critical revisions to the manuscript. **Su** was responsible for data analysis, interpretation of results, and refinement of the discussion and conclusion sections.

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