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Integrating STEAM Principles in E-Book Design for Game Development Learning: A Systematic Literature Review

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Abstrak
Integrasi prinsip-prinsip Science, Technology, Engineering, Arts, dan Mathematics (STEAM) ke dalam sumber belajar digital telah mendapatkan perhatian yang semakin besar dalam pendidikan menengah, terutama dalam pembelajaran pengembangan game pada Fase F (Kelas XI). Studi ini bertujuan untuk melakukan tinjauan sistematis terhadap literatur mengenai desain dan implementasi pedagogis buku elektronik berbasis STEAM untuk pendidikan pengembangan game. Tinjauan literatur sistematis dilakukan dengan menganalisis artikel jurnal yang telah direview oleh rekan sejawat dan terindeks di basis data akademik utama, termasuk Scopus, Web of Science, ERIC, dan Google Scholar, yang diterbitkan antara tahun 2015 dan 2024. Studi yang dipilih disaring menggunakan kriteria inklusi dan eksklusi yang telah ditentukan sebelumnya dan dianalisis melalui sintesis tematik kualitatif. Temuan menunjukkan bahwa e-book berbasis STEAM umumnya mengintegrasikan tugas pemecahan masalah interdisipliner, elemen multimedia interaktif, dan aktivitas pembelajaran berbasis proyek yang mendukung pemahaman konseptual dan pengembangan keterampilan kreatif dalam desain game. Hasil pembelajaran yang dilaporkan meliputi peningkatan keterlibatan siswa, peningkatan keterampilan pemikiran komputasional dan desain, serta peningkatan kolaborasi dan kreativitas. Namun, tinjauan ini juga mengidentifikasi kelemahan dalam validasi empiris, dampak pembelajaran jangka panjang, dan keselarasan dengan standar kurikulum tingkat menengah. Studi ini berkontribusi pada diskursus pedagogis dengan mensintesis bukti terkini mengenai desain e-book berorientasi STEAM. Studi ini memberikan rekomendasi bagi pendidik, perancang instruksional, dan penelitian masa depan dalam pengembangan pembelajaran berbasis permainan digital.
Kata Kunci: *Pendidikan STEAM; desain e-book; pembelajaran pengembangan game; pendidikan menengah; tinjauan literatur sistematis.*

Abstract
The integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM) principles into digital learning resources has gained increasing attention in secondary education, particularly in game development learning at Phase F (Grade XI). This study aims to systematically review the literature on the design and pedagogical implementation of STEAM-based e-books for game development education. A systematic literature review was conducted by analysing peer-reviewed journal articles indexed in major academic databases, including Scopus, Web of Science, ERIC, and Google Scholar, published between 2015 and 2024. The selected studies were screened using predefined inclusion and exclusion criteria and analysed through qualitative thematic synthesis. The findings indicate that STEAM-based e-books commonly integrate interdisciplinary problem-solving tasks, interactive multimedia elements, and project-oriented learning activities that support conceptual understanding and the development of creative skills in game design. Reported learning outcomes include improved student engagement, enhanced computational and design thinking skills, and increased collaboration and creativity. However, the review also reveals gaps in empirical validation, long-term learning

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impact, and alignment with secondary-level curriculum standards. This study contributes to the pedagogical discourse by synthesising current evidence on STEAM-oriented e-book design. It offers recommendations for educators, instructional designers, and future research in digital game development learning.
Keywords: *STEAM education; e-book design; game development learning; secondary education; systematic literature review.*

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Introduction

The rapid advancement of digital technology has profoundly transformed secondary education, particularly in disciplines such as game development, which require an amalgamation of technical, creative, and problem-solving skills. In light of these changes, educators are increasingly compelled to design interdisciplinary learning experiences that are both engaging and aligned with real-world contexts. A prominent pedagogical framework that addresses these challenges is Science, Technology, Engineering, Arts, and Mathematics (STEAM) education. This educational model emphasises not only analytical thinking and creativity but also innovation through authentic learning tasks.

Game development learning in the Phase F (Grade XI) curriculum is an opportune context for implementing STEAM principles. This subject inherently combines various skills such as programming logic, system design, artistic visualisation, mathematical reasoning, and the use of technological tools. Studies suggest that STEAM education fosters a holistic and multidisciplinary approach, encouraging students to engage creatively with complex problems and challenges (Aguilera & Ortiz-Revilla, 2021; Flores-Nicolás et al., 2023). The integration of artistic elements into STEM disciplines has also been shown to catalyse improvements in critical thinking, communication, and collaborative skills that are essential for students' future careers (Aguilera & Ortiz-Revilla, 2021). Moreover, the effectiveness of STEAM-oriented instruction hinges significantly on the quality and suitability of the learning media employed. Digital e-books have surfaced as a versatile instructional medium capable of blending text, visuals, simulations, and interactive elements, thereby facilitating a more complex learning process (Aguilera & Ortiz-Revilla, 2021; Özer & Demirbatır, 2023). By designing e-books aligned with STEAM principles, educators can enhance interdisciplinary understanding and promote active learning, particularly in game development contexts.

Despite the growing recognition of STEAM education and digital learning media, there is a significant gap in research focused on the design of STEAM-based e-books for game development education. Current studies vary in their focus, pedagogical strategies, and reported learning outcomes, complicating educators' and instructional designers' efforts to gain comprehensive insights. For instance, a systematic literature review indicates that while STEAM education is gaining traction worldwide, gaps in understanding its applied methodologies remain, particularly in the context of digital tools(Aguilera & Ortiz-Revilla, 2021; Martín-Cudero et al., 2024; Sanz-Camarero et al., 2023).

Further, while methodologies such as game jams have shown promise in fostering teamwork and innovative thinking among students, the literature still lacks a cohesive synthesis of how these methodologies can be systematically integrated into STEAM-oriented e-book design or curricula (Aurava & Meriläinen, 2021; Espinosa & Eguia-Gómez, 2022). This fragmentation underscores the need for a systematic review of the existing literature to identify prevailing design approaches, pedagogical impacts, and areas warranting additional research (Sanz-Camarero et al., 2023). The integration of digital technology into secondary education, particularly through a STEAM lens, offers a compelling framework for enhancing learning across disciplines such as game development. The multifaceted nature of this subject aligns perfectly with the interdisciplinary focus of STEAM education, advancing students' capabilities in various critical skill areas. However, more systematic research is necessary to clarify practical design principles and pedagogical strategies that educators can implement to maximise the potential within this evolving educational landscape.

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This study aims to systematically review and synthesise empirical and conceptual studies on the integration of STEAM principles in e-book design for game development learning at the secondary education level. Specifically, it seeks to address the following research questions: (1) how STEAM principles are integrated into e-book design for game development learning, (2) what pedagogical impacts are reported, and (3) what gaps and future research directions emerge from the literature. The findings of this review are expected to contribute to the theoretical development of STEAM-based digital pedagogy and provide practical guidance for educators, curriculum developers, and future researchers.

Methodology

Research Design

This study employed a Systematic Literature Review (SLR) to synthesise and critically analyse existing research on the integration of STEAM principles into e-book design for game development learning at the secondary education level (Phase F/Grade XI). The SLR approach was selected to ensure methodological rigour, transparency, and replicability, in line with international pedagogical research standards.

Data Sources

The literature search was conducted across several reputable academic databases to ensure comprehensive coverage of relevant studies. These databases included Scopus, Web of Science, ERIC, and Google Scholar. Only peer-reviewed journal articles were considered to maintain the academic quality of the review.

Search Strategy

A structured search strategy was applied, combining keywords such as STEAM education, e-book, digital learning media, game development, game-based learning, and secondary education. Boolean operators (AND, OR) were used to refine the search. The review focused on studies published between 2015 and 2024 to capture recent developments in STEAM-oriented digital learning. Inclusion criteria comprised studies that (1) discussed STEAM integration, (2) involved e-books or digital book–based learning media, and (3) were situated in secondary or equivalent educational contexts. Studies not written in English, conference papers, theses, and non-empirical reports were excluded.

Study Selection Process

The selection process followed a multi-stage screening procedure. Initially, titles and abstracts were reviewed to remove irrelevant and duplicate records. Full-text screening was then conducted to assess eligibility based on the predefined criteria. The selection process was documented using a PRISMA-based flow framework to enhance transparency.

Data Extraction and Analysis

Relevant data were systematically extracted from each selected study, including publication details, research context, methodological approach, STEAM components, e-book design features, and reported learning outcomes. A qualitative thematic analysis was conducted by coding the extracted data and grouping them into key themes related to STEAM integration, pedagogical functions, and learning impacts in game development education.

Results And Discussion

Overview of Selected Studies

This section presents an overview of the studies included in the systematic literature review to provide a general picture of the research landscape on STEAM-based e-books in game development learning. Mapping the characteristics of the selected studies is essential to understand publication trends, educational contexts, and methodological approaches that shape current knowledge in this field, as in Table 1. Such an overview also helps identify dominant research patterns and potential gaps that inform subsequent analysis and discussion.

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Table 1. Overview of Selected Studies (n = 32)

Aspect	Category	Number of Studies	Percentage (%)
Publication Year	2015–2017	4	12.5
	2018–2020	10	31.3
	2021–2024	18	56.2
Educational Level	Secondary education (general)	21	65.6
	Upper secondary vocational	7	21.9
	Pre-university / equivalent	4	12.5
Research Method	Qualitative	14	43.8
	Mixed methods	11	34.4
	Experimental / quasi-experimental	7	21.8

As shown in Table 1, the majority of the reviewed studies were published between 2018 and 2024, reflecting a notable increase in scholarly attention to STEAM-based digital learning media in recent years. This trend suggests that integrating STEAM principles into e-book design is an emerging, rapidly developing research area, particularly in response to digital transformation in education. In the educational context, most studies focused on general secondary education, suggesting that STEAM-based e-books are primarily used as learning resources for mainstream upper secondary students. A smaller proportion of studies addressed vocational and pre-university contexts, which are directly relevant to game development learning but remain comparatively underrepresented.

Regarding methodology, qualitative and mixed-methods approaches dominated the literature, emphasising exploratory analysis, design evaluation, and learner perceptions. Experimental and quasi-experimental studies were less common, indicating a limited body of evidence on causal effects and measurable learning outcomes. This distribution highlights the need for more rigorous empirical research to strengthen the evidence base on the effectiveness of STEAM-based e-books in game development education.

STEAM Integration in E-Book Design

This section analyses how STEAM principles are embedded within e-book designs used for game development learning. Understanding the distribution and depth of STEAM components is essential to evaluate whether e-books truly support interdisciplinary learning or merely emphasise selected domains. The analysis focuses on the representation of each STEAM element and the instructional features used to connect them within game development contexts, as in Table 2.

Table 2. STEAM Integration in E-Book Design Across Reviewed Studies

STEAM Component	Design Focus in E-Books	Number of Studies	Percentage (%)
Science	Simulation, algorithmic thinking, logic modelling	14	43.8
Technology	Programming tutorials, coding simulations, software tools	26	81.3
Engineering	Game mechanics, system design, problem-solving tasks	22	68.8
Arts	Visual design, storytelling, character and interface design	25	78.1
Mathematics	Mathematical modelling, scoring systems, logic structures	13	40.6
Interactive Features	Videos, simulations, design challenges, reflective prompts	28	87.5

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Table 2 shows that Technology and Arts were the most prominently integrated STEAM components in e-book design for game development learning. This reflects the natural alignment of programming skills and visual creativity with game development activities. Engineering elements were also well represented, particularly through system design and game mechanics tasks that require structured problem-solving. In contrast, Science and Mathematics components were less consistently integrated. When present, science-related elements focused on algorithmic reasoning and simulations, while mathematics was often embedded implicitly through logic structures and scoring systems rather than explicit mathematical instruction. This imbalance indicates that many e-books adopt a partial STEAM approach, emphasising practical and creative aspects over analytical foundations.

Interactive features were widely used to support cross-disciplinary connections, suggesting that e-books function not only as content repositories but also as active learning environments. However, the variation in STEAM depth underscores the need for more intentional, balanced design frameworks to ensure comprehensive interdisciplinary learning in game development education. The working concept is as shown in Figure 1.

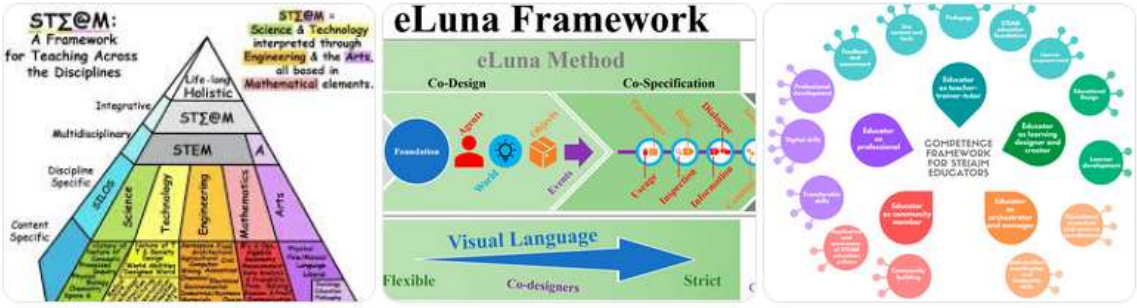

Figure 1. STEAM Integration Framework in E-Book Design for Game Development Learning

Figure 1 illustrates a conceptual framework of **STEAM integration in e-book design for game development learning**. The model positions the **STEAM components (Science, Technology, Engineering, Arts, and Mathematics)** as interconnected domains that collectively support game development competencies.

- **Technology** and **Engineering** form the core of the framework, representing programming logic, coding practices, and game mechanics design.
- **Arts** complements these domains through visual design, storytelling, character development, and user interface aesthetics.
- **Mathematics** underpins logical structures, scoring systems, algorithms, and rule-based mechanics.
- **Science** supports analytical reasoning, simulation, and algorithmic thinking relevant to game behaviour and system dynamics.

These five components are mediated through **interactive e-book features**, such as embedded videos, coding simulations, design challenges, and reflective prompts, which function as pedagogical scaffolding. The integration of STEAM elements through interactive e-books ultimately leads to enhanced **learning outcomes**, including computational thinking, creativity, problem-solving skills, and interdisciplinary understanding in game development learning at the secondary education level.

Pedagogical Functions of STEAM-Based E-Books

This section examines the pedagogical functions of STEAM-based e-books as reported in the reviewed studies, as in Table 3. Beyond serving as digital content repositories, e-books in STEAM-oriented game development learning are designed to support specific instructional strategies that align with constructivist, project-based, and inquiry-oriented pedagogies. Understanding these functions is essential to explaining how STEAM-based e-books mediate learning processes and foster meaningful student engagement and skill development.

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Table 3. Pedagogical Functions of STEAM-Based E-Books in Game Development Learning

Pedagogical Function	Description	Number of Studies	Percentage (%)
Instructional scaffolding	Step-by-step guidance, tutorials, and worked examples	27	84.4
Project-based learning support	Structured game development projects and tasks	24	75.0
Inquiry-oriented learning	Problem prompts, exploration tasks, reflective questions	21	65.6
Student engagement	Interactive content, multimedia, and challenges	26	81.3
Collaborative learning	Group tasks, discussion prompts, peer feedback	18	56.3
Creative exploration	Open-ended design tasks, storytelling, and visual creation	23	71.9

As presented in Table 3, the dominant pedagogical function of STEAM-based e-books is **instructional scaffolding,** with most studies emphasising structured guidance to help students navigate complex game development processes. This scaffolding allows learners progressively build technical and creative competencies while reducing cognitive overload. STEAM-based e-books also strongly support **project-based learning**, aligning with the iterative nature of game development. Inquiry-oriented learning functions were frequently incorporated through contextualised problems and reflective prompts, encouraging students to explore, test ideas, and refine solutions.

High levels of **student engagement** were consistently reported, primarily attributed to the use of interactive and multimedia features. Additionally, many studies highlighted the role of e-books in fostering **creative exploration**, particularly in visual design and storytelling aspects of game development. While **collaborative learning** was less consistently emphasised, its presence increased when e-books were integrated with classroom discussions and group-based projects. Overall, the findings indicate that STEAM-based e-books function as active pedagogical tools that support both structured learning and creative inquiry in game development education.

Learning Outcomes in Game Development

This section synthesises the learning outcomes reported in studies examining STEAM-based e-books for game development learning. The analysis focuses on cognitive, affective, and skills-based outcomes to assess how these digital resources contribute to students' motivation, thinking skills, and conceptual understanding, as in Table 4. Identifying the range and strength of reported outcomes also helps clarify the current evidence base and its limitations.

Table 4. Reported Learning Outcomes of STEAM-Based E-Books in Game Development Learning

Learning Outcome	Description	Number of Studies	Percentage (%)
Student motivation and engagement	Increased interest, persistence, and enjoyment in learning	25	78.1
Computational thinking	Algorithmic thinking, coding logic, and debugging skills	22	68.8
Design thinking	Iterative design, prototyping, and evaluation	20	62.5
Creativity	Original ideas, visual design, storytelling	23	71.9
Conceptual understanding	Understanding of game mechanics and development processes	21	65.6
Problem-solving skills	Identifying problems and developing	19	59.4

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Learning Outcome	Description	Number of Studies	Percentage (%)
	solutions		
Interdisciplinary thinking	Ability to connect STEAM domains	17	53.1
Long-term learning impact	Retention and transfer of knowledge	6	18.8
Standardised performance outcomes	Test scores or formal assessments	5	15.6

Table 4 indicates that the most frequently reported outcomes of STEAM-based e-books are increased student motivation and enhanced creativity, reflecting the engaging and interactive nature of digital game development tasks. Cognitive outcomes, particularly computational thinking and design thinking, were also strongly represented, highlighting the alignment between STEAM-based e-books and the core competencies required in game development learning.

Improvements in conceptual understanding**,** problem-solvin**g**, and interdisciplinary thinking were reported in more than half of the reviewed studies, suggesting that STEAM-based e-books support deeper learning beyond technical skill acquisition. However, evidence on the long-term impact of education and standardised performance outcomes was limited. This indicates that most studies focused on short-term or perception-based measures rather than longitudinal or objective assessments. Consequently, further rigorous empirical research is needed to evaluate the sustained effectiveness of STEAM-based e-books in game development education.

The implementation of STEAM principles in e-book design for game development education at the secondary education level has emerged as a promising area of inquiry. This systematic literature review indicates that integrating science, technology, engineering, arts, and mathematics (STEAM) into educational resources effectively supports interdisciplinary learning, particularly in authentic game development tasks (Ozkan, 2022). The reviewed studies collectively demonstrate that STEAM approaches enhance learners' ability to connect disparate fields, such as programming, system design, artistic expression, and mathematical reasoning, providing a comprehensive educational experience in game development (Bertrand & Namukasa, 2020; Ozkan, 2022).

Research consistently shows that STEAM-based educational activities lead to greater engagement and understanding among secondary school students (YALÇIN et al., 2022). For instance, STEAM applications have been shown to influence students' attitudes towards technology positively and to facilitate the development of creative activities (Ozkan, 2022). This engagement is particularly beneficial in secondary education, where students are expected to apply their knowledge across various domains, aligning well with learning objectives. Furthermore, studies have indicated that STEAM-based initiatives can promote critical thinking, problem-solving abilities, and collaboration skills among students, essential competencies for success in today's technological landscape (YALÇIN et al., 2022; Bertrand & Namukasa, 2020).

Game development tasks often require a synthesis of knowledge and skills from multiple disciplines, which aligns with the cognitive demands of STEAM-centred education (Ceylan & Topsakal, 2022; Sevimli & Ünal, 2022). For example, students are encouraged to engage in interdisciplinary exploration, linking concepts from programming with artistic design and mathematical calculations during the game design process. This curriculum design offers a rich context for students to explore their interests and apply theoretical knowledge to practical situations, fostering a deeper understanding of content across the STEAM fields. Additionally, research highlights the importance of metacognitive skills and self-regulation, which improve as students undertake collaborative STEAM projects (Ceylan & Topsakal, 2022; Fernández-Morante et al., 2022).

Despite the advantages, a notable inconsistency exists in the depth and balance of STEAM integration within various e-books (GÜRLER & Kaplan, 2023). Many resources tend to prioritise technological and artistic components over strict scientific and mathematical frameworks, leading to a skewed interdisciplinary approach (GÜRLER & Kaplan, 2023). This lack of balance can limit students' potential to fully appreciate and integrate all facets of STEAM into their learning. As identified by Zhang and Lam, educators need to address the contributions of mathematical knowledge within the STEAM curriculum to ensure holistic development (Zhang & Lam, 2024).

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To optimise the effectiveness of STEAM integration into e-book design, future studies must focus on developing resources that maintain a balanced representation of all STEAM components. As educational institutions continue to evolve, greater emphasis can be placed on interdisciplinary teaching methods that foster collaboration among educators from different fields, potentially addressing challenges in implementing STEAM education at the secondary level (López et al., 2021). This approach will not only enhance the quality of e-books developed for game-based learning but also prepare students for real-world applications by equipping them with a versatile skill set applicable across contexts.

The findings from this systematic literature review underscore the potential of STEAM-informed e-book design to enrich secondary education game development programs. By promoting interdisciplinary learning and engaging students in authentic tasks, educators can foster an enriched learning environment that prepares them for the complexities of modern careers in technology and design. However, to achieve the desired outcomes, it is critical to address the current challenges and develop a more balanced integration of all STEAM disciplines.

Alignment with Pedagogical Theory

The integration of STEAM principles in e-book design, particularly for the context of game development education, closely aligns with constructivist learning theory. This approach emphasises the importance of active learner engagement through project-based and inquiry-based learning models. The studies reviewed illustrate how STEAM-based e-books act as scaffolding tools, guiding learners through iterative design processes and problem-solving activities essential for game creation (Hidayat, 2023; Xu et al., 2020). This active approach allows students to engage in hands-on experiences, fostering more profound understanding and retention of knowledge, which is a cornerstone of constructivist learning (Choy et al., 2022; Xu et al., 2020).

Project-based learning (PBL) encourages students to explore real-world problems and challenges, enabling them to apply classroom knowledge to practical situations (Bónus & Antal, 2021; Charro, 2020). Similarly, inquiry-based learning promotes a questioning mindset, urging students to collaboratively seek solutions (Bónus & Antal, 2021; Charro, 2020). The interactive nature of STEAM-based e-books reinforces these pedagogical models by embedding interactive elements and reflective prompts that enhance student agency and critical thinking (Barrett et al., 2020; Mastuinda & Yaswinda, 2023). The iterative design process inherent in game development tasks allows students to engage in hypothesis testing, exploration, and reflection, key components of both PBL and inquiry learning (Fields & Kafai, 2023; Valls et al., 2022).

In constructivist theory, scaffolding is vital for maximising student learning (Winandari et al., 2022). STEAM-based e-books provide this support by offering guided learning experiences that are tailored to students' needs. Research indicates that scaffolding within educational resources enhances students' ability to actively construct knowledge (Schmidthaler et al., 2023). Moreover, the design of these e-books facilitates not only comprehension but also the development of higher-order thinking skills (HOTS), such as analysis, synthesis, and evaluation (Yang et al., 2024). By engaging students in iterative design frameworks and encouraging them to construct solutions, e-books become pivotal in promoting a deeper understanding of game development and enhancing creative engagement.

Furthermore, the design of STEAM-based e-books supports active knowledge construction through experiential learning. This pedagogical approach emphasises direct experience as a mode for learning, reinforcing the significance of doing and reflecting on one's learning experiences (Filipe et al., 2024; Jamil et al., 2024). Evidence from studies indicates that when learners are provided with interactive elements within e-books, their engagement and comprehension significantly improve, making these tools invaluable for facilitating experiential learning (López-Escribano et al., 2021; Tongal et al., 2024). By enabling students to connect theoretical concepts with practical application in game development, STEAM-based e-books fulfil the desire for relevant learning experiences characteristic of constructivist approaches.

The reviewed literature strongly supports the effectiveness of STEAM-based e-books as pedagogical instruments that not only facilitate content delivery but also mediate higher-order thinking and creative engagement through active learning methodologies aligned with constructivist learning theory. These resources exemplify a modern educational approach that values interdisciplinary learning and prepares secondary education students to thrive in complex, real-world contexts.

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Implications for Educational Practice

The findings from the literature review indicate practical implications for educators and instructional designers in developing STEAM-based e-books for game development learning. A balanced STEAM framework is essential for optimising these resources to meet curriculum objectives and support effective assessment practices. The design of e-books should intentionally integrate all elements of the STEAM framework, science, technology, engineering, arts, and mathematics, ensuring each component is represented equally within the educational tasks presented. Studies highlight that when all STEAM components are harmonised, students engage in enriched learning experiences that foster interdisciplinary knowledge and skills (Hidayat, 2023; Ozkan, 2022). This balanced integration not only helps learners grasp complex concepts but also aligns with pedagogical goals by promoting critical inquiry, creativity, and collaboration, skills vital for contemporary educational success (Forrest, 2022).

In addition to employing a balanced framework, teachers play a crucial role in facilitating the effective use of STEAM-based e-books. Instructors' contextualisation of activities can enhance students' understanding and engagement (Dewi & Agung, 2021). Educators should encourage collaborative efforts among students, emphasising peer-to-peer interactions that enrich the design and development processes during game creation. Providing regular feedback is also essential, as formative assessment practices directly contribute to improved learning trajectories and student outcomes (Hsu et al., 2022; Tsakeni, 2024). Supportive instructional environments bolster student awareness and self-regulation, leading to deeper learning (Jabaay et al., 2020).

To maximise the potential of STEAM-oriented digital resources, there is a critical need for professional development initiatives tailored for teachers. These initiatives should focus on equipping educators with the skills and strategies to integrate STEAM concepts into their instruction. Research underscores the importance of ongoing training that addresses both technological advancements and pedagogical practices relevant to STEAM education (Cydis et al., 2021; Julien et al., 2022). By empowering teachers to design and implement STEAM-based curricula effectively, educational institutions can enhance the quality of learning and student engagement (Thepwongsa et al., 2023). Moreover, STEAM-based e-book development must align with established curriculum objectives and assessment practices. Effective instructional design must clearly articulate learning outcomes and include assessment criteria that reflect the interdisciplinary nature of STEAM. By ensuring that both learning activities and assessments resonate with these objectives, educators can create a holistic educational experience that prepares students for real-world applications and fosters lifelong learning habits (Dewi, Ni Komang Asih Kurnia, 2022; Fadhilah et al., 2021).

The integration of STEAM principles into e-book design for game development requires a balance that encompasses all elements of the STEAM framework while enhancing pedagogical practices. By focusing on teacher involvement, professional development, and curriculum alignment, educators can significantly improve the effectiveness of STEAM-oriented digital resources. The framework established by this review provides a directive for future research and practical implementation to achieve optimal student learning outcomes.

Conclusion

This systematic literature review examined how STEAM principles are integrated into e-book design for game development learning at the secondary education level. The findings indicate that STEAM-based e-books have strong potential to support interdisciplinary learning by combining technological skills, engineering design processes, artistic creativity, and mathematical reasoning within authentic game development activities. Interactive and project-oriented e-book features were consistently reported to enhance student engagement, creativity, and problem-solving abilities, which are essential competencies in Phase F learning. From a theoretical perspective, this study contributes to the growing body of knowledge on STEAM education and digital pedagogy by synthesising evidence on the pedagogical roles of e-books as scaffolding tools rather than passive learning resources. The review highlights the importance of aligning e-book design with constructivist and project-based learning approaches to maximise learning outcomes in game development education.

In practice, the findings suggest that educators and instructional designers should adopt a balanced, intentional integration of all STEAM components when developing e-books, ensuring alignment with curriculum standards and assessment objectives. Teachers' facilitation and instructional

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support remain critical to the effective implementation of STEAM-based e-books in classroom settings. Despite these contributions, this review is limited by the variability of study designs and the lack of longitudinal empirical evidence in the existing literature. Future research is recommended to employ rigorous experimental and longitudinal methods, develop validated assessment instruments, and explore contextual factors influencing the effectiveness of STEAM-based e-books in game development learning

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