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Design thinking approach to powerful material development in educational contexts: From theory to practice

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Abstract

Design Thinking (DT), originating in industrial design, has evolved into a transformative framework for addressing global educational challenges, particularly in the development of teaching materials. By emphasizing empathy, ideation, and iterative prototyping, DT fosters creativity, collaboration, and adaptability, supporting active, interdisciplinary learning. However, challenges persist in integrating DT into curriculum design, pedagogy, and teaching materials, as well as evaluating its impact on student outcomes. This systematic literature review analyses the worldwide studies from 2010 to 2024 using a semi-systematic approach. Peer-reviewed literature from Scopus, Web of Science, and Google Scholar was examined through thematic analysis to identify DT's principles, educational impacts, and implementation barriers. The findings demonstrate DT's ability to enhance critical thinking, problem-solving, and engagement while aligning with technological and sustainability goals. Despite these benefits, institutional and cultural barriers, inadequate teacher training, and resource constraints limit its effectiveness. The review highlights the need for localized frameworks, integration of emerging technologies, and robust empirical research. Addressing these gaps can help educators create inclusive, innovative, and student-centred learning environments, equipping students with skills for an increasingly complex and globalized world.

***Keywords**: Design thinking, Educational materials development, Technology-enhanced learning, Pedagogical innovation, Instructional design*

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1. Introduction

The integration of design thinking (DT) into teaching materials development represents a pivotal evolution in educational practices, reshaping how learning environments are designed to foster innovation, engagement, and adaptability. Originally rooted in industrial design and architecture, where it served as a methodology for creating tangible products and solutions (Carlgren et al., 2016), DT has evolved into a multidisciplinary framework. This transition reflects a broader shift in educational strategies toward methods that prioritize creativity, collaboration, and problem-solving to address the dynamic needs of modern learners (Beligatamulla et al., 2019; Johansson-Sköldberg et al., 2013).

Central to DT's methodology are its defining elements—empathy, ideation, and iterative prototyping—which offer educators a structured yet flexible approach to tackling complex educational challenges. By incorporating these principles, DT enables the development of teaching materials that are functional, inclusive, and aligned with diverse learner needs (Lopez et al., 2023; Wang, 2023). For instance, in language education and STEM fields, DT has been instrumental in fostering active learning and encouraging students to engage deeply with instructional content (Alashwal, 2020; Kijima & Sun, 2021). Furthermore, DT's iterative nature ensures continuous refinement of materials, aligning with contemporary pedagogical demands for dynamic and adaptable solutions (Razzouk & Shute, 2012).

As educational paradigms increasingly emphasize experiential and collaborative learning models, DT emerges as a robust framework that aligns with these trends. It facilitates environments that nurture critical thinking, creativity, and problem-solving, which are essential for preparing students for complex interdisciplinary challenges (Nilmanee, 2024; Koh et al., 2015). This potential is evident across diverse educational contexts, including engineering, where DT has improved design competency (Li et al., 2021), and sustainability education, where it fosters innovative solutions to global challenges (Taimur et al., 2022). By bridging theory and practice, DT has become a cornerstone of 21st-century education, encouraging educators to adopt learner-centred approaches that emphasize empathy and innovation (Dorland, 2024; Kimbell, 2011).

However, despite its promise, significant gaps persist in DT's integration into curriculum design and instructional strategies, particularly regarding subject-specific pedagogy and materials development. While DT is widely recognized for its versatility, inconsistencies in its application highlight the need for more systematic approaches to embedding its principles into educational frameworks (Novak & Mulvey, 2020; Hatt, 2023). For instance, in K-12 education, while DT has shown potential in promoting creativity and collaboration, challenges related to teacher training and resource availability often hinder its effective implementation (Li & Zhan, 2022; Gerardou et al.,

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2022). Similarly, in higher education, DT's integration into materials development remains underexplored, especially in disciplines beyond STEM (Aris, 2024; Pande & Bharathi, 2020).

Empirical research on the noticeable impacts of DT on student learning outcomes is also limited. Although DT has been associated with improved creative confidence and problem-solving abilities (Baričević & Luić, 2023; Yang & Hsu, 2020), its broader impact on instructional efficacy and student engagement requires further investigation (Wang, 2023; Liedtka, 2018). Moreover, the cultural and institutional factors influencing the successful adoption of DT in diverse educational settings remain under-researched, underscoring the need for context-specific studies (Panke & Harth, 2019; Tickoo & Grammer, 2022).

This systematic literature review addresses these gaps by synthesizing research on the evolution and applications of DT in educational contexts, with a particular focus on materials development. By analysing a wide range of studies, this review aims to identify key principles, practices, and trends while highlighting barriers that limit DT's full potential. The findings are intended to provide both theoretical insights and actionable strategies for educators, curriculum designers, and policymakers, emphasizing DT's capacity to revolutionize teaching and learning practices in diverse educational settings (Rahman et al., 2023; Shé et al., 2021).

To achieve this, the review addresses the following research questions:

1. What are the key principles and practices of DT identified in the literature?
2. In what ways has DT been integrated into the development of teaching materials, and what impacts has it had on student learning outcomes?
3. What challenges and barriers have been encountered in the implementation of DT in educational settings, particularly in materials development?
4. What are the opportunities for future research and practice in education and particularly in materials development?

By systematically addressing these questions, this review contributes to the ongoing discourse on innovative pedagogical practices. It highlights the transformative potential of DT in reshaping educational materials and methodologies to better prepare learners for an increasingly complex and interconnected world (Lopez et al., 2023; Razzouk & Shute, 2012; Meinel & Leifer, 2011).

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2. Literature review

2.1. Design thinking development over periods

Design thinking (DT), which originated in the mid-20th century, has evolved from its initial use in architecture and industrial design into a multidisciplinary approach utilized across various fields. Early conceptualizations, such as those by Rowe (1991), defined DT as a structured methodology distinct from scientific and artistic paradigms, offering a systematic way to approach complex challenges. Buchanan (1992) further advanced the discourse by introducing the concept of "wicked problems," emphasizing DT's capacity to address intricate societal and organizational issues through interdisciplinary collaboration. Brown and Wyatt (2010) extended DT's scope into the social sector, where its emphasis on systemic thinking has inspired practitioners and policymakers to pursue innovative solutions for societal challenges.

In industrial contexts, DT has been proven instrumental in fostering organizational creativity and innovation. Carlgren et al. (2016a, 2016b) examined its practical application within large firms, identifying both the challenges of DT adoption and its transformative potential. Liedtka (2018) argued that DT's iterative nature supports organizations in navigating ambiguity and enhancing customer-centric solutions, reinforcing its versatility as a problem-solving framework. Similarly, Mahato et al. (2021) highlighted DT's role in promoting social innovation within tourism entrepreneurship, where it encourages sustainable practices and user-centered approaches.

Beyond industry, DT has been integrated into diverse fields such as healthcare, where it has supported patient-centred design processes (Krolikowski et al., 2022), and the public sector, where it has guided policymaking and service design (Brinkman et al., 2023). These contributions underscore DT's adaptability, bridging creativity and analytical rigor to address challenges across domains. Johansson-Sköldberg et al. (2013) explored DT's evolution, categorizing it as a practice-based methodology that has transitioned from creative industries to broader societal applications. This foundation set the stage for DT's introduction into education, where it has been reimagined to meet the needs of modern learners and educators (Razali et al., 2022).

2.2. Design thinking studies and uses in educational contexts

The incorporation of DT into education has been driven by its potential to foster creativity, problem-solving, and innovation. Dym et al. (2005) highlighted DT's early role in enhancing student creativity through problem-based learning, emphasizing its alignment with constructivist pedagogies. Over time, DT's application expanded to include curricula development across disciplines, particularly in STEM, arts, and business education, where it has supported critical thinking and interdisciplinary collaboration (Sandars & Goh, 2020; Alashwal, 2020).

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Recent advancements have focused on DT's integration into project-based learning environments, where students engage with real-world challenges using human-centered approaches. Gerardou et al. (2022) discussed how DT facilitates challenge-based learning, emphasizing collaboration and iterative problem-solving to address contemporary educational demands. Hatt (2023) highlighted the role of DT as both a pedagogy and mindset, enabling educators to create dynamic, student-centered learning experiences. The infusion of digital tools has further extended DT's reach, allowing for its implementation in online and hybrid educational settings, thus enhancing accessibility and student engagement (Kim, 2023).

Despite these advancements, significant gaps persist. Researchers such as Razali et al. (2022) and Novak and Mulvey (2020) noted a lack of actionable strategies for embedding DT principles into diverse curricula, which limits its operationalization as a core pedagogic tool. Beligatamulla et al. (2019) critiqued the generalized application of DT, arguing for subject-specific methodologies that account for disciplinary nuances. For example, Aris (2024) called for frameworks tailored to STEM education, while Panke and Harth (2019) emphasized inclusive community design.

DT's iterative nature aligns well with instructional design, but its application to material development remains underexplored. Wang (2023) identified a need for structured guidance for educators, particularly in designing adaptive materials for diverse learners. The development of digital and gamified resources has shown promise in bridging this gap, as demonstrated by Souza et al. (2020), who explored DT's role in creating engaging learning environments through gamification. This underscores the importance of further research into DT's integration into teaching materials development.

2.3. Gaps in design thinking studies

This systematic review highlights critical gaps in DT research and application within educational contexts. While DT has proven effective in fostering creativity and problem-solving, its potential for transforming teaching materials development remains underutilized. Existing studies often focus on broad pedagogical applications, leaving a dearth of research on discipline-specific frameworks and methodologies (Novak & Mulvey, 2020; Alashwal, 2020). Additionally, the superficial integration of DT into curricula, often reduced to a buzzword, undermines its transformative potential (Panke & Harth, 2019; Dorland, 2024).

A particular challenge lies in aligning DT's theoretical principles with practical strategies for instructional design. Limited empirical evidence evaluates its impact on learning outcomes, especially in non-traditional educational settings (Razali et al., 2022; Wang, 2023). This calls for a more robust exploration of DT's application in developing adaptive, innovative teaching resources. Addressing these gaps is essential for leveraging

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DT to its fullest potential, equipping educators with the tools to create impactful and inclusive educational experiences.

This review aims to fill these voids, offering a comprehensive framework that integrates DT's principles into actionable strategies for educational material development. By bridging theoretical insights with practical applications, this study contributes to the evolving discourse on innovative pedagogy, providing pathways for future research and implementation.

3. Method

This study adopts the semi-systematic literature review approach, including criteria for study inclusion and exclusion, sources and databases searched, search strategies and keywords, as well as data extraction and analysis methods.

3.1. Semi-systematic literature review approach

A semi-systematic literature review method is particularly suitable for synthesizing diverse studies in emerging and interdisciplinary fields (Snyder, 2019; Okoli, 2015), such as design thinking in educational materials development. Unlike systematic reviews strictly adhering to meta-analysis or quantitative synthesis, the semi-systematic approach focuses on identifying key patterns, themes, and gaps within a broad body of qualitative and mixed-methods research. While informed by the structured principles of the PRISMA framework (Page et al., 2021), this review prioritizes flexibility in exploring varied methodologies and conceptual insights. The approach ensures rigor through clear documentation of the review process while embracing the exploratory nature of semi-systematic research.

3.2. Criteria for inclusion and exclusion of studies

Studies were included if they addressed the application of design thinking in educational environment, and particularly for developing educational materials, were published in peer-reviewed journals, and written in English. The review considered literature from 2010 to 2024 to focus on recent advancements. Exclusion criteria encompassed studies unrelated to design thinking, theoretical or conceptual papers lacking empirical data, and research focusing on unrelated educational methodologies. These criteria align with recommendations for ensuring quality in semi-systematic reviews (Snyder, 2019).

3.3. Databases and sources searched

The literature search included Scopus, Web of Science, and Google Scholar, selected for their broad disciplinary coverage and relevance to educational research. Additionally, manual searches of reference lists from key articles were conducted to capture studies

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potentially overlooked in database queries. This triangulated search strategy ensures comprehensive coverage while mitigating publication bias (Snyder, 2019).

3.4 Search strategy and keywords used

The search strategy employed iterative keyword combinations such as "design thinking," "educational materials," "materials development," "pedagogical innovation," and "English language teaching." Boolean operators (AND, OR) were used to refine results. This iterative approach, common in semi-systematic reviews, facilitates the inclusion of studies reflecting diverse perspectives within the scope of the research (Xiao & Watson, 2019).

3.5 Data extraction and analysis process

A standardized data extraction form was used to record study details, including authorship, publication year, research design, findings, and implications for practice. Thematic analysis was employed to synthesize qualitative insights, allowing the identification of recurring patterns such as the influence of design thinking on instructional strategies, student engagement, and curriculum innovation across diverse studies (Okoli, 2015). This method, aligned with semi-systematic review practices, enables rigorous understanding of conceptual and empirical trends without relying on meta-analytic synthesis (Snyder, 2019; Xiao & Watson, 2019).

4. Findings and discussion

Over periods, design thinking has evolved from a problem-solving framework rooted in the field of design to a transformative approach and methodology applicable across diverse fields such as education, healthcare, environment, and digital innovation. This development reveals an ongoing adaptability driven by the multifaceted challenges of the modern era, thus strengthening its relevance in diverse contexts.

Design thinking (DT) has progressively reshaped educational practices by offering a framework that integrates empathy, collaboration, and iterative problem-solving into curriculum design, pedagogy, and materials development. This systematic approach has reshaped traditional educational models, enabling the creation of dynamic, learner-centred environments that foster creativity and critical thinking (Lopez et al., 2023; Carlgren et al., 2016; Wang, 2023). Its adaptability across disciplines makes DT a transformative tool in addressing complex educational challenges.

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4.1. Design thinking in curriculum, pedagogy, and materials development

DT has emerged as a basis in curriculum innovation, particularly in disciplines requiring creativity, interdisciplinary collaboration, and real-world problem-solving. Its application in nursing education, for example, emphasizes empathy and patient-centred care, preparing students to navigate complex healthcare challenges (Bravo, 2022). In engineering education, DT promotes interdisciplinary collaboration and hands-on learning, as shown by its incorporation into curricula that use empathy and user feedback to solve societal challenges (Al-Qaralleh et al., 2021; English & King, 2015).

In STEM education, DT's iterative processes enhance engagement and deepen conceptual understanding, as demonstrated by the development of a DT-based chemistry module that connects abstract concepts to real-world applications (Aris, 2024). Similarly, Alashwal (2020) highlighted how DT fosters the development of interdisciplinary STEM modules, equipping students with the tools to address global challenges. DT also enhances undergraduate learning through experiential approaches that prioritize creativity and teamwork (Dorland, 2024). Further, the integration of DT in challenge-based learning environments illustrates its capacity to inspire problem-solving and critical thinking across disciplines. This is evident in Gerardou et al.'s (2022) findings, which emphasize DT's role in fostering collaborative learning and addressing complex societal issues through innovative curricular models.

DT has also significantly influenced pedagogical strategies, providing educators with tools and mindsets to foster participatory and creative learning environments. It enables a transition from passive learning to active engagement, where students become co-creators of their educational experiences (Beligatamulla et al., 2019; Liedtka, 2018). Empathy and collaboration—core elements of DT—play pivotal roles in creating inclusive pedagogies that meet diverse learner needs (Wang, 2023; Hatt, 2023). DT's iterative nature encourages active learning approaches that emphasize critical thinking and creativity. Baričević and Luić (2023) demonstrated how integrating DT into active learning models prepares students for real-world challenges by fostering problem-solving skills. In physical education, DT has been adapted to address unique pedagogical challenges, offering frameworks that bridge practical implementation with innovative teaching practices (Chambers, 2020). In hybrid and technology-enhanced settings, DT supports transformative pedagogy by integrating digital tools and collaborative frameworks. Studies in sustainability education reveal that DT fosters innovative thinking and inclusivity in both in-person and online environments (Taimur & Onuki, 2022). Similarly, Koh et al. (2015) emphasized DT's ability to enhance learning outcomes by aligning pedagogical methods with the evolving demands of digital classrooms.

Perhaps the most significant application of DT in education lies in the development of teaching materials. DT's emphasis on empathy and prototyping ensures that these

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resources align with students' real-world experiences and learning preferences (Lopez et al., 2023; Aris, 2024). Iterative processes allow for continuous refinement, resulting in adaptive and innovative materials that respond to both educator and learner needs. Empirical studies confirm the effectiveness of DT-based teaching materials in fostering creativity and critical thinking. For example, Rahman et al. (2023) demonstrated how integrating DT with the TPACK framework leads to the development of technologically enriched materials that improve accessibility and engagement in modern classrooms. Similarly, Baričević and Luić (2023) found that students using DT-inspired materials exhibited significantly higher engagement and problem-solving skills compared to those using traditional resources. DT also plays a crucial role in game-based learning, where it fosters empathy and collaboration. Shultz Colby (2023) explored DT in game design pedagogy, showing how it builds students' critical thinking and fosters a deeper understanding of learning objectives. In interdisciplinary contexts, DT facilitates the creation of materials that address the specific needs of diverse disciplines, from STEAM education to engineering (Kijima & Sun, 2021; Li et al., 2021).

4.2. Principles and practices of design thinking in material development

The literature on design thinking (DT) extensively discusses its foundational principles and practices, emphasizing their relevance and applicability in diverse contexts, including teaching material development. By integrating empathy, prototyping, collaboration, creativity, reflection, technology, and customization, DT offers a comprehensive framework for addressing the evolving needs of learners across diverse educational contexts.

4.2.1. Empathy as a foundational principle

Empathy is a fundamental principle of DT, serving as the starting point for understanding user needs and creating meaningful solutions. It fosters a user-centred approach critical for designing effective educational materials. Beckman and Barry (2007) emphasize that empathy helps uncover latent needs that users may not articulate directly, a process vital for educators aiming to address diverse learner challenges. The transformative role of empathy is evident in Dawbin et al. (2021), where empathy-building exercises in secondary education enhanced student engagement and collaboration. Bravo (2022) and Razali et al. (2022) demonstrate that integrating empathy into curricula design aligns teaching materials with learners' unique preferences and obstacles. This emphasis on empathy resonates with Shultz Colby (2023), who explores the application of game design as a tool for empathy-building, highlighting its potential for fostering inclusivity and deeper understanding in educational settings. Additionally, Gerardou et al. (2022) advocate for incorporating empathy exercises into challenge-based learning, suggesting that such practices can create more personalized and impactful learning experiences.

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4.2.2. Iterative prototyping and testing

Iterative prototyping is a hallmark of DT, enabling continuous refinement of ideas through cycles of testing and feedback. This principle is pivotal in educational contexts, where adaptive teaching materials are essential for addressing diverse learning needs (Beligatamulla et al., 2019). Aris (2024) describes this in the creation of a chemistry module, where iterative design ensured alignment with pedagogical objectives. Hehn and Mendez (2022) extend this idea to software education, showing how prototyping enhances human-centred design, an approach readily transferable to instructional design. Hsu et al. (2021) document iterative design in mobile application programming courses, revealing its impact on fostering creativity and technical proficiency among learners. Liedtka (2018) underscores the value of prototyping in minimizing risk and maximizing user satisfaction, a perspective echoed by Koh et al. (2015), who discuss iterative approaches in adapting DT for education.

4.2.3. Collaboration and interdisciplinarity

Collaboration is integral to DT, emphasizing teamwork across disciplines to generate holistic solutions. In educational settings, this fosters a culture of shared knowledge and innovation. Al-Qaralleh et al. (2021) illustrate how DT in engineering curricula prepares students for interdisciplinary problem-solving in real-world scenarios. Ardoin et al. (2022) similarly highlight how DT unites stakeholders from diverse fields to co-create sustainable solutions, an approach equally relevant to teaching materials development. In nursing education, Bravo (2022) demonstrates that collaborative DT projects promote teamwork and problem-solving, enhancing both learning and application. Further insights from Lynch et al. (2021) reveal that blending DT with entrepreneurial education fosters interdisciplinary skills, encouraging students to tackle complex challenges creatively.

4.2.4. Creativity and Ideation

Creativity is the driving force behind DT, enabling innovative problem-solving through structured ideation techniques. Boydell et al. (2021) document the use of brainstorming and visual mapping tools to stimulate creativity in knowledge translation projects, practices that can directly inform teaching material development. Baričević and Luić (2023) emphasize the transformative impact of DT processes on student creativity, linking these practices to improved academic outcomes. Henriksen et al. (2020) discuss the balance educators must strike between fostering creative freedom and adhering to structured frameworks, suggesting that guided ideation can effectively channel creativity into actionable teaching strategies. Further, Johansson-Sköldberg et al. (2013) highlight the role of ideation in connecting conceptual thinking with practical implementation, a process essential for designing innovative educational materials.

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4.2.5. Reflection and feedback

Reflection is a critical aspect of DT, facilitating the ongoing evaluation of processes and outcomes. Beckman and Barry (2007) describe iterative reflection as key to ensuring continuous alignment with user needs. Sandars and Goh (2020) explore reflective practices in medical education, demonstrating how feedback loops improve the relevance and impact of DT-based interventions. Similarly, McLaughlin et al. (2019) emphasize the role of reflection in refining educational strategies, advocating for its integration into teaching material design. These perspectives align with Kimbell (2011), who underscores the importance of reflective practices in maintaining the adaptability and effectiveness of DT frameworks, particularly in educational contexts requiring frequent adjustments.

4.2.6. Alignment with technology and digital tools

The integration of digital tools has expanded DT's scope, making it more adaptable and accessible in education. Wang (2023) discusses the use of digital platforms to enhance collaboration and iterative testing, while Hsu et al. (2021) highlight the role of mobile technologies in increasing engagement, particularly in STEM education. Nilmanee (2024) presents a learning experience platform designed using DT, which promotes innovation and scalability in creating teaching materials. Rahman et al. (2023) demonstrate the potential of combining DT with frameworks like TPACK to create digitally enriched instructional resources, further emphasizing the synergy between DT and technology in modern education. Similarly, Taimur and Onuki (2022) highlight DT's transformative potential in hybrid and online learning environments, suggesting avenues for further exploration.

4.2.7. Customization and contextual adaptation

The ability to customize DT principles for specific educational contexts is vital for its effectiveness. Beligatamulla et al. (2019) argue that generic applications risk diluting DT's impact, advocating for context-sensitive adaptations. This is evident in Ardoin et al. (2022), where DT practices are tailored for sustainability education, and in Bravo (2022), who focuses on healthcare applications. Li and Zhan (2022) extend this discussion to K-12 education, emphasizing the need for customization to address the unique challenges of younger learners. Hatt (2023) also explores contextual adaptations of DT in curriculum design, highlighting its potential to create inclusive and effective teaching materials.

4.3. Challenges and barriers in implementing design thinking

The implementation of design thinking (DT) in educational contexts is fraught with challenges spanning institutional, educator, student, and resource dimensions. These barriers impede the adoption of DT as a transformative pedagogical framework and highlight critical areas requiring attention to unlock its full potential.

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4.3.1. Institutional challenges

Systemic constraints within educational institutions often pose significant hurdles to the adoption of DT. Structural limitations, such as rigid institutional frameworks and traditional curricula, clash with the iterative and flexible nature of DT (Razali et al., 2022). These constraints hinder deviation from standardized teaching practices, making it difficult to incorporate DT's exploratory methods. Additionally, resource constraints exacerbate these challenges, as institutions often lack the financial and logistical capacity to implement DT effectively. The misalignment between DT principles and existing pedagogical paradigms further complicates its adoption (Beligatamulla et al., 2019). Educational systems frequently prioritize exam-oriented approaches, leaving little room for the time-intensive processes of ideation, prototyping, and refinement (Aris, 2024). Furthermore, Gerardou et al. (2022) emphasize the challenges of integrating DT into challenge-based learning frameworks, particularly in environments resistant to pedagogical innovation. These systemic barriers highlight the need for institutional reforms that align with DT's collaborative and iterative ethos.

4.3.2. Educator-related challenges

Educators play a central role in implementing DT, yet many lack the necessary training and resources to do so effectively. Insufficient professional development programs limit educators' ability to integrate DT into their instructional practices (Wang, 2023). This gap often results in a superficial application of DT principles, which diminishes its effectiveness and fails to deliver the intended learning outcomes. Resistance to change among educators also poses a significant barrier. Shifting from teacher-centered to learner-centered methodologies demands not only new skills but also a fundamental change in mindset, which many educators find challenging (Baričević and Luić, 2023). Additionally, Johansson-Sköldberg et al. (2013) highlight that educators often struggle to balance traditional teaching demands with the exploratory and iterative nature of DT. These barriers underscore the importance of targeted interventions, such as workshops and peer-learning networks, to support educators in adopting DT practices.

4.3.3. Student-related challenges

Students, as the primary beneficiaries of DT, face their own set of challenges in adapting to this methodology. The abstract and open-ended nature of DT can be overwhelming for students accustomed to structured and linear learning environments (Alashwal, 2020). The ambiguity inherent in the processes of ideation and problem framing may lead to frustration and disengagement, particularly among students with limited prior exposure to exploratory learning approaches. Furthermore, the collaborative and iterative nature of DT can be difficult for students from diverse educational and cultural backgrounds to navigate effectively (Baričević and Luić, 2023). Without adequate scaffolding and support, such as clear guidelines and incremental tasks, students

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may struggle to fully engage with DT methodologies. Kijima and Sun (2021) also note that fostering creative confidence is critical, particularly in STEAM education, where students may hesitate to embrace DT due to perceived complexity. Addressing these barriers requires understanding of student needs and tailored interventions to ensure inclusivity and accessibility.

4.3.4. Resource constraints

Resource limitations present a recurring obstacle in the adoption of DT. Many educational institutions, particularly those in underfunded regions, lack access to the technology, materials, and infrastructure necessary for effective DT integration (Razali et al., 2022). Prototyping tools and digital resources, which are essential for many DT activities, are often unavailable in these settings. Teachers frequently lack the technical expertise needed to implement technology-driven DT solutions, further complicating its integration (Agung et al., 2022). Financial constraints exacerbate these issues, preventing schools from investing in teacher training or upgrading infrastructure. Lin et al. (2021) highlight the importance of resource availability in STEM education, noting that DT's success is often contingent on the provision of adequate tools and support. These constraints underscore the need for policy interventions and funding initiatives to bridge the resource gap.

4.3.5. Contextual and cultural barriers

The cultural and contextual diversity of educational systems presents unique challenges for DT implementation. The collaborative and non-hierarchical nature of DT often clashes with traditional educational cultures that emphasize rote learning and authority-based teaching (Beligatamulla et al., 2019). In such contexts, the adoption of DT may be met with resistance from both educators and students. Razali et al. (2022) note that the lack of localized DT frameworks limits its adaptability to diverse cultural and institutional contexts. Generic DT models often fail to address region-specific needs, resulting in suboptimal outcomes. Kimbell (2011) argues that culturally sensitive adaptations of DT are crucial for its successful implementation in varied educational settings. These insights highlight the importance of developing regionally tailored DT frameworks that respect local traditions while fostering innovation.

4.3.6. Theoretical and practical disconnect

A persistent barrier to DT adoption is the disconnect between its theoretical underpinnings and practical implementation. DT is often treated as a buzzword, with limited understanding of its deeper pedagogical implications (Aris, 2024). This superficial incorporation undermines its potential as a transformative framework for education. The absence of empirical studies evaluating the long-term impact of DT on learning outcomes further complicates its integration (Razali et al., 2022). Hatt (2023)

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emphasizes the need for robust research to bridge this gap, arguing that evidence-based practices are essential for embedding DT into educational contexts effectively. Additionally, Koh et al. (2015) call for interdisciplinary research that aligns theoretical insights with practical applications, ensuring that DT is not merely an abstract concept but a tangible tool for educational reform.

4.4. Opportunities for future study and practice

The review reveals critical gaps in the literature and identifies underexplored areas where design thinking (DT) can significantly advance teaching materials development. These opportunities include the need for localized frameworks, empirical evaluations of learning outcomes, integration with emerging technologies, addressing systemic and cultural barriers, and expanding DT's role in interdisciplinary and sustainability education.

4.4.1. Development of localized frameworks

While DT principles are globally recognized, their application often lacks adaptation to specific cultural, linguistic, and educational contexts. This absence of localized frameworks limits DT's effectiveness in diverse learning environments (Wang, 2023). Culturally responsive frameworks are particularly important in higher education, where standardized approaches may fail to address unique regional challenges (Aris, 2024). For instance, STEM education often employs generalized DT models that inadequately reflect local curricular needs or learner contexts. Future research could focus on co-creating localized DT frameworks in collaboration with educators and stakeholders. Such frameworks would provide tailored methodologies for instructional design, improving relevance and engagement (Carlgren et al., 2016a; Gerardou et al., 2022). Additionally, exploring community-driven approaches in specific educational systems, as emphasized by Boydell et al. (2021), can offer actionable insights into adapting DT to diverse settings.

4.4.2. Empirical evaluation of learning outcomes

The literature highlights a lack of rigorous empirical evidence on DT's influence on learning outcomes such as critical thinking, creativity, and problem-solving (Beligatamulla et al., 2019). Current studies often rely on anecdotal or qualitative data, leaving a gap in robust assessments across academic disciplines (Alashwal, 2020). For example, in STEM education, there is limited quantitative evaluation of DT's impact on specific pedagogical challenges or long-term knowledge retention. Expanding longitudinal studies and experimental research designs is essential to comprehensively measure DT's effects on diverse learning outcomes. These studies could also explore discipline-specific adaptations of DT, as suggested by Li and Zhan (2022) in K-12 settings. Furthermore, integrating advanced data analytics tools, as proposed by Kimbell (2011), could enhance the granularity and reliability of such evaluations.

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4.4.3. Integration with emerging technologies

Emerging technologies such as artificial intelligence (AI), virtual reality (VR), and Experience API (xAPI) present significant opportunities to enhance DT applications in education. However, their integration within DT frameworks remains limited (Nilmanee, 2024). Platforms leveraging xAPI have been shown to facilitate innovative learning experiences, though practical classroom applications are still nascent. Similarly, combining DT with TPACK frameworks has the potential to optimize digital teaching materials, but empirical validation of such integrations is scarce (Rahman et al., 2023). Future research should investigate how technologies like AI can enhance empathy-building phases or iterative prototyping processes, enabling more dynamic and personalized learning experiences. Studies like those by Lynch et al. (2021) on entrepreneurial education illustrate how digital tools can effectively complement DT in fostering creative and interdisciplinary learning.

4.4.4. Addressing systemic and cultural barriers

Systemic and cultural barriers remain significant impediments to the widespread adoption of DT in education. These include institutional rigidity, resistance to change, and inadequate teacher training programs (Razali et al., 2022). Underfunded educational systems face additional challenges, where resource constraints hinder the implementation of collaborative and iterative DT processes. To address these barriers, professional development programs should focus on equipping educators with the skills needed to effectively apply DT (Baričević and Luić, 2023). Pilot programs that demonstrate the value of DT in addressing localized challenges, as proposed by Liedtka (2018), could foster greater institutional buy-in. Additionally, exploring frameworks for integrating DT into existing educational policies could provide practical strategies for overcoming resistance (Pande and Bharathi, 2020).

4.4.5. Expanding DT's role in interdisciplinary and sustainability education

Design thinking offers untapped potential for addressing interdisciplinary and sustainability challenges, yet its practical applications in these areas remain underdeveloped. DT has been recognized as a catalyst for sustainability education, promoting systems thinking and collaborative approaches to global challenges (Ardoin et al., 2022). However, scalable models for integrating sustainability into educational curricula are still lacking. Clark et al. (2020) emphasize the role of DT in embedding sustainability principles into higher education but highlight the need for broader interdisciplinary applications. For instance, Gerardou et al. (2022) advocate for using DT in challenge-based learning to address real-world sustainability problems collaboratively. Future research could explore DT's iterative and adaptive nature as a tool for fostering global citizenship and sustainability across fields such as arts, humanities, and STEM.

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5. Conclusion

This systematic literature review explores the evolution and application of design thinking (DT) in educational contexts, particularly in developing teaching materials. It emphasizes DT's transformative potential in creating student-centered, innovative learning environments. The review synthesizes various studies to highlight DT's core principles—empathy, ideation, prototyping, and iteration—which guide the creation of teaching materials that cater to diverse learner needs. Empathy enhances engagement and inclusivity, while iterative processes refine educational strategies, especially in STEM and interdisciplinary settings. DT promotes real-world problem-solving and collaborative learning, fostering critical thinking and creativity.

The integration of DT into educational practices has led to innovative methods like project-based learning and the use of digital tools, improving accessibility and engagement. However, challenges such as inconsistent implementation, inadequate teacher training, and superficial application hinder its broader adoption. The review suggests developing localized frameworks and robust empirical studies to strengthen DT's theoretical foundations and practical applications. It also highlights the potential of emerging technologies to enhance DT's scalability in modern education. Therefore, DT is positioned as a vital strategy for enhancing educational practices, fostering essential competencies, and addressing diverse learner needs, thus paving the way for inclusive and impactful educational environments.

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