

# Design Thinking in the Development of Digital Books for Climate Change Education: A Systematic Review

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## Abstract

*The rapid advancement of digital technology has increased the need for innovative learning media, particularly in environmental education aimed at fostering climate change awareness among students. Digital books offer interactive and accessible learning experiences; however, their educational value depends largely on how effectively they are designed to respond to learners' needs. This study examines how a design thinking approach contributes to the development of interactive digital books and supports student engagement and learning in climate change education. Using a systematic literature review, this study analysed 37 peer-reviewed articles published within the last five years and retrieved from Scopus, Web of Science, JSTOR and Google Scholar. The search process applied combinations of keywords related to design thinking, digital books, climate change or environmental education. This review adopts a broader perspective, acknowledging that existing research spans primary, secondary and higher education levels, with duplicate records removed prior to screening. The review focused on how the key stages of design thinking—empathize, define, ideate, prototype and test—were reflected in the development of digital learning media. The results suggest that digital books informed by design thinking are often associated with improved usability, stronger learner engagement and better support for understanding complex environmental concepts through interactive features and visualizations. In addition, the user-centred orientation of design thinking appears to enhance content relevance and responsiveness to students' learning needs. Overall, the review suggests*

*that integrating design thinking into digital book development may strengthen climate change awareness education at schools, although further empirical research is needed to examine long-term learning outcomes across diverse educational contexts.*

**Keywords:** *design thinking; digital learning media; climate change education; interactive multimedia; student engagement; user-centred design*

## Introduction

Design thinking has emerged as a significant approach in developing digital platforms, emphasizing user-centred solutions and iterative prototyping. This methodology has been widely applied across various domains, from enhancing user experience to fostering sustainable innovation. However, the specific requirements for designing learning tools that promote environmental awareness, particularly in the context of climate change education, remain underexplored. A notable gap exists in the literature regarding the application of design thinking to develop digital books that foster climate change awareness among school students. Addressing this gap is essential for guiding future research and practice in this field (Alfirahmi et al., 2023).

This study reviews key elements such as ideation, prototyping and user feedback in developing interactive digital books, drawing insights from various design thinking-based projects and educational initiatives focused on environmental awareness in education.

Climate change represents one of the most pressing global challenges, which requires international cooperation, technological innovation and collective behavioural change to mitigate its escalating impacts (Kehler & Birchall, 2023; Mariappan et al., 2022). A deeper understanding of the complexity of climate issues, supported by a strong global commitment, can enable the implementation of concrete measures to safeguard the planet for future generations. Nonetheless, geopolitical disagreements, competing economic interests, unequal access to green technologies and widespread apathy continue to hinder progress. A fundamental rethinking of educational approaches is urgently needed to address these challenges effectively.

The development of digital books has become a crucial component of modern education, harnessing technology to enrich the learning experience (Mashfufah et al., 2019; Siregar et al., 2021). Interactive digital books transform learners' engagement with content, offering immersive experiences beyond traditional text. These resources hold considerable potential to bridge the gap between theoretical knowledge and practical understanding (Mashfufah et al., 2019; Pradita et al., 2023; Puji Lestari et al., 2022; Siregar et al., 2021; Van Wyk et al., 2020). With interactive features such as videos, simulations, quizzes and games, digital books can significantly enhance student engagement and motivation (Nadeem et al., 2023). Furthermore, they can be tailored to accommodate diverse learning needs and preferences, which makes education more personalized and inclusive.

Despite these advantages, challenges persist, such as ensuring equitable access to technology and equipping educators with the skills to utilize digital resources effectively. Addressing these barriers is critical to unlocking the full potential of digital learning tools. Common issues include poor screen layout, difficult navigation and low-resolution visuals that detract from the user experience (Van Wyk et al., 2020).

Developing digital books to promote climate change awareness in education requires thoughtful integration of design, technology, and strategies to foster student engagement. By employing user-centered design principles, integrating emerging technologies and applying gamification and collaborative learning approaches, developers can create digital books that are both educationally impactful and engaging. Overcoming these challenges is vital to ensure that such resources effectively cultivate awareness and inspire proactive attitudes toward climate change among young learners.

Recent published studies highlight that digital learning environments have become increasingly central in contemporary education, particularly in fostering student engagement, autonomy and academic performance through interactive and technology-enhanced approaches (Janković et al., 2025; Liu, 2024). At the same time, environmental education research emphasizes that environmental awareness can be effectively developed through structured and contextually relevant learning experiences from early educational stages (Erdem & Belgin Özyaydın, 2023). However, there remains a lack of integrative approaches that combine user-centered design frameworks such as design thinking with digital learning media to specifically support climate change awareness across educational contexts. This gap underscores the need for a systematic synthesis of how design thinking can inform the development of interactive digital books for environmental education.

## **Methodology**

This study employed a systematic literature review (SLR) to examine how design thinking contributes to the development and effectiveness of interactive digital books for climate change awareness education at schools. The review was structured to enhance transparency and reproducibility through explicit eligibility criteria, stepwise screening and structured data extraction.

### ***Research question and analytical focus***

The central research question guiding this review was: How does design thinking contribute to learning effectiveness and user engagement in interactive digital books for climate change education contexts?

To address this question, the synthesis focused on three analytical dimensions: (1) challenges faced by students when using digital books for climate-related learning, (2) development strategies of interactive digital books informed by design thinking, and (3) the ways design thinking supports learning effectiveness and engagement through its key stages (empathize, define, ideate, prototype and test).

### Information sources and search strategy

The literature search was conducted across four major databases: Scopus, Web of Science, JSTOR and Google Scholar. The search used combinations of keywords including: ('design thinking' AND 'digital book' OR 'interactive e-book') AND ('climate change education' OR 'environmental education'). Duplicate records were removed prior to screening. In addition, citation tracking (screening reference lists and citing articles) was used to identify potentially relevant studies not captured in the initial database search.

### Eligibility criteria

Studies were included if they were peer-reviewed journal articles or conference papers published within the last five years and explicitly addressed design thinking or clearly operationalized its key stages (empathize, define, ideate, prototype and test), in the development of digital learning media. Eligible studies were also required to focus on digital books, e-books or closely related forms of interactive digital reading media, and to demonstrate relevance to climate change, environmental or sustainability education, with clear applicability to education contexts. Studies were excluded if they were not peer-reviewed, were unrelated to the development of educational media, did not provide sufficient methodological detail to enable extraction of key variables or fell outside the specified publication period.

The five-year publication window was adopted to capture recent developments in digital learning media, applications of design thinking and innovations in climate-related education. Google Scholar was used as a supplementary source to broaden retrieval coverage and support citation tracking, while Scopus, Web of Science and JSTOR served as the principal databases. To be included, studies had to address all of the following aspects with sufficient clarity: design thinking or its operational stages, digital books or closely related digital reading media, relevance to environmental or climate-related learning, and applicability to education. The process of study identification, screening, eligibility assessment and final inclusion is summarized in Figure 1.

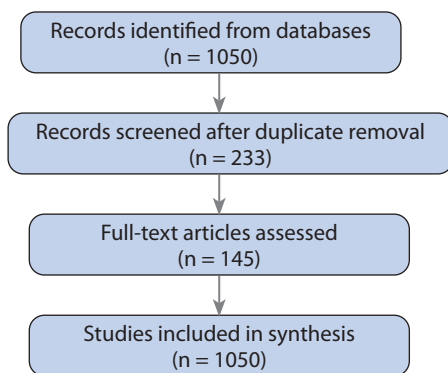


Figure 1. PRISMA Flow Diagram. Study selection process used in the systematic literature review

### ***Screening and study selection procedure***

The initial database search yielded 1,050 records. After preliminary filtering for relevance, publication type and accessibility, 145 records were retained for screening. Citation tracking identified an additional 93 records, bringing the total to 233 records screened for eligibility. Screening proceeded in two stages: (1) title/abstract screening to remove off-topic records, followed by (2) full-text screening against the inclusion criteria. Through this process, 37 studies were included in the final synthesis.

### ***Reviewer characteristics and the decision process***

To align with systematic review standards, the screening and extraction procedures were conducted by two independent reviewers, one with expertise in educational technology/instructional design and the other in environmental education. Both reviewers agreed on the eligibility criteria and data extraction template before screening commenced. Each reviewer independently conducted title/abstract screening and full-text eligibility assessment. Any disagreements were resolved through discussion until consensus was reached, thereby reducing selection bias and strengthening the reliability of the decision.

### ***Data extraction***

A structured data extraction template was developed prior to analysis to ensure consistent capture of key study information. For each included study, we extracted bibliographic details (author, year and publication source), educational context and setting characteristics (e.g., country/region, grade level and participant descriptions where reported), and the type of digital book or media along with its interactive features (such as multimedia elements, quizzes, simulations and navigation design). We also recorded how design thinking was operationalized, including which stages were applied and how they were implemented, as well as key characteristics of the development process, such as user research activities, prototyping and iteration cycles, and mechanisms for collecting user feedback. In addition, we extracted information on evaluation methods (including usability testing, engagement indicators and learning outcome measures) and summarized the main findings relevant to learning effectiveness and user engagement.

Data extraction was conducted independently by the two reviewers and then compared. Any inconsistencies were reconciled through discussion and re-checking the original sources to ensure accuracy.

### ***Quality considerations***

Because the included studies varied in research design (e.g., development studies, classroom implementations, quasi-experimental evaluations), methodological rigor was considered during synthesis. Findings supported by clearly described procedures

(e.g., explicit user testing protocols and defined outcome measures) were prioritized. Studies with limited reporting were interpreted cautiously and used primarily for contextual insight.

### ***Quality appraisal of included studies***

To enhance the rigor of the review, each included study was appraised using three criteria: (1) clarity of research design, (2) transparency of data collection and analysis procedures, and (3) relevance to the development or evaluation of digital learning media for climate, environmental or sustainability education contexts. For each criterion, studies were rated as clearly met, partially met or insufficiently reported. Based on the overall completeness and transparency of reporting, studies were then categorized as having high, moderate or limited methodological transparency. Studies rated as high transparency provided clear descriptions of research design, procedures and educational relevance; those rated as moderate transparency met these criteria only partially; and those rated as limited transparency lacked sufficient methodological detail in one or more areas. No studies were excluded solely on the basis of quality appraisal; however, studies with higher methodological transparency were given greater interpretive weight during the synthesis. A summary table of methodological transparency categories was prepared to support consistency and transparency in the review process.

### ***Data synthesis***

A narrative synthesis approach was used due to heterogeneity in study designs and outcome measures. Evidence was organized thematically into: (1) challenges and barriers to implementing digital books for climate learning, (2) design thinking-based development strategies across the five stages, and (3) reported outcomes related to usability, engagement, comprehension and skills development. Patterns recurring across multiple studies were emphasized as higher-confidence trends, while context-specific findings were reported with appropriate caution.

The consolidated thematic synthesis reveals that the reviewed studies can be grouped into nine overarching themes, reflecting the multifaceted role of design thinking in digital learning environments. The most dominant themes include student engagement, critical thinking and multimedia-supported learning, which indicates that design thinking primarily contributes to enhancing active and meaningful learning experiences. Importantly, the distribution of studies across themes confirms that applications of design thinking are not confined to elementary education but extend across secondary and higher education contexts. At the same time, themes related to climate literacy and digital book development show stronger representation in primary and school-level contexts, which highlights a specific opportunity for further research. Overall, this thematic consolidation provides a clearer and more structured interpretation of the findings, moving beyond descriptive reporting toward analytical synthesis.

Table 1.  
Consolidated Thematic Synthesis of Reviewed Studies (n = 37)

No.	Main Theme	Sub-themes Merged	Representative Studies	Educational Level Distribution	Core Findings
1.	User-centred Design & Usability	- User-centred design - UX/UI design - Needs analysis	Haque & Indah (2022); Fami et al. (2023); Aini & Wardhana (2025)	Primary–Higher	Design thinking enhances usability, accessibility and alignment with learner needs, resulting in more effective and relevant digital learning media
2.	Student Engagement & Motivation	- Engagement - Gamification - Active learning	Cooke (2022); Nadeem et al. (2023); Grau & Rockett (2022); Gwangwava (2021)	All levels	Interactive and gamified features significantly increase motivation, participation and sustained learner engagement
3.	Critical Thinking & Higher-order Skills	- Critical thinking - Problem-solving - Creativity	Anwar et al. (2023); Ramos & Inocian (2022); Chavan et al. (2023); Nordin et al. (2024)	Secondary–Higher (dominant)	Design thinking strengthens higher-order thinking, creativity and problem-solving skills through iterative and inquiry-based processes
4.	Multimedia & Visualization for Conceptual Understanding	- Multimedia learning - VR/AR - Simulation-based learning	Cho & Park (2023); Karagöz et al. (2023); Kreimeier et al. (2023); Suryati et al. (2025)	All levels	Visualization technologies improve comprehension of complex climate concepts and reduce cognitive barriers
5.	Climate Literacy & Environmental Awareness	- Climate education - Sustainability awareness - Ecoliteracy	Hoffmann et al. (2022); Hajj-Hassan et al. (2024); Pradita et al. (2023); Marhraoui & Ojbanire (2025)	Primary–Secondary (dominant)	Digital learning media support climate awareness and pro-environmental attitudes, especially when contextually relevant
6.	Participatory & Collaborative Learning	- Co-design - Collaboration - Team-based learning	Gauthier et al. (2024); Abich et al. (2024); Jussila et al. (2022); Wingfield et al. (2024)	Secondary–Higher (dominant)	Participatory design increases ownership, collaboration and real-world problem engagement
7.	Digital Book Development & Learning Media Innovation	- Digital book development - Interactive e-books - Learning platforms	Siregar et al. (2021); Puji Lestari & Sukartingsih (2022); Mashfuhah et al. (2019)	Primary–Secondary	Digital books enhance learning experience, flexibility and higher-order thinking when properly designed
8.	Design Thinking as Pedagogical Framework	- Theoretical models - Instructional frameworks - Classroom innovation	Dell’Era et al. (2020); Dragičević et al. (2023); Mardiah et al. (2023); Przybilla et al. (2022)	All levels	Design thinking provides a structured, iterative framework for innovation in digital learning environments
9.	Implementation Challenges & Constraints	- Infrastructure limitations - Teacher readiness - Curriculum alignment	Hoffmann et al. (2022); Tang (2022); Oranga et al. (2023); Van Wyk et al. (2020)	All levels	Effective implementation is constrained by digital divide, lack of training and institutional barriers

## Results and discussion

### *Challenges in integrating digital books into climate change education*

Integrating digital books into climate change education offers considerable potential for enhancing students' awareness and engagement; however, this integration is accompanied by a range of interconnected challenges. One of the most prominent barriers is unequal access to technology. In many regions, particularly in developing contexts, students do not consistently have access to digital devices such as smartphones, tablets or computers, which limits their ability to benefit from digital learning resources. Even when devices are available, inadequate or unstable internet connectivity often restricts access to online digital books and interactive content, thereby exacerbating the digital divide and reducing the reach and effectiveness of digital-based climate education initiatives (Hoffmann et al., 2022; Marhraoui & Ojubanire, 2025; Suryati et al., 2025).

In addition to infrastructural constraints, pedagogical challenges significantly influence the effectiveness of digital book implementation. Many teachers lack sufficient training and professional support to integrate digital books meaningfully into their instructional practices. As a result, digital resources may be underutilized or used in ways that do not fully exploit their interactive and pedagogical potential (Hoffmann et al., 2022; Tang, 2022). Furthermore, aligning digital book content with existing curricula and assessment frameworks can be difficult, particularly when instructional objectives and syllabus requirements are rigid or traditionally structured. These challenges often lead to inconsistent or fragmented use of digital books within classroom instruction (Hoffmann et al., 2022; Suryati et al., 2025).

Learner engagement and motivation also present critical challenges in the context of climate change education. For digital books to be effective, they must be designed to capture students' interest and sustain their motivation to engage with complex environmental topics. When digital content lacks interactivity or relevance, it may fail to stimulate meaningful learning experiences (Beach & Smith, 2022; Gabriel & Schmölder, 2022). Moreover, the inherent complexity of climate change concepts can result in cognitive overload, particularly when information is presented in dense or poorly structured formats. This may hinder students' ability to process, retain and apply knowledge effectively (Cho & Park, 2023; Hajj-Hassan et al., 2024).

Content quality and design considerations further shape the educational value of digital books. Ensuring the accuracy, credibility and timeliness of climate-related information is essential, as inaccurate or outdated content can undermine learning outcomes and misinform students (Hoffmann et al., 2022; Josephine Oranga et al., 2023). In addition, digital books must be culturally and contextually relevant to resonate with diverse student populations. Content that does not reflect local environmental issues or students' lived experiences may limit engagement and reduce the perceived relevance of climate change education (Hoffmann et al., 2022; Marhraoui & Ojubanire, 2025).

Finally, psychological and cognitive factors play a crucial role in shaping students' learning experiences. Poorly designed digital books can increase cognitive load, which leads to reduced comprehension and retention of climate change concepts (Cho & Park, 2023; Hajj-Hassan et al., 2024). Climate change is also an emotionally charged topic, and exposure to alarming or catastrophic narratives through digital media may evoke feelings of anxiety, helplessness or eco-anxiety among students. Such emotional responses can act as barriers to learning if not carefully managed through age-appropriate content and supportive pedagogical strategies (Kreimeier et al., 2023; Suryati et al., 2025).

Overall, while digital books hold significant promise for advancing climate change awareness education, their effective integration requires a comprehensive and multifaceted approach. Addressing technological inequities, strengthening teacher capacity, ensuring high-quality and contextually relevant content, and carefully considering learners' cognitive and emotional needs are essential steps in maximizing the educational potential of digital books. By systematically addressing these challenges, digital books can serve as powerful tools for fostering climate literacy and promoting sustainable development among young learners.

These findings are consistent with previous studies which indicate that the effectiveness of digital learning implementation is strongly influenced by institutional readiness, technological infrastructure and teachers' professional competences in ICT (Janković et al., 2025; Županić Benić & Kajm Ferčec, 2025). Without adequate support in these areas, digital learning innovations often fail to achieve their intended educational impact.

### ***Strategies for developing interactive digital books based on design thinking***

Digital books are technology-based learning media that integrate text, images, audio and video into a single platform. Their key advantages include high accessibility, printing cost savings and the ability to update content quickly (Ridha & Kusasi, 2024). However, to ensure learning effectiveness, digital books must be designed with careful consideration of students' pedagogical and psychological needs.

Interactive digital books serve as digital learning media that enable active user interaction with content. These books should feature engaging visualizations, simulations, interactive quizzes and intuitive navigation. They must also be flexible, accessible anytime and anywhere, and capable of delivering content compellingly. Digital books developed for environmental education should be meaningful to students; the design and content should convey knowledge and aim to foster attitudes, awareness, concern and skills for environmental preservation, all within the students' context.

Design thinking is a creative problem-solving approach that emphasizes a deep understanding of users (Verganti et al., 2021). It is a student-centered methodology aimed at developing relevant and meaningful solutions (Cooke, 2022; Dragičević et al., 2023; Mardiah et al., 2023). By applying the principles of design thinking, developers

can create interactive digital books that not only deliver information but also stimulate interest, enhance motivation and encourage active student participation (Gwangwava, 2021; Przybilla et al., 2022). This iterative method is typically illustrated through five key stages: empathize, define, ideate, prototype and test (Dell’Era et al., 2020; Dina Marwah Alfirahmi & Kania, 2023).

In educational contexts, this approach allows educators to design more personalized and meaningful learning experiences (Dell’Era et al., 2020; Pande & Bharathi, 2020). Through the application of design thinking, developers can produce digital books that are not only informative but also engaging and interactive, catering to diverse user preferences and enhancing the overall reading experience.

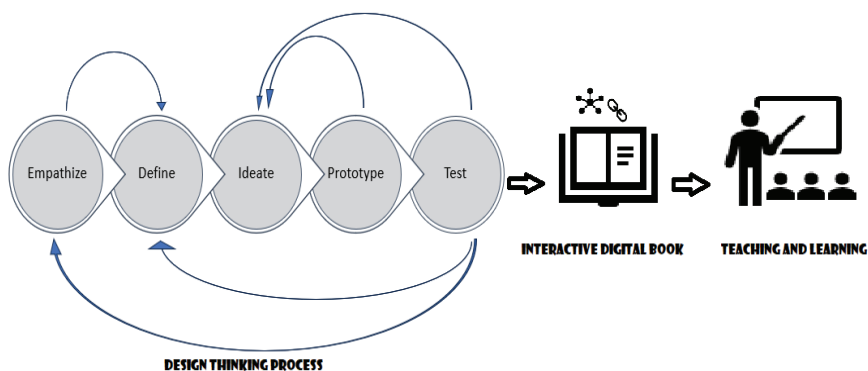


Figure 2. A Nonlinear Design Thinking Process

Empathize and define stages of design thinking emphasize the importance of understanding students’ needs, habits and learning challenges (Watini, 2024). Digital books designed based on such insights are more likely to be relevant and engaging for students. This stage involves deeply exploring users’ needs, desires and challenges through user research methods such as interviews, observations and surveys. The subsequent define stage entails clearly articulating the problem to be addressed based on findings from the empathize phase. For example, in developing an interactive e-book for the Candirejo Village community, researchers engaged with residents to identify their informational needs and preferences, guiding the design process (Fami et al., 2023). Similarly, developing a digital library prototype prioritized usability and user experience, which ensured that the final product met users’ needs (Haque & Indah, 2022).

The ideate stage encourages designers to generate a wide range of creative solutions. Resulting digital books may include interactive features such as quizzes, animations and simulations, which enriches students’ learning experiences (Verganti et al., 2021; Watini, 2024). This stage is crucial for producing innovative solutions and involves applying techniques like brainstorming, mind mapping or card sorting. Interactive e-book development may include multimedia elements such as Augmented Reality (AR) and 3D animations to enhance student-content interaction (Karagöz et al., 2023).

The prototype and test stages enable preliminary testing of digital books with actual users. Feedback from students can be used to refine the design, content and interactive features (Carter et al., 2022; Dragičević et al., 2023; Watini, 2024). Prototyping allows these ideas to be tested in a tangible form, through sketches, mockups or simple functional models. For instance, developing a mobile interactive picture book involved creating a prototype tested for compatibility with children's cognitive characteristics (Lee et al., 2018). Testing prototypes with real users provides valuable insights for product improvement. In the case of the Candirejo interactive e-book, user testing ensured the final product met the community's expectations (Fami et al., 2023). Similarly, a digital library prototype was evaluated using a User Experience Questionnaire, which received high ratings across several aspects, highlighting the importance of iterative testing in achieving user satisfaction (Haque & Indah, 2022).

### ***How design thinking enhances the effectiveness of interactive digital books development for climate change awareness education***

Design thinking has the potential to significantly enhance the effectiveness of interactive digital books aimed at fostering environmental awareness about climate change. By integrating participatory design and interactive multimedia, these digital books can promote critical thinking, learner engagement and pro-environmental behaviour among students. Technology-enhanced learning environments, including those supported by immersive and interactive features, have been associated with improved academic performance and deeper learning experiences (Liu, 2024). This suggests that the effectiveness of digital books depends not only on content quality but also on how learning experiences are designed.

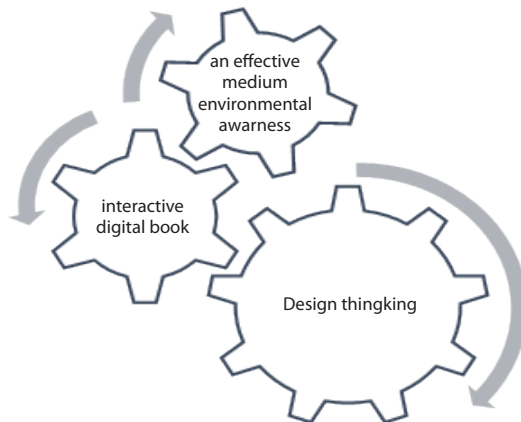


Figure 3. The Role of Design Thinking in Enhancing the Effectiveness of Environmental Awareness Education

The application of design thinking in developing digital books is not without challenges, such as limited resources, insufficient teacher training and the time required for iterative design processes. Nevertheless, this approach holds considerable promise

when supported by adaptive and collaborative educational management. Design thinking fosters collaboration among educators, designers, software developers and students. Such collaboration enhances the design quality and ensures that digital books effectively address real needs in the field.

### ***Design thinking enhances student interaction and engagement***

Participatory design involves users directly in the creation process so that the final product reflects their needs and preferences more closely (Jussila et al., 2022). In educational contexts, this approach has shown promise in engaging children in climate action through interactive and meaningful learning experiences. For example, the Our Eco-Logbook project demonstrates how participatory design can support children's involvement in school-based climate initiatives through interactive data visualization (Gauthier et al., 2024). More broadly, involving young learners in sustainability-oriented design processes may help bridge the value–action gap and foster sustainability-related competencies (Castaño et al., 2025).

Design thinking offers a structured framework that includes stages such as empathizing, defining, ideating, prototyping and testing. These stages guide learners through a comprehensive problem-solving process while encouraging deeper engagement with content and more purposeful collaboration with peers (Aini & Wardhana, 2025). The Design Framework for Student Engagement (DFSE), for instance, illustrates how design thinking principles can be applied to create more engaging student experiences both inside and outside the classroom (Grau & Rockett, 2022).

The reviewed literature also suggests that design thinking may support interaction and participation by fostering collaborative learning environments in which students work together to address real-world problems. Such collaboration appears to strengthen communication, teamwork and critical thinking, particularly in problem-based learning contexts (Nordin et al., 2024). In engineering education, design thinking has been associated with increased student interaction and participation, as reflected in improved learning coefficients in courses such as metrology (Chavan et al., 2023). Similarly, empirical research in vocational higher education suggests that teaching models based on design thinking may positively influence student engagement and classroom behaviour, with possible implications for improved educational outcomes (Wei et al., 2023). Interactive learning applications developed using design thinking principles have also been reported to enhance student motivation and interest, particularly in challenging subjects such as mathematics (Aini & Wardhana, 2025).

At the same time, the literature points to several implementation challenges. Some educators may have limited familiarity with design thinking principles, and integrating this approach into existing curricula may require additional time, pedagogical preparation and institutional support. These challenges suggest that the effectiveness of design thinking depends not only on the quality of the digital tools produced but also on the readiness of teachers and schools to implement learner-centred and iterative approaches in practice.

Taken together, these studies suggest that the contribution of design thinking to student engagement lies not merely in the addition of interactive features, but in the way it structures participation, iteration and learner relevance. Across contexts, engagement appears to increase when learners are positioned as contributors to the design or refinement of learning experiences rather than as passive users of digital content. This indicates that the value of design thinking in digital learning environments is pedagogical as much as technological, as it promotes ownership, responsiveness and meaningful interaction with content.

This pattern aligns with empirical findings which show that interactive digital learning environments significantly enhance student motivation, participation and academic outcomes, particularly when learners are actively involved in the learning process (Köseoğlu & Boyacı, 2025; Yan, 2025). Such findings reinforce the importance of integrating interactive and participatory elements into digital book design.

### ***Optimizing visualization and technology in the learning process***

Design thinking optimizes using visualization and technology in learning by promoting creative and analytical problem-solving approaches, which thereby enhances instructional design. This methodology encourages educators to create engaging learning experiences tailored to students' needs, which ultimately lead to improved learning outcomes. The role of multimedia and multimodal representation in enhancing conceptual understanding is also well documented. Multimodal learning approaches that integrate visual, textual and interactive elements have been shown to improve learners' ability to construct meaning and engage with complex content (Gül & Coştu, 2024).

Interactive multimedia can enhance students' understanding of global warming and strengthen critical thinking skills when combined with design thinking. This method encourages students to analyse and address climate change-related issues, as demonstrated in studies on global warming education (Susanto & Suyatna, 2015). Digital tools and games designed for sustainability education can reframe environmental problems as opportunities for innovation and community engagement, which fosters a deeper understanding of urban complexity and the impacts of climate change (Gabriel Kaprielian & Renee Jackson, 2022).

Design thinking promotes critical thinking and creativity, skills essential for educational problem-solving (Anwar et al., 2023). It encourages students to identify and analyse complex problems, which leads to innovative solutions in disciplines such as visual communication design (Anwar et al., 2023). Visualization tools and techniques are integral to the design thinking process, aiding in the clarification of complex processes and ideas (Yang, 2018). Such visualizations can assist educators in developing accessible instructional designs that align with desired learning outcomes (Ramos & Inocian, 2022).

Technology-enhanced learning environments benefit from design thinking by integrating various educational models and tools, such as Learning Activity Management

Systems (Ramos & Inocian, 2022; Tham et al., 2022; Yang, 2018). These integrations support collaborative learning and reflection, which are crucial for effective educational design (Ramos & Inocian, 2022).

Design thinking-based digital books go beyond plain text by incorporating technologies such as interactive infographics, environmental simulations and gamified quizzes. These features enhance visual appeal and facilitate students' understanding of climate change concepts. By encouraging exploration through technology, learning becomes more enjoyable and aligns with the expectations of the digital age.

Across the reviewed studies, visualization and multimedia appear to be most effective when they are pedagogically aligned with learners' needs and cognitive readiness. In this sense, design thinking contributes not only by encouraging technological innovation but also by helping educators select, adapt and refine digital features that make abstract climate-related concepts more understandable, accessible and developmentally appropriate. The reviewed evidence therefore suggests that the educational value of digital media depends less on the complexity of the technology itself than on how well it is designed to support learning.

### ***Fostering collaboration and critical thinking skills***

One notable strength of design thinking is its potential to foster critical thinking and collaboration skills from an early age. Interactive digital books can include discussion forums where students share opinions and ideas for climate change solutions. Students work in virtual teams to develop projects, which strengthens their communication and problem-solving skills. Through iterative ideation, they learn that solutions can evolve, which cultivates resilience and critical thinking in the face of complex challenges. Thus, digital books move beyond mere reading tools to become collaborative platforms that train children to think strategically. Students are more inspired to act, not just understand theoretical concepts.

Design thinking promotes communication, coordination and teamwork among participants, as demonstrated in a study involving software engineering students engaged in an 18-week collaborative project (Abich et al., 2024). Initiatives such as the Global Classroom for Democracy Innovation further illustrate how design thinking facilitates international collaboration, enabling students to tackle complex issues like climate change through joint project development (Wingfield et al., 2024). The design thinking process encourages students to reframe problems, which enhances their adaptability and resilience, key components of critical thinking (Dell'Era et al., 2020; Susanto & Suyatna, 2015).

A quasi-experimental study showed that design thinking significantly improved critical thinking, communication and creativity among students learning world history, highlighting its effectiveness in developing 21st-century skills (Ramos & Inocian, 2022). While design thinking has shown promise in enhancing collaboration and critical thinking, some students may struggle in collaborative settings, which

underscores the need for differentiated approaches to ensure all learners can thrive (Bene & McNeilly, 2020).

Interactive digital books based on design thinking have great potential to improve students' environmental knowledge and awareness. With engaging design, relevant content and rich interactive features, digital books can make environmental education more enjoyable and meaningful. However, the successful implementation of digital books depends on various factors, including school support, infrastructure availability and teachers' competencies.

The stages of the design thinking approach can be systematically applied in the development of interactive digital books for climate change awareness education at schools. During the empathize stage, students are encouraged to observe their surrounding environment through photographs, videos or reflective activities, which helps foster emotional engagement with climate change issues (Chavan et al., 2023). This is followed by the define stage, in which students articulate environmental problems based on their own experiences, which enables them to develop a deeper understanding of the need for concrete and contextually relevant solutions rather than passively receiving information (Nordin et al., 2024). In the ideate stage, students generate creative ideas to address climate change challenges through digital discussions and structured brainstorming activities (Gauthier et al., 2024; Grau & Rockett, 2022). These ideas are then translated into tangible outputs during the prototype stage, where students develop simple digital projects such as environmental campaign posters or short explanatory videos that illustrate the impacts of climate change (Cho & Park, 2023; Gabriel & Schmölzer, 2022; Gauthier et al., 2024). Finally, in the test stage, the projects are presented through digital exhibitions and evaluated based on feedback from peers and teachers, which allows students to refine their understanding and improve the quality of their solutions through reflective learning processes (He et al., 2023; Tham et al., 2022; Yang, 2018).

Overall, the reviewed literature suggests that design thinking may support collaboration and critical thinking by engaging learners in iterative processes of problem framing, idea generation, prototyping and solution testing. These processes appear to encourage discussion, reflection and shared decision-making, which are central to higher-order thinking and collaborative learning. However, the reported benefits also seem to depend on supportive instructional conditions, including teacher facilitation, sufficient time allocation and tasks that are appropriately scaffolded for learners' developmental level. This suggests that design thinking is not inherently transformative, but becomes more effective when implemented within well-supported learning environments.

### ***Practical synthesis and research implications***

Rather than reporting individual study findings descriptively, the synthesis identifies recurring pedagogical patterns that emerge across the reviewed literature. Across the reviewed studies, three consistent patterns emerge regarding the educational

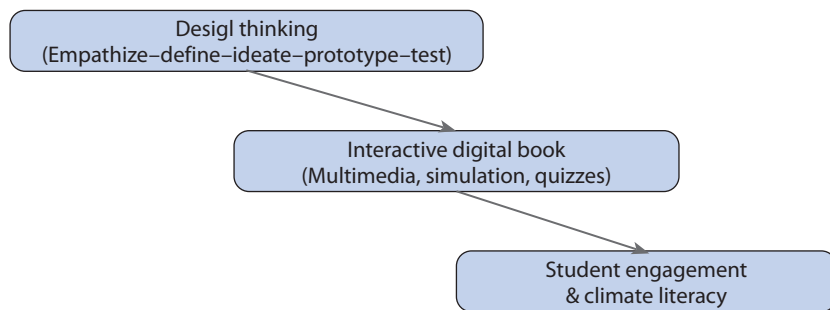


Figure 4. Conceptual overview of the relationship between design thinking, digital book development and climate literacy outcomes.

value of design thinking in digital learning environments. First, design thinking frameworks tend to increase learner engagement by embedding iterative problem-solving activities within the learning process (Grau & Rockett, 2022; Wei et al., 2023). Second, participatory design approaches enable students to actively co-create learning artefacts, which strengthens their sense of ownership toward environmental issues (Gauthier et al., 2024). Third, the integration of multimedia and visualization tools within design thinking-based digital media appears to reduce conceptual barriers when students engage with complex topics such as climate change (Cho & Park, 2023; Karagöz et al., 2023). These patterns indicate that the pedagogical value of design thinking lies not only in technological innovation but also in its ability to structure meaningful learner participation.

The findings of this review have several implications for educational practice and future research. For educators, the integration of design thinking into digital book development provides a structured approach for designing climate education resources that are both interactive and learner-centred. For curriculum developers, the results highlight the importance of combining multimedia visualization with participatory learning processes to enhance environmental understanding among young learners. From a research perspective, future studies should investigate long-term learning outcomes and behavioural impacts of design thinking-based digital learning media through experimental or longitudinal designs.

## Conclusion

This literature review suggests that the development of interactive digital books informed by a design thinking approach holds considerable promise for strengthening environmental education, particularly in supporting climate change awareness among school students. By integrating interactive elements, engaging visualizations and learner-centred design principles, such digital books may offer more immersive and meaningful learning experiences. Across the reviewed studies, design thinking-based digital books appear to be associated with improved support for students' understanding of environmental concepts, more active engagement in learning and

the development of 21st-century competencies such as critical thinking, creativity, collaboration and communication, all of which are relevant to addressing complex environmental challenges.

This review also indicates that design thinking can reposition students from passive recipients of content to more active participants in the learning process. By linking environmental observation, problem identification, idea generation, prototyping and iterative testing, digital books may function not only as instructional resources but also as interactive and participatory learning media. In this sense, design thinking appears to support learning environments in which students can develop a stronger sense of ownership, responsibility and agency in responding to climate-related issues, making environmental education more reflective, contextualized and action-oriented.

At the same time, several limitations should be acknowledged. The inclusion of only peer-reviewed and open-access studies published within the last five years helped ensure relevance and accessibility, but it may also have excluded earlier foundational works and subscription-based studies, thereby limiting the comprehensiveness of the review. Although major databases were used, research published in regional, non-indexed or non-English sources may remain underrepresented, which may reduce geographical and contextual diversity. In addition, the use of narrative synthesis rather than meta-analysis means that the conclusions are based on recurring thematic patterns rather than quantified effect sizes. Many of the included studies were also small-scale or context-specific, and differences in infrastructure, teacher readiness and curriculum context across settings may influence the applicability of the findings.

Future research should expand database coverage, incorporate multilingual and regionally diverse sources, and apply more robust synthesis methods, including meta-analytic approaches where feasible. Longitudinal and context-sensitive empirical studies are also needed to examine the longer-term educational and behavioural implications of design thinking-based digital learning media in climate change education. Overall, this review supports the considered use of design thinking in the development of digital learning media, particularly when the aim is to create environmental education resources that are interactive, learner-centred, and responsive to the needs of young learners.

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# Design thinking u razvoju digitalnih knjiga za obrazovanje o klimatskim promjenama: sustavni pregled literature

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## Sažetak

Brzi razvoj digitalne tehnologije povećao je potrebu za inovativnim medijima za učenje, osobito u području obrazovanja o okolišu usmjerenoga na jačanje svijesti učenika o klimatskim promjenama. Digitalne knjige omogućuju interaktivna i pristupačna iskustva učenja, no njihova obrazovna vrijednost uvelike ovisi o tome u kojoj su mjeri osmišljene tako da odgovaraju potrebama učenika. U ovome se radu ispituje doprinos pristupa design thinking razvoju interaktivnih digitalnih knjiga te njegov utjecaj na angažman učenika i procese učenja u obrazovanju o klimatskim promjenama. Primjenom metode sustavnoga pregleda literature analizirano je 37 recenziranih radova objavljenih tijekom posljednjih pet godina, preuzetih iz baza Scopus, Web of Science, JSTOR i Google Scholar. U postupku pretraživanja korištene su kombinacije ključnih riječi povezanih s pristupom design thinking, digitalnim knjigama, klimatskim promjenama i obrazovanjem o okolišu. Ovaj pregled polazi od šire perspektive, uzimajući u obzir da postojeća istraživanja obuhvaćaju osnovno, srednje i visoko obrazovanje, pri čemu su duplicirani zapisi uklonjeni prije faze probira. Posebna je pozornost usmjerena na to kako se ključne faze design thinking pristupa — empatija, definiranje, generiranje ideja, izrada prototipa i testiranje — odražavaju u razvoju digitalnih medija za učenje. Rezultati upućuju na to da su digitalne knjige razvijene primjenom pristupa design thinking često povezane s boljom uporabljivošću, većim angažmanom učenika i učinkovitijom podrškom razumijevanju složenih okolišnih koncepata putem interaktivnih elemenata i vizualizacija. Nadalje, čini se da usmjerenost design thinking pristupa na korisnika pridonosi većoj relevantnosti sadržaja i njegovoj prilagodbi potrebama učenika. Općenito, rezultati pregleda sugeriraju da integracija pristupa design thinking u razvoj digitalnih knjiga može osnažiti obrazovanje o klimatskim promjenama u školama, premda su potrebna daljnja empirijska istraživanja radi ispitivanja dugoročnih ishoda učenja u različitim obrazovnim kontekstima.

**Ključne riječi:** digitalni mediji za učenje; obrazovanje o klimatskim promjenama; interaktivna multimedija; angažman učenika; dizajn usmjeren na korisnika; design thinking

## Uvod

*Design thinking* nametnuo se kao značajan pristup u razvoju digitalnih platformi, s naglaskom na rješenja usmjerena na korisnika i iterativnu izradu prototipa. Ova se metodologija široko primjenjuje u različitim područjima, od unaprjeđenja korisničkoga iskustva do poticanja održivih inovacija. Međutim, specifični zahtjevi za oblikovanje alata za učenje koji promiču ekološku osviještenost, osobito u kontekstu obrazovanja o klimatskim promjenama, još uvijek nisu dovoljno istraženi. U literaturi postoji zamjetna praznina u pogledu primjene pristupa *design thinking* u razvoju digitalnih knjiga koje potiču svijest o klimatskim promjenama među učenicima školske dobi. Popunjavanje te praznine ključno je za usmjeravanje budućih istraživanja i prakse u ovome području (Alfirahmi i sur., 2023).

Ova studija razmatra ključne elemente poput generiranja ideja, izrade prototipa i povratnih informacija korisnika u razvoju interaktivnih digitalnih knjiga, oslanjajući se na spoznaje iz različitih projekata i obrazovnih inicijativa utemeljenih na pristupu *design thinking*, a usmjerenih na razvoj ekološke osviještenosti u obrazovanju.

Klimatske promjene predstavljaju jedan od najozbiljnijih globalnih izazova koji zahtijeva međunarodnu suradnju, tehnološke inovacije i zajedničke promjene u ponašanju kako bi se ublažili njihovi sve izraženiji učinci (Kehler i Birchall, 2023; Mariappan i sur., 2022). Dublje razumijevanje složenosti klimatskih pitanja, potkrijepljeno snažnom globalnom predanošću, može omogućiti provedbu konkretnih mjera za očuvanje planeta za buduće generacije. Ipak, geopolitička neslaganja, suprotstavljeni gospodarski interesi, nejednak pristup zelenim tehnologijama i raširena apatija i dalje usporavaju napredak. Kako bi se na te izazove djelotvorno odgovorilo, nužno je temeljito preispitati postojeće obrazovne pristupe.

Razvoj digitalnih knjiga postao je važna sastavnica suvremenoga obrazovanja, pri čemu se tehnologija koristi za obogaćivanje iskustva učenja (Mashfufah i sur., 2019; Siregar i sur., 2021). Interaktivne digitalne knjige mijenjaju način na koji učenici pristupaju sadržaju i uključuju se u njega, nudeći iskustva učenja koja nadilaze tradicionalni tekstualni format. Takvi resursi imaju znatan potencijal za premošćivanje jaza između teorijskoga znanja i praktičnoga razumijevanja (Mashfufah i sur., 2019; Pradita i sur., 2023; Puji Lestari i sur., 2022; Siregar i sur., 2021; Van Wyk i sur., 2020). Zahvaljujući interaktivnim značajkama poput videozapisa, simulacija, kvizova i igara, digitalne knjige mogu značajno povećati angažman i motivaciju učenika (Nadeem i sur., 2023). Nadalje, mogu se prilagoditi različitim potrebama i preferencijama učenika, čime obrazovanje postaje personaliziranije i uključivije za sve učenike.

Unatoč tim prednostima i dalje postoje brojni izazovi, poput osiguravanja pravednoga pristupa tehnologiji i osposobljavanja nastavnika za učinkovitu uporabu digitalnih resursa. Uklanjanje tih prepreka ključno je za ostvarivanje punog potencijala digitalnih alata za učenje. Česti problemi uključuju loš raspored sadržaja na zaslonu, otežanu navigaciju i vizuale niske rezolucije, što negativno utječe na korisničko iskustvo (Van Wyk i sur., 2020).

Razvoj digitalnih knjiga usmjerenih na poticanje svijesti o klimatskim promjenama u obrazovanju zahtijeva pažljivu integraciju dizajna, tehnologije i strategija za poticanje angažmana učenika. Primjenom načela dizajna usmjerenoga na korisnika, uključivanjem novih tehnologija te korištenjem gamifikacije i suradničkoga učenja, moguće je razviti digitalne knjige koje su istodobno obrazovno učinkovite i privlačne učenicima. Prevladavanje navedenih izazova od presudne je važnosti kako bi takvi resursi doista mogli učinkovito razvijati svijest i poticati proaktivan odnos mlađih učenika prema klimatskim promjenama.

Nedavna istraživanja pokazuju da digitalna okružja za učenje imaju sve važniju ulogu u suvremenome obrazovanju, osobito u poticanju angažmana učenika, autonomije i akademske uspješnosti putem interaktivnih i tehnološki unaprjeđenih pristupa (Janković i sur., 2025; Liu, 2024). Istodobno, istraživanja u području obrazovanja o okolišu naglašavaju da se ekološka osviještenost može učinkovito razvijati putem strukturiranih i kontekstualno relevantnih iskustva učenja od najranijih obrazovnih razina (Erdem i Belgin Özaydınlı, 2023). Međutim, i dalje nedostaju integrativni pristupi koji povezuju okvire dizajna usmjerene na korisnika, poput *design thinkinga*, s digitalnim medijima za učenje radi specifične potpore razvoju svijesti o klimatskim promjenama u različitim obrazovnim kontekstima. Ta praznina ukazuje na potrebu za sustavnom sintezom načina na koji *design thinking* može usmjeravati razvoj interaktivnih digitalnih knjiga za obrazovanje o okolišu.

## Metodologija

U ovome je istraživanju primijenjen sustavni pregled literature (*systematic literature review*, SLR) kako bi se ispitalo na koji način *design thinking* doprinosi razvoju i učinkovitosti interaktivnih digitalnih knjiga za obrazovanje o svijesti o klimatskim promjenama u školama. Pregled je bio strukturiran s ciljem povećanja transparentnosti i ponovljivosti primjenom jasno definiranih kriterija uključivanja, postupnoga probira i strukturiranoga izdvajanja podataka.

### **Istraživačko pitanje i analitički fokus**

Središnje istraživačko pitanje koje je usmjeravalo ovaj pregled glasilo je: na koji način *design thinking* doprinosi učinkovitosti učenja i angažmanu korisnika u interaktivnim digitalnim knjigama u kontekstu obrazovanja o klimatskim promjenama?

Kako bi se odgovorilo na to pitanje, sinteza je bila usmjerena na tri analitičke dimenzije: (1) izazove s kojima se učenici susreću pri korištenju digitalnih knjiga za učenje o klimatskim temama, (2) strategije razvoja interaktivnih digitalnih knjiga oblikovane pristupom *design thinking* te (3) načine na koje *design thinking*, svojim ključnim fazama (empatija, definiranje, generiranje ideja, izrada prototipa i testiranje), podupire učinkovitost učenja i angažman

### **Izvori informacija i strategija pretraživanja**

Pretraživanje literature provedeno je u četirima glavnim bazama podataka: Scopus, Web of Science, JSTOR i Google Scholar. U pretraživanju su korištene kombinacije ključnih

riječi, uključujući: („design thinking” AND „digital book” OR „interactive e-book”) AND („climate change education” OR „environmental education”). Duplicirani zapisi uklonjeni su prije faze probira. Osim toga, za identifikaciju potencijalno relevantnih studija koje nisu bile obuhvaćene početnim pretraživanjem baza podataka korišteno je i praćenje citata, odnosno pregled referentnih popisa i radova koji citiraju odabrane studije.

### **Kriteriji uključivanja**

Studije su uključene ako su bile recenzirani znanstveni članci ili radovi sa znanstvenih skupova objavljeni tijekom posljednjih pet godina te ako su izričito obrađivale *design thinking* ili su jasno operacionalizirale njegove ključne faze (empatija, definiranje, generiranje ideja, izrada prototipa i testiranje) u razvoju digitalnih medija za učenje. Prihvatljive studije također su morale biti usmjerene na digitalne knjige, e-knjige ili srodne oblike interaktivnih digitalnih medija za čitanje te pokazivati relevantnost za obrazovanje o klimatskim promjenama, okolišu ili održivosti, uz jasnu primjenjivost u obrazovnim kontekstima. Studije su isključene ako nisu bile recenzirane, ako nisu bile povezane s razvojem obrazovnih medija, ako nisu pružale dovoljno metodoloških pojedinosti za izdvajanje ključnih varijabli ili ako su bile izvan utvrđenoga razdoblja objave.

Petogodišnje razdoblje objavljivanja odabrano je kako bi se obuhvatio recentan razvoj digitalnih medija za učenje, primjene pristupa *design thinking* i inovacija u obrazovanju povezanom s klimatskim temama. Google Scholar korišten je kao dopunski izvor radi proširenja obuhvata pretraživanja i potpore praćenju citata, dok su Scopus, Web of Science i JSTOR služili kao glavne baze podataka. Da bi bile uključene, studije su morale s dovoljnom jasnoćom obuhvatiti sve sljedeće aspekte: *design thinking* ili njegove operativne faze, digitalne knjige ili blisko povezane digitalne medije za čitanje, relevantnost za učenje o okolišu ili klimatskim pitanjima te primjenjivost u obrazovanju. Postupak identifikacije studija, probira, procjene prihvatljivosti i konačnoga uključivanja sažeto je prikazan na Slici 1.

Slika 1

### **Postupak probira i odabira studija**

Početno pretraživanje baza podataka rezultiralo je s 1 050 zapisa. Nakon preliminarnoga filtriranja prema relevantnosti, vrsti publikacije i dostupnosti, za probir je zadržano 145 zapisa. Praćenjem citata identificirana su dodatna 93 zapisa, čime je ukupan broj zapisa uključenih u procjenu prihvatljivosti dosegnuo 233. Probir je proveden u dvije faze: (1) pregled naslova i sažetaka radi uklanjanja tematski nepovezanih zapisa, a potom (2) pregled cjelovitih tekstova prema kriterijima uključivanja. Tim je postupkom u konačnu sintezu uključeno 37 studija.

### **Obilježja recenzenata i postupak donošenja odluka**

Kako bi se osigurala usklađenost sa standardima sustavnoga pregleda, postupke probira i izdvajanja podataka provela su dva neovisna recenzenta, od kojih je jedan

imao stručnost u području obrazovne tehnologije i instruktivnoga dizajna, a drugi u području obrazovanja o okolišu. Oba su se recenzenta prije početka probira usuglasila o kriterijima prihvatljivosti i predložka za izdvajanje podataka. Svaki je recenzent neovisno proveo pregled naslova i sažetaka te procjenu prihvatljivosti cjelovitih tekstova. Sve nesuglasice rješavane su raspravom do postizanja konsenzusa, čime se smanjila pristranost pri odabiru i povećala pouzdanost donesenih odluka.

### ***Izdvajanje podataka***

Prije početka analize izrađen je strukturirani predložak za izdvajanje podataka kako bi se osiguralo dosljedno bilježenje ključnih informacija iz uključenih studija. Za svaku uključenu studiju izdvojeni su bibliografski podatci (autor, godina i izvor publikacije), obrazovni kontekst i obilježja okružja (primjerice država ili regija, obrazovna razina i opis sudionika, kada je bio naveden), kao i vrsta digitalne knjige ili medija te njegove interaktivne značajke (poput multimedijjskih elemenata, kvizova, simulacija i navigacijskoga dizajna). Također je zabilježeno na koji je način operacionaliziran *design thinking*, pri čemu su analizirane primijenjene faze, kao i ključna obilježja razvojnoga procesa, poput aktivnosti istraživanja korisnika, ciklusa izrade prototipa i iteracija te mehanizama za prikupljanje povratnih informacija korisnika. Osim toga, izdvojene su informacije o metodama vrednovanja, uključujući testiranje uporabljivosti, pokazatelje angažmana i mjere ishoda učenja, a zatim su sažeti glavni nalazi relevantni za učinkovitost učenja i angažman korisnika.

Izdvajanje podataka provela su neovisno oba recenzenta, nakon čega su rezultati uspoređeni. Sve nedosljednosti usklađene su putem rasprave i ponovne provjere izvornih publikacija kako bi se osigurala točnost podataka.

### ***Razmatranja kvalitete***

Budući da su se uključene studije razlikovale prema istraživačkom dizajnu, primjerice obuhvaćajući razvojna istraživanja, provedbe u razrednom okružju i kvaziekperimentalne evaluacije, tijekom sinteze se vodilo računa o metodološkoj rigoroznosti. Prednost su imali nalazi potkrijepljeni jasno opisanim postupcima, kao što su izričiti protokoli testiranja korisnika i jasno definirane mjere ishoda. Studije s ograničenim izvještavanjem tumačene su s oprezom te su korištene ponajprije radi kontekstualnoga uvida.

### ***Procjena kvalitete uključenih studija***

Radi povećanja metodološke utemeljenosti pregleda, svaka uključena studija procijenjena je prema trima kriterijima: (1) jasnoća istraživačkoga dizajna, (2) transparentnost postupaka prikupljanja i analize podataka te (3) relevantnost za razvoj ili evaluaciju digitalnih medija za učenje u kontekstu obrazovanja o klimatskim promjenama, okolišu ili održivosti. Za svaki kriterij studije su ocijenjene kao: jasno zadovoljen, djelomično zadovoljen ili nedostavno prikazan. Na temelju ukupne cjelovitosti i transparentnosti izvještavanja studije su zatim razvrstane u kategorije visoke, umjerene ili ograničene

metodološke transparentnosti. Studije ocijenjene visokom transparentnošću pružale su jasne opise istraživačkoga dizajna, postupaka i obrazovne relevantnosti. One ocijenjene umjerenom transparentnošću zadovoljavale su te kriterije samo djelomično, dok su studije s ograničenom transparentnošću pokazivale manjak dostatnih metodoloških pojedinosti u jednom ili više područja. Nijedna studija nije isključena isključivo na temelju procjene kvalitete. Međutim, studijama s višom razinom metodološke transparentnosti pridana je veća interpretativna težina tijekom sinteze. Pripremljena je i sažeta tablica kategorija metodološke transparentnosti radi potpore dosljednosti i transparentnosti postupka pregleda.

### **Sinteza podataka**

Zbog heterogenosti istraživačkih dizajna i mjera ishoda primijenjen je pristup narativne sinteze. Dokazi su tematski organizirani u tri skupine: (1) izazovi i prepreke u primjeni digitalnih knjiga za učenje o klimatskim temama, (2) strategije razvoja utemeljene na pristupu *design thinking* putem njegovih pet faza te (3) prijavljeni ishodi povezani s uporabljivošću, angažmanom, razumijevanjem i razvojem vještina. Obrasci koji su se ponavljali u većem broju studija istaknuti su kao trendovi veće pouzdanosti, dok su nalazi specifični za pojedini kontekst prikazani uz odgovarajući oprez.

#### Tablica 1

Konsolidirana tematska sinteza pokazuje da se pregledane studije mogu grupirati u devet nadređenih tema koje odražavaju višestruku ulogu *design thinkinga* u digitalnim okruženjima za učenje. Najzastupljenije teme uključuju angažman učenika, kritičko mišljenje i učenje potpomognuto multimedijom, što upućuje na to da *design thinking* ponajprije pridonosi unaprjeđenju aktivnih i smislenih iskustava učenja. Važno je istaknuti da raspodjela studija po temama potvrđuje kako primjena pristupa *design thinking* nije ograničena na osnovno obrazovanje, nego se proteže i na kontekste srednjega i visokoga obrazovanja. Istodobno, teme povezane s klimatskom pismenošću i razvojem digitalnih knjiga snažnije su zastupljene u kontekstu osnovnoga i općenito školskoga obrazovanja, što upućuje na specifičnu mogućnost za daljnja istraživanja. Općenito, ova tematska konsolidacija omogućuje jasnije i strukturiranije tumačenje nalaza, nadilazeći deskriptivno prikazivanje i usmjeravajući se prema analitičkoj sintezi.

## **Rezultati i diskusija**

### ***Izazovi u integraciji digitalnih knjiga u obrazovanje o klimatskim promjenama***

Integracija digitalnih knjiga u obrazovanje o klimatskim promjenama pruža znatan potencijal za jačanje svijesti i angažmana učenika, međutim, takvu integraciju prati niz međusobno povezanih izazova. Jedna od najizraženijih prepreka jest nejednak pristup tehnologiji. U mnogim regijama, osobito u kontekstima zemalja u razvoju, učenici nemaju stalan pristup digitalnim uređajima poput pametnih telefona, tableta ili

računala, što ograničava njihovu mogućnost korištenja digitalnih obrazovnih resursa. Čak i kada su uređaji dostupni, nedostatna ili nestabilna internetska povezanost često ograničava pristup mrežnim digitalnim knjigama i interaktivnim sadržajima, čime se dodatno produbljuje digitalni jaz te smanjuju doseg i učinkovitost inicijativa obrazovanja o klimatskim promjenama koje se temelje na digitalnim alatima (Hoffmann i sur., 2022; Marhraoui i Ojubanire, 2025; Suryati i sur., 2025).

Uz infrastrukturna ograničenja, pedagoški izazovi također značajno utječu na učinkovitost primjene digitalnih knjiga. Mnogi nastavnici nemaju dovoljnu osposobljenost i stručnu potporu za smislenu uključivanje digitalnih knjiga u svoju nastavnu praksu. Kao rezultat toga, digitalni se resursi mogu nedovoljno koristiti ili se koriste na načine koji ne iskorištavaju u potpunosti njihov interaktivni i pedagoški potencijal (Hoffmann i sur., 2022; Tang, 2022). Nadalje, usklađivanje sadržaja digitalnih knjiga s postojećim kurikulumima i okvirima vrednovanja može biti otežano, osobito kada su odgojno-obrazovni ciljevi i zahtjevi nastavnih planova rigidni ili tradicionalno strukturirani. Ti izazovi često dovode do nedosljedne ili fragmentirane uporabe digitalnih knjiga u razrednoj nastavi (Hoffmann i sur., 2022; Suryati i sur., 2025).

Angažman i motivacija učenika također predstavljaju ključne izazove u kontekstu obrazovanja o klimatskim promjenama. Da bi digitalne knjige bile učinkovite, moraju biti oblikovane tako da privuku interes učenika i održe njihovu motivaciju za uključivanje u složene teme povezane s okolišem. Kada digitalni sadržaj nema dovoljno interaktivnosti ili relevantnosti, može izostati poticanje smislenih iskustava učenja (Beach i Smith, 2022; Gabriel i Schmölzer, 2022). Osim toga, sama složenost koncepata klimatskih promjena može dovesti do kognitivnoga preopterećenja, osobito kada su informacije prikazane u gustim ili slabo strukturiranim formatima. To može otežati učenicima učinkovitu obradu, zadržavanje i primjenu znanja (Cho i Park, 2023; Hajj-Hassan i sur., 2024).

Kvaliteta sadržaja i pitanja dizajna dodatno oblikuju obrazovnu vrijednost digitalnih knjiga. Osiguravanje točnosti, vjerodostojnosti i ažurnosti informacija povezanih s klimatskim promjenama od presudne je važnosti jer netočan ili zastario sadržaj može narušiti ishode učenja i dovesti učenike u zabludu (Hoffmann i sur., 2022; Josephine Oranga i sur., 2023). Osim toga, digitalne knjige moraju biti kulturno i kontekstualno relevantne kako bi bile bliske različitim skupinama učenika. Sadržaj koji ne odražava lokalne okolišne probleme ili životna iskustva učenika može ograničiti njihov angažman i smanjiti percipiranu relevantnost obrazovanja o klimatskim promjenama (Hoffmann i sur., 2022; Marhraoui i Ojubanire, 2025).

Naposljetku, psihološki i kognitivni čimbenici imaju važnu ulogu u oblikovanju iskustava učenja učenika. Loše osmišljene digitalne knjige mogu povećati kognitivno opterećenje, što dovodi do slabijega razumijevanja i zadržavanja koncepata povezanih s klimatskim promjenama (Cho i Park, 2023; Hajj-Hassan i sur., 2024). Klimatske promjene ujedno su i emocionalno osjetljiva tema, a izloženost alarmantnim ili katastrofičnim narativima putem digitalnih medija može kod učenika izazvati osjećaje

anksioznosti, bespomoćnosti ili ekološke anksioznosti. Takve emocionalne reakcije mogu predstavljati prepreku učenju ako se njima ne upravlja pažljivo, uz sadržaj prilagođen dobi i odgovarajuće pedagoške strategije potpore (Kreimeier i sur., 2023; Suryati i sur., 2025).

Općenito, iako digitalne knjige imaju velik potencijal za unaprjeđenje obrazovanja o svijesti o klimatskim promjenama, njihova učinkovita integracija zahtijeva cjelovit i višedimenzionalan pristup. Rješavanje tehnoloških nejednakosti, jačanje kompetencija nastavnika, osiguravanje visokokvalitetnoga i kontekstualno relevantnoga sadržaja te pažljivo uvažavanje kognitivnih i emocionalnih potreba učenika predstavljaju ključne korake za maksimalno iskorištavanje obrazovnoga potencijala digitalnih knjiga. Sustavnim odgovaranjem na te izazove digitalne knjige mogu postati snažni alati za razvoj klimatske pismenosti i promicanje održivoga razvoja među mladim učenicima.

Ovi su nalazi u skladu s prethodnim istraživanjima koja pokazuju da na učinkovitost provedbe digitalnoga učenja snažno utječu institucionalna spremnost, tehnološka infrastruktura i profesionalne kompetencije nastavnika u području informacijsko-komunikacijskih tehnologija (Janković i sur., 2025; Županić Benić i Kajm Ferčec, 2025). Bez odgovarajuće potpore u tim područjima, inovacije u digitalnom učenju često ne uspijevaju ostvariti svoj predviđeni obrazovni učinak.

### ***Strategije razvoja interaktivnih digitalnih knjiga utemeljene na pristupu design thinking***

Digitalne knjige predstavljaju medije za učenje utemeljene na tehnologiji koji objedinjuju tekst, slike, zvuk i video unutar jedinstvene platforme. Njihove ključne prednosti uključuju visoku dostupnost, smanjenje troškova tiska i mogućnost brze nadogradnje sadržaja (Ridha i Kusasi, 2024). Međutim, kako bi se osigurala učinkovitost učenja, digitalne knjige moraju biti osmišljene uz pažljivo uvažavanje pedagoških i psiholoških potreba učenika.

Interaktivne digitalne knjige služe kao digitalni mediji za učenje koji korisnicima omogućuju aktivnu interakciju sa sadržajem. Takve knjige trebale bi sadržavati privlačne vizualizacije, simulacije, interaktivne kvizove i intuitivnu navigaciju. Također moraju biti fleksibilne, dostupne bilo kada i bilo gdje te sposobne prenositi sadržaj na uvjerljiv i zanimljiv način. Digitalne knjige razvijene za obrazovanje o okolišu trebale bi imati jasno značenje za učenike; njihov dizajn i sadržaj trebaju prenositi znanje, ali i poticati stavove, svijest, zabrinutost i vještine potrebne za očuvanje okoliša osobito unutar konteksta u kojem učenici žive i uče.

Design thinking predstavlja kreativan pristup rješavanju problema koji naglašava duboko razumijevanje korisnika (Verganti i sur., 2021). Riječ je o metodologiji usmjerenoj na učenika, čiji je cilj razvoj relevantnih i smislenih rješenja (Cooke, 2022; Dragičević i sur., 2023; Mardiah i sur., 2023). Primjenom *design thinking* načela razvojni timovi mogu osmisлити interaktivne digitalne knjige koje ne samo da prenose informacije, nego i potiču interes, povećavaju motivaciju i ohrabruju aktivno sudjelovanje učenika

(Gwangwawa, 2021; Przybilla i sur., 2022). Ova iterativna metoda obično se prikazuje u pet ključnih faza: empatija, definiranje, generiranje ideja, izrada prototipa i testiranje (Dell'Era i sur., 2020; Dina Marwah Alfirahmi i Kania, 2023).

U obrazovnim kontekstima takav pristup omogućuje nastavnicima osmišljavanje personaliziranih i smislenijih iskustava učenja (Dell'Era i sur., 2020; Pande i Bharathi, 2020). Primjenom *design thinking* pristupa moguće je razviti digitalne knjige koje nisu samo informativne, nego i privlačne te interaktivne, pri čemu odgovaraju različitim preferencijama korisnika i unaprjeđuju cjelokupno iskustvo čitanja.

## Slika 2

Faze empatije i definiranja u *design thinking* pristupu naglašavaju važnost razumijevanja potreba, navika i izazova učenja učenika (Watini, 2024). Digitalne knjige osmišljene na temelju takvih uvida vjerojatnije će biti relevantne i privlačne učenicima. Ova faza uključuje dubinsko istraživanje potreba, očekivanja i poteškoća korisnika primjenom metoda istraživanja korisnika, kao što su intervjui, opažanja i ankete. Naknadna faza definiranja podrazumijeva jasno formuliranje problema koji treba riješiti na temelju nalaza iz faze empatije. Primjerice, pri razvoju interaktivne e-knjige za zajednicu sela Candirejo, istraživači su surađivali sa stanovnicima kako bi utvrdili njihove informacijske potrebe i preferencije, što je usmjerilo proces oblikovanja (Fami i sur., 2023). Slično tome, u razvoju prototipa digitalne knjižnice prioritet su imali uporabljivost i korisničko iskustvo, čime se osiguralo da konačni proizvod odgovara potrebama korisnika (Haque i Indah, 2022).

Faza generiranja ideja potiče dizajnere na osmišljavanje širokoga raspona kreativnih rješenja. Tako razvijene digitalne knjige mogu uključivati interaktivne značajke poput kvizova, animacija i simulacija, čime se obogaćuju iskustva učenja učenika (Verganti i sur., 2021; Watini, 2024). Ova je faza ključna za stvaranje inovativnih rješenja i obuhvaća primjenu tehnika kao što su *brainstorming*, izrada mentalnih mapa ili razvrstavanje kartica. Razvoj interaktivnih e-knjiga može uključivati i multimedijske elemente poput proširene stvarnosti (AR) i trodimenzionalnih animacija radi unaprjeđenja interakcije između učenika i sadržaja (Karagöz i sur., 2023).

Faze izrade prototipa i testiranja omogućuju početno ispitivanje digitalnih knjiga sa stvarnim korisnicima. Povratne informacije učenika mogu se iskoristiti za doradu dizajna, sadržaja i interaktivnih značajki (Carter i sur., 2022; Dragičević i sur., 2023; Watini, 2024). Izrada prototipa omogućuje provjeru tih ideja u upipljivom obliku, putem skica, modela sučelja ili jednostavnih funkcionalnih modela. Primjerice, razvoj mobilne interaktivne slikovnice uključivao je izradu prototipa koji je testiran s obzirom na usklađenost s kognitivnim obilježjima djece (Lee i sur., 2018). Testiranje prototipova sa stvarnim korisnicima pruža vrijedne uvide za unaprjeđenje proizvoda. U slučaju interaktivne e-knjige Candirejo, testiranje s korisnicima osiguralo je da konačni proizvod odgovara očekivanjima zajednice (Fami i sur., 2023). Slično tome, prototip digitalne knjižnice vrednovan je pomoću Upitnika korisničkoga iskustva, pri čemu

je dobio visoke ocjene u više aspekata, što dodatno potvrđuje važnost iterativnoga testiranja za postizanje zadovoljstva korisnika (Haque i Indah, 2022).

### ***Kako design thinking može povećati učinkovitost razvoja interaktivnih digitalnih knjiga u obrazovanju o klimatskim promjenama***

*Design thinking* ima potencijal značajno povećati učinkovitost interaktivnih digitalnih knjiga usmjerenih na razvoj ekološke osviještenosti o klimatskim promjenama. Integriranjem participativnoga dizajna i interaktivne multimedije takve digitalne knjige mogu poticati kritičko mišljenje, angažman učenika i proekološko ponašanje. Okružja učenja unaprijeđena tehnologijom, uključujući ona koja se oslanjaju na uranjajuće i interaktivne značajke, povezana su s boljim akademskim postignućima i dubljim iskustvima učenja (Liu, 2024). To upućuje na to da učinkovitost digitalnih knjiga ne ovisi samo o kvaliteti sadržaja, nego i o načinu na koji su iskustva učenja osmišljena.

#### Slika 3

Primjena *design thinking* pristupa u razvoju digitalnih knjiga nije bez izazova, kao što su ograničeni resursi, nedostatna osposobljenost nastavnika i vrijeme potrebno za iterativne procese oblikovanja. Ipak, ovaj pristup pokazuje znatan potencijal kada je podržan prilagodljivim i suradnički usmjerenim upravljanjem obrazovanjem. *Design thinking* potiče suradnju među nastavnicima, dizajnerima, programerima i učenicima. Takva suradnja unaprjeđuje kvalitetu dizajna i osigurava da digitalne knjige učinkovito odgovaraju stvarnim potrebama u obrazovnoj praksi.

### ***Design thinking povećava interakciju i angažman učenika***

Participativni dizajn uključuje korisnike izravno u proces stvaranja kako bi konačni proizvod u većoj mjeri odražavao njihove potrebe i preferencije (Jussila i sur., 2022). U obrazovnim kontekstima ovaj je pristup pokazao potencijal za uključivanje djece u djelovanje povezano s klimatskim promjenama primjenom interaktivnih i smislenih iskustva učenja. Primjerice, projekt Our Eco-Logbook pokazuje kako participativni dizajn može poduprijeti uključenost djece u školske klimatske inicijative putem interaktivne vizualizacije podataka (Gauthier i sur., 2024). Šire gledano, uključivanje mladih učenika u procese dizajna usmjerene na održivost može pomoći u premošćivanju jaza između vrijednosti i djelovanja te potaknuti razvoj kompetencija povezanih s održivošću (Castaño i sur., 2025).

*Design thinking* nudi strukturirani okvir koji uključuje faze empatije, definiranja, generiranja ideja, izrade prototipa i testiranja. Te faze vode učenike kroz cjelovit proces rješavanja problema, istodobno potičući dublji angažman sa sadržajem i svrhovitiju suradnju s vršnjacima (Aini i Wardhana, 2025). Primjerice, Design Framework for Student Engagement (DFSE) pokazuje kako se *design thinking* načela mogu primijeniti za oblikovanje privlačnijih iskustava učenika unutar i izvan učionice (Grau i Rockett, 2022).

Pregledana literatura također upućuje na to da *design thinking* može poduprijeti interakciju i sudjelovanje poticanjem suradničkih okružja za učenje u kojima učenici zajedno rade na rješavanju problema iz stvarnoga života. Čini se da takva suradnja jača komunikaciju, timski rad i kritičko mišljenje, osobito u kontekstima učenja temeljenoga na problemima (Nordin i sur., 2024). U inženjerskom obrazovanju *design thinking* povezuje se s povećanom interakcijom i sudjelovanjem učenika, što se očitovalo u poboljšanim koeficijentima učenja u kolegijima kao što je metrologija (Chavan i sur., 2023). Slično tomu, empirijska istraživanja u visokom strukovnom obrazovanju upućuju na to da modeli poučavanja utemeljeni na *design thinking* pristupu mogu pozitivno utjecati na angažman učenika i ponašanje u učionici, s mogućim implikacijama za poboljšanje obrazovnih ishoda (Wei i sur., 2023). Također se izvještava da interaktivne aplikacije za učenje razvijene prema *design thinking* načelima povećavaju motivaciju i interes učenika, osobito u zahtjevnim predmetima poput matematike (Aini i Wardhana, 2025).

Istodobno, literatura ukazuje i na nekoliko izazova u provedbi. Neki nastavnici mogu imati ograničeno poznavanje *design thinking* načela, a integracija ovoga pristupa u postojeće kurikule može zahtijevati dodatno vrijeme, pedagošku pripremu i institucionalnu potporu. Ti izazovi upućuju na to da učinkovitost *design thinking* pristupa ne ovisi samo o kvaliteti proizvedenih digitalnih alata, nego i o spremnosti nastavnika i škola da u praksi primjenjuju pristupe usmjerene na učenika i iterativni razvoj.

U cjelini, ova istraživanja pokazuju da doprinos *design thinking* pristupa angažmanu učenika ne leži samo u dodavanju interaktivnih značajki, nego u načinu na koji strukturira sudjelovanje, iteraciju i relevantnost za učenika. U različitim kontekstima čini se da se angažman povećava kada su učenici postavljeni kao aktivni sudionici u osmišljavanju ili unaprjeđenju iskustava učenja, a ne samo kao pasivni korisnici digitalnoga sadržaja. To pokazuje da je vrijednost *design thinking* pristupa u digitalnim okružjima za učenje podjednako pedagoška koliko i tehnološka jer potiče osjećaj vlasništva, prilagodljivost i smisleniju interakciju sa sadržajem.

Ovaj obrazac podudara se s empirijskim nalazima koji pokazuju da interaktivna digitalna okružja za učenje značajno povećavaju motivaciju učenika, njihovo sudjelovanje i akademske ishode, osobito kada su učenici aktivno uključeni u proces učenja (Köseoğlu i Boyacı, 2025; Yan, 2025). Takvi nalazi dodatno potvrđuju važnost uključivanja interaktivnih i participativnih elemenata u dizajn digitalnih knjiga.

### **Optimizacija vizualizacije i tehnologije u procesu učenja**

*Design thinking* optimizira uporabu vizualizacije i tehnologije u učenju promicanjem kreativnih i analitičkih pristupa rješavanju problema, čime se unaprjeđuje instruktivni dizajn. Ova metodologija potiče nastavnike na oblikovanje privlačnih iskustava učenja prilagođenih potrebama učenika, što u konačnici dovodi do boljih ishoda učenja. Uloga multimedije i multimodalnoga prikazivanja u jačanju konceptualnoga razumijevanja također je dobro dokumentirana. Pokazalo se da multimodalni pristupi učenju, koji integriraju vizualne, tekstualne i interaktivne elemente, poboljšavaju sposobnost učenika da konstruiraju značenje i uključe se u složen sadržaj (Gül i Coştu, 2024).

Interaktivna multimedija može unaprijediti razumijevanje globalnoga zatopljenja kod učenika i ojačati vještine kritičkoga mišljenja kada se kombinira s *design thinking* pristupom. Ova metoda potiče učenike na analizu i rješavanje problema povezanih s klimatskim promjenama, što je pokazano u istraživanjima o obrazovanju o globalnom zatopljenju (Susanto i Suyatna, 2015). Digitalni alati i igre osmišljeni za obrazovanje o održivosti mogu preoblikovati okolišne probleme u prilike za inovacije i uključivanje zajednice, čime se potiče dublje razumijevanje urbane složenosti i učinaka klimatskih promjena (Gabriel Kaprielian i Renee Jackson, 2022).

*Design thinking* potiče kritičko mišljenje i kreativnost, vještine koje su ključne za rješavanje problema u obrazovanju (Anwar i sur., 2023). On ohrabruje učenike da prepoznaju i analiziraju složene probleme, što vodi inovativnim rješenjima u područjima poput dizajna vizualnih komunikacija (Anwar i sur., 2023). Alati i tehnike vizualizacije sastavni su dio *design thinking* procesa jer pomažu u razjašnjavanju složenih procesa i ideja (Yang, 2018). Takve vizualizacije mogu pomoći nastavnicima u razvoju pristupačnih instruktivnih rješenja usklađenih sa željenim ishodima učenja (Ramos i Inocian, 2022).

Okružja učenja unaprijeđena tehnologijom imaju koristi od *design thinking* pristupa jer omogućuju integraciju različitih obrazovnih modela i alata, kao što su sustavi za upravljanje aktivnostima učenja (Learning Activity Management Systems) (Ramos i Inocian, 2022; Tham i sur., 2022; Yang, 2018). Takve integracije podupiru suradničko učenje i refleksiju, koji su ključni za učinkovito oblikovanje obrazovanja (Ramos i Inocian, 2022).

Digitalne knjige razvijene na temelju *design thinking* pristupa nadilaze običan tekst uključivanjem tehnologija kao što su interaktivne infografike, okolišne simulacije i gamificirani kvizovi. Te značajke povećavaju vizualnu privlačnost i olakšavaju učenicima razumijevanje pojmova povezanih s klimatskim promjenama. Poticanjem istraživanja pomoću tehnologije učenje postaje ugodnije i usklađeno s očekivanjima digitalnoga doba.

U pregledanim studijama vizualizacija i multimedija pokazale su se najučinkovitijima kada su pedagoški usklađene s potrebama učenika i njihovom kognitivnom spremnošću. U tom smislu, *design thinking* pridonosi ne samo poticanjem tehnoloških inovacija, nego i pomažući nastavnicima da odaberu, prilagode i dorade digitalne značajke koje apstraktne koncepte povezane s klimatskim promjenama čine razumljivijima, dostupnijima i razvojno primjerenima. Pregledani dokazi stoga upućuju na to da obrazovna vrijednost digitalnih medija manje ovisi o složenosti same tehnologije, a više o tome koliko je dobro osmišljena da podupre učenje.

### **Poticanje suradnje i vještina kritičkoga mišljenja**

Jedna od istaknutih prednosti *design thinking* pristupa jest njegov potencijal za poticanje kritičkoga mišljenja i suradničkih vještina od rane dobi. Interaktivne digitalne knjige mogu uključivati forume za raspravu u kojima učenici razmjenjuju mišljenja

i ideje o rješenjima za klimatske promjene. Učenici rade u virtualnim timovima na razvoju projekata, čime jačaju svoje komunikacijske vještine i sposobnost rješavanja problema. Iterativnim generiranjem ideja uče da se rješenja mogu razvijati i mijenjati, što pridonosi razvoju otpornosti i kritičkoga mišljenja pri suočavanju sa složenim izazovima. Na taj način digitalne knjige nadilaze ulogu pukih alata za čitanje i postaju suradničke platforme koje osposobljavaju djecu za strateško promišljanje. Učenici su više potaknuti na djelovanje, a ne samo na razumijevanje teorijskih koncepata.

*Design thinking* potiče komunikaciju, koordinaciju i timski rad među sudionicima, što je pokazano u istraživanju provedenom među studentima softverskoga inženjerstva uključenima u osamnaestotjedni suradnički projekt (Abich i sur., 2024). Inicijative poput Global Classroom for Democracy Innovation dodatno pokazuju kako *design thinking* olakšava međunarodnu suradnju, omogućujući studentima da se zajedničkim razvojem projekata bave složenim pitanjima poput klimatskih promjena (Wingfield i sur., 2024). *Design thinking* pristup potiče učenike na preoblikovanje problema, čime se jačaju njihova prilagodljivost i otpornost, važne sastavnice kritičkoga mišljenja (Dell'Era i sur., 2020; Susanto i Suyatna, 2015).

Kvazieksperimentalno istraživanje pokazalo je da *design thinking* značajno unaprjeđuje kritičko mišljenje, komunikaciju i kreativnost među učenicima koji su učili svjetsku povijest, što potvrđuje njegovu učinkovitost u razvoju vještina 21. stoljeća (Ramos i Inocian, 2022). Iako *design thinking* pokazuje velik potencijal za jačanje suradnje i kritičkoga mišljenja, neki učenici mogu imati poteškoća u suradničkim okružjima, što upućuje na potrebu za diferenciranim pristupima kako bi svi učenici mogli uspješno napredovati (Bene i McNeilly, 2020).

Interaktivne digitalne knjige utemeljene na *design thinking* pristupu imaju velik potencijal za unaprjeđenje ekološkoga znanja i svijesti učenika. Zahvaljujući privlačnom dizajnu, relevantnom sadržaju i bogatim interaktivnim značajkama, digitalne knjige mogu obrazovanje o okolišu učiniti ugodnijim i smislenijim. Međutim, uspješna primjena digitalnih knjiga ovisi o različitim čimbenicima, uključujući potporu škole, dostupnost infrastrukture i kompetencije nastavnika.

Faze *design thinking* pristupa mogu se sustavno primijeniti u razvoju interaktivnih digitalnih knjiga u obrazovanju o klimatskim promjenama u školama. U fazi empatije učenike se potiče da promatraju svoje okružje putem fotografija, videozapisa ili refleksivnih aktivnosti, što pomaže u razvoju emocionalne uključenosti u pitanja klimatskih promjena (Chavan i sur., 2023). Nakon toga slijedi faza definiranja u kojoj učenici formuliraju okolišne probleme na temelju vlastitih iskustava, što im omogućuje dublje razumijevanje potrebe za konkretnim i kontekstualno relevantnim rješenjima, umjesto da informacije primaju pasivno (Nordin i sur., 2024). U fazi generiranja ideja učenici osmišljavaju kreativne prijedloge za suočavanje s izazovima klimatskih promjena putem digitalnih rasprava i strukturiranih aktivnosti *brainstorminga* (Gauthier i sur., 2024; Grau i Rockett, 2022). Te se ideje zatim pretvaraju u konkretne rezultate tijekom faze izrade prototipa u kojoj učenici razvijaju jednostavne digitalne projekte, kao što su plakati za okolišne kampanje ili kratki objašnjavajući videozapisi koji prikazuju

učinke klimatskih promjena (Cho i Park, 2023; Gabriel i Schmölzer, 2022; Gauthier i sur., 2024). Naposljetku, u fazi testiranja, projekti se predstavljaju putem digitalnih izložbi i vrednuju na temelju povratnih informacija vršnjaka i nastavnika, što učenicima omogućuje da prodube svoje razumijevanje i unaprijede kvalitetu svojih rješenja u refleksivnim procesima učenja (He i sur., 2023; Tham i sur., 2022; Yang, 2018).

Općenito, pregledana literatura pokazuje da *design thinking* može poduprijeti suradnju i kritičko mišljenje uključivanjem učenika u iterativne procese oblikovanja problema, generiranja ideja, izrade prototipa i testiranja rješenja. Čini se da ti procesi potiču raspravu, refleksiju i zajedničko donošenje odluka, što su središnje sastavnice mišljenja višega reda i suradničkoga učenja. Međutim, prijavljene koristi očito ovise i o povoljnim nastavnim uvjetima, uključujući nastavničko vođenje, dovoljno vremena i zadatke koji su primjereno strukturirani u skladu s razvojnom razinom učenika. To upućuje na to da *design thinking* nije sam po sebi transformativan, nego postaje učinkovitiji kada se provodi u dobro podržanim okružjima za učenje.

### **Praktična sinteza i implikacije za istraživanje**

#### Slika 4

Umjesto deskriptivnoga prikazivanja nalaza pojedinačnih studija, ova sinteza identificira ponavljajuće pedagoške obrasce koji se pojavljuju u pregledanoj literaturi. U analiziranim studijama uočavaju se tri dosljedna obrasca u vezi s obrazovnom vrijednošću *design thinking* pristupa u digitalnim okružjima za učenje. Prvo, okviri *design thinking* pristupa imaju tendenciju povećati angažman učenika uključivanjem iterativnih aktivnosti rješavanja problema u sam proces učenja (Grau i Rockett, 2022; Wei i sur., 2023). Drugo, participativni pristupi dizajnu omogućuju učenicima aktivno suoblikovanje obrazovnih artefakata, čime se jača njihov osjećaj odgovornosti i uključenosti u pitanja okoliša (Gauthier i sur., 2024). Treće, integracija multimedije i alata za vizualizaciju u digitalne medije razvijene na temelju *design thinking* pristupa čini se da smanjuje konceptualne prepreke kada se učenici suočavaju sa složenim temama poput klimatskih promjena (Cho i Park, 2023; Karagöz i sur., 2023). Ovi obrasci pokazuju da pedagoška vrijednost *design thinking* pristupa ne leži samo u tehnološkoj inovaciji, nego i u njegovoj sposobnosti strukturiranja smislenoga sudjelovanja učenika.

Nalazi ovoga pregleda imaju nekoliko važnih implikacija za obrazovnu praksu i buduća istraživanja. Za nastavnike, integracija *design thinking* pristupa u razvoj digitalnih knjiga pruža strukturiran pristup oblikovanju obrazovnih resursa za klimatsko obrazovanje koji su istodobno interaktivni i usmjereni na učenika. Za autore kurikula, rezultati naglašavaju važnost povezivanja multimedijske vizualizacije s participativnim procesima učenja kako bi se unaprijedilo razumijevanje pitanja zaštite okoliša među mlađim učenicima. Iz istraživačke perspektive, buduća bi istraživanja trebala ispitati dugoročne ishode učenja i učinke na ponašanje povezane s digitalnim medijima za učenje razvijenima na temelju *design thinking* pristupa i to primjenom eksperimentalnih ili longitudinalnih istraživačkih nacrta.

## Zaključak

Ovaj pregled literature upućuje na to da razvoj interaktivnih digitalnih knjiga utemeljen na *design thinking* pristupu ima znatan potencijal za jačanje obrazovanja o okolišu, osobito u podupiranju svijesti učenika o klimatskim promjenama. Integriranjem interaktivnih elemenata, privlačnih vizualizacija i načela dizajna usmjerenoga na učenika, takve digitalne knjige mogu ponuditi uranjajuća i smislenija iskustva učenja. U pregledanim studijama digitalne knjige razvijene na temelju *design thinking* pristupa povezuju se s boljom podrškom razumijevanju koncepta zaštite okoliša među učenicima, aktivnijim angažmanom u učenju te razvojem kompetencija 21. stoljeća, poput kritičkoga mišljenja, kreativnosti, suradnje i komunikacije, koje su sve relevantne za suočavanje sa složenim okolišnim izazovima.

Ovaj pregled također pokazuje da *design thinking* može promijeniti položaj učenika iz pasivnih primatelja sadržaja u aktivnije sudionike procesa učenja. Povezivanjem promatranja okoliša, prepoznavanja problema, generiranja ideja, izrade prototipa i iterativnoga testiranja, digitalne knjige mogu funkcionirati ne samo kao nastavni resursi, nego i kao interaktivni i participativni mediji za učenje. U tom smislu, čini se da *design thinking* podupire okružja učenja u kojima učenici mogu razviti snažniji osjećaj vlasništva, odgovornosti i djelatnosti u odgovoru na pitanja povezana s klimatskim promjenama, čime obrazovanje o okolišu postaje reflektivnije, kontekstualiziranije i usmjereno na djelovanje.

Istodobno, potrebno je priznati nekoliko ograničenja. Uključivanje samo recenziranih i otvoreno dostupnih studija objavljenih tijekom posljednjih pet godina pridonijelo je relevantnosti i dostupnosti, ali je istodobno moglo isključiti ranije temeljne radove i studije dostupne samo pretplatom, čime se ograničava sveobuhvatnost pregleda. Iako su korištene glavne baze podataka, istraživanja objavljena u regionalnim, neindeksiranim ili neengleskim izvorima mogu ostati nedovoljno zastupljena, što može smanjiti geografsku i kontekstualnu raznolikost. Dodatno, uporaba narativne sinteze umjesto metaanalize znači da se zaključci temelje na ponavljajućim tematskim obrascima, a ne na kvantificiranim veličinama učinka. Mnoge uključene studije bile su također manjega opsega ili specifične za određeni kontekst, a razlike u infrastrukturi, spremnosti nastavnika i kurikularnom kontekstu među različitim okružjima mogu utjecati na primjenjivost nalaza.

Buduća bi istraživanja trebala proširiti obuhvat baza podataka, uključiti višejezične i regionalno raznolike izvore te primijeniti metodološki robusnije pristupe sintezi, uključujući metaanalitičke postupke kada je to izvedivo. Također su potrebna longitudinalna i kontekstualno osjetljiva empirijska istraživanja kako bi se ispitale dugoročne obrazovne i bihevioralne implikacije digitalnih medija za učenje razvijenih na temelju *design thinking* pristupa u obrazovanju o klimatskim promjenama. Općenito, ovaj pregled podupire promišljenu primjenu *design thinking* pristupa u razvoju digitalnih medija za učenje, osobito kada je cilj oblikovati resurse za obrazovanje o okolišu koji su interaktivni, usmjereni na učenika i prilagođeni potrebama mlađih učenika.