Jurnal Pemberdayaan Masyarakat
Volume 5 Issue 1 Year 2026 | Pages 138–155
ykgm.org

E-ISSN 2962-8091
DOI: https://doi.org/10.46843/jpm.v5i1.528

Integrating Design Thinking into Science Education: A Systematic Literature Review

Risya Pramana Situmorang[1]*, Miranita Khusniati[2], Panggih Priyambodo[3], Winarto[4], Sefni Oemolos[5]
[1]*Biology Education Study Program, Faculty of Biology, Universitas Kristen Satya Wacana, Indonesia*
[2]*Department of Integrated Sciences, Universitas Negeri Semarang, Indonesia*
[3]*Department of Science and Mathematics Education, Universitas Lampung, Lampung, Indonesia*
[4]*Department of Science Education, Universitas Negeri Yogyakarta, Indonesia*
[5]*Mary Lou Fulton Teachers College, Arizona State University, United States of America*

ABSTRACT

The accelerating trend of applying Design Thinking (DT) in modern science education has not been accompanied by enough investigation into its effectiveness among different types of learning environments. Using the PRISMA approach, an SLR of SCOPUS-indexed papers from 2015 to 2025 is conducted to investigate global trends, methodological perspectives, and challenges in DT integration. Thirty-two eligible articles were identified and analyzed bibliometrically using VOSviewer Explorative research. Findings – An obvious surge in publications involving DT has been observed since 2019, with qualitative methods most widely used in recent years, especially case studies and design-based research. Case-based or collaborative learning, supported by digital tools such as prototyping platforms and simulations, is also a suitable means for integrating DT. Some of the issues revolve around constraints on interdisciplinary research and the application of DT within content-driven curricula. The study proposal shows a need for integrated tools and hybrid pedagogical scenarios to facilitate the implementation and assessment of DT. Implications for science education include presenting an evidence-based model for embedding DT across diverse inquiry contexts to support students in developing creative capabilities, problem-solving skills, and readiness to tackle complex scientific challenges.

ARTICLE INFORMATION

Keywords:
curriculum integration; design thinking; instructional technology; science education; systematic literature review

Correspondent Author:
Risya Pramana Situmorang

Email:
risya.situmorang@uksw.edu

© Yayasan Keluarga Guru Mandiri. This is an open-access article under the CC Attribution 4.0 International License.
Article info: Submitted: 2025-08-11 | Revised: 2025-10-03 | Accepted: 2025-12-16 | Published: 2026-02-24
Recommended citation: Situmorang, R. P., Khusniati, M., Priyambodo, P., Winarto., & Oemolos, S. (2026). Integrating Design Thinking into Science Education: A Systematic Literature Review. *Jurnal Pemberdayaan Masyarakat, 5*(1), 138-155.

INTRODUCTION

There has been significant evolution in the 21st-century educational context, leaving room for schools and educators to champion creative learning models as an imperative in molding a new generation better able to tackle the daunting science and technology issues it will face. Design Thinking (DT) is one of the 21st-century skills that has become a foundation for improving pedagogical roles, such as in science education, by providing a problem-solving method that integrates creativity and collaboration (Lin et al., 2025; Ogegbo & Ramnarain, 2022). The existence of DT in the learning process has received extensive attention, especially in science education, as a way of thinking that emphasizes analytical and iterative thinking skills, thus providing space for students to actively engage through solution- oriented thinking in constructive learning activities, such as experiments, making prototypes or finished products, and providing creative solutions (Li & Zhan, 2022). This human-centered way of thinking can enrich the learning experience because knowledge will be systematically constructed through teachers' efforts, empowering individuals and groups to solve

contextual, even authentic, science problems, thereby providing a more meaningful impact inside and outside the classroom than traditional classroom implementation.

DT has become increasingly relevant in science education, particularly as our expectations of the curriculum encourage skill-based learning and the use of real problems in project-based learning (Nguyện et al., 2025). Additional insight into scientific terms grounded in design helps these students see things from a design perspective, enabling them to comprehend better the theory and application of these concepts in practical problems. DT can add value to domain knowledge through its hands-on applications (e.g., free space in STEM education) and it promotes innovation and flexibility of thought – two competencies indispensable in the age of the Fourth Industrial Revolution (Grönman et al., 2025). Notwithstanding its immense potential, DT is encountering challenges in adapting it to science education, such as teachers' limited exposure and familiarity with the techniques being used and inadequate learning environment resources (Beligatamulla et al., 2019; Öztürk & Korkut, 2023). From a circular perspective, results and observations in the DT also demonstrate that teachers' limited knowledge of implementing DT, as well as schools' general material paucity, are significant impediments to the innovation (Henriksen et al., 2020; Yüksel, 2025). In addition, the appropriate tools for evaluating its effect on science learning effects (Oshima et al., 2024; Yu et al., 2024) remain an issue. However, in an era where digital technology is increasingly available and used, and hybrid learning models are gaining popularity (Couzens & Cattoni, 2023; Shanmugam et al., 2025), there have been recent developments that may open new paths toward overcoming these challenges and more effectively supporting DT in a larger number of science education venues.

Recent Systematic Literature Review (SLR) studies (Arifin & Mahmud, 2021; Li et al., 2019; Liang, 2024) have identified significant research on the application of DT in secondary science education, yet unresolved research gaps remain. While DT effectiveness has been covered by several empirical studies throughout the last decade (e.g., Orozco et al., 2023; Ramos-Mejía & Padilla, 2025) an SLR for 31 empirical studies reported by (Fatkhurrohman, 2023) points to uneven distributions in research across scientific disciplines: 42% targeted in biology sphere (especially ecology and anatomy), while study aimed at chemistry concerns only reached the proportion of 28% (specifically electrochemistry and thermodynamics). Even a narrower scope was found within the physics account, accounting for only 8% specifically for mechanics and optics. These results suggest that, although DT in relation to fundamental physics and analytical chemistry ideas is under-researched, these domains can pose challenging cognitive demands for secondary students.

The difficulties associated with enacting a DT approach are further exacerbated by teachers' struggle to translate traditional content-based curricula into an integrated STEM structure (Fallin, 2025). Content-based curricula often focus on the pure subject matter (against core concepts and basic principles of the science), e.g., for physics on the laws of nature or for chemistry on a chemical reaction, which does not fit with an exploratory and process-oriented approach such as DT with its fixed material scope and assessment model (Stammes et al., 2025; Wang, 2024). Initial findings from this misalignment indicate that this mismatch can contribute to teacher frustration and limited use in these spaces. On the other hand, in integrated STEM curricula that emphasize interdisciplinary, project-based learning, DT offers a more authentic and structured context for designing and testing prototypes when confronting ill-structured problem-solving (English & King, 2019; He et al., 2025). Thus, a review of the literature is imperative and should critically consider DT adaptation to maximize success, including the use of hybrid models applied to content-based curricula and the strategic design of technology use. For instance, technology can promote the development of multitasking testing instruments that assess both conceptual understanding and DT skills concurrently, thereby increasing the practical challenges of implementation across learning contexts.

Based on a systematic review of literature of those sources, this paper aims to identify trends in which DT is used in science education and investigate what is meant by such use. First, the research takes a global view of trends, analyzing publication outputs, keyword networks, and international collaboration dynamics to identify priorities at any given time. Second, it offers a comprehensive examination of the embedding of DT within science curricula, with detailed reflection on redistricting, pedagogical models, and STEAM competencies. Third, we examine pedagogical approaches for teaching DT skills, including project- and inquiry-based learning, as well as experiential-constructionist models. Fourth, it investigates the adoption of technology-enhanced learning tools, such as virtual labs and digital prototyping platforms, to support DT. The findings are also anticipated to have implications for practice, as they provide direct practical recommendations for educational practitioners, curriculum developers, and policymakers who wish to investigate the many potential DT offers in (re)designing science education at different levels of the educational system, thus addressing some of the literature gaps. It also offers a practical, extendable framework for various learning environments.

METHOD

The initial search string in Scopus for our SLR process was narrowed down through screening and refinement, with the following terms (used as title/abstract/keyword) present: "design," "thinking," "science," and 'education' (Page et al., 2021; Situmorang et al., 2024). To keep the findings regarding design trends relevant and current (Liberati et al., 2009), we limited searches to publications from 2015 to 2025. Additional screening limitations were applied, including whether an article was a journal article (not a conference proceeding or a book), published in full text (not a preprint), and written in English, which allowed for more relevant and consistent findings (Tricco et al., 2018). Authors also screened freely accessible (open access) papers using various open-access models (gold, green, hybrid, or bronze OA) to assess full-text availability (Piwowar et al., 2018).

In the comprehensive search, 783 eligible papers were identified. At the discipline level, articles were most often located in Social Sciences, Psychology, and Computer Science (1 and 2, respectively). This consideration seems to reflect a hybridized profile of research on design thinking in science education (Henriksen et al., 2017). The most common were ‘education’, ‘students’ and 'computational thinking', reflecting a focus on the educational design rather than solely on practice design in educational environments (Dotson et al., 2020).

No studies from the SLR met the inclusion criteria for this review. To alleviate such bias, we included a screening procedure to favor high-quality, thematically relevant studies that were also available. Screening limitations are adjustable and can be widened or narrowed by specifying additional filters (e.g., country-specific, or other document types, such as reviews). The methodological framework allowed the development of an exhaustive and accurate literature synthesis based on meticulous research strategies, in line with search API provided by Scopus database: TITLE-ABS-KEY (design AND thinking AND science AND education) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO(DOCTYPE,"ar")) AND (LIMIT-TO(PUBSTAGE,"final")) AND (LIMIT-TO(SRCTYPE,"j")) AND (LIMIT-TO(LANGUAGE,"English")) AND (LIMIT-TO(OA,"all")).

The first step in our SLR was to define the research scope to establish a clear focus (Haddaway et al., 2022; Zupic & Čater, 2014). The purpose of this paper is to investigate the research foci of design thinking in science education. Research questions were developed in relation to the selected topic, and included: 1) RQ1: What are the general research foci of design thinking in science education depicted by publication year distribution, keyword analysis, and international collaborations? RQ2: What are the pedagogical approaches for incorporating design thinking in science curricula? RQ3: What teaching strategies or methodologies are used to teach design thinking in science education?

RQ4: How are media for technology-based learning used to implement design thinking in science education?

The second step in the research involved identifying, selecting, and evaluating literature relevant to the study (Gusenbauer, 2024; Snyder, 2019). The primary data source for this study was the Scopus database, selected for its credibility as an indexed platform, its accessibility in academic institutions, and its established use in previous similar studies. The Scopus database was selected as the primary data source for this study because its platform is highly credible, academic users can access it relatively easily through their institutions, and it is also an important medium used in other similar studies. The optimized string query search function used in this post was built from articles on 'design thinking' in science education. The search results were stored in both CSV and RIS formats to ensure data completeness (Aria & Cuccurullo, 2017). They were then systematically arranged with Mendeley for efficient reference management. Thus, further bibliometric analysis with VOSviewer was performed to: 1) Map the research network; 2) Identify inter-study relationships; 3) Uncover underexplored research areas.

According to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), this systematic review will be transparent and replicable (Munn et al., 2018; Rethlefsen et al., 2021). From an initial pool of 783 potentially relevant papers, we used a multistage sifting system based on five unambiguous inclusion criteria. The criteria for selecting papers were as follows: 1) only peer-reviewed experimental studies were accepted, with other types of article such as review articles rejected; 2) to come to terms with possible language biases, they were only allowed to be in English; 3) papers published in the last decade (2015-2025) were accepted so as not to be trapped forever in school practices dead and gone; 4) for the sake of access, the corpus was restricted to open-access works; 5) every paper had to show clear commitment in design thinking achievement, be in a laboratory science education context After following this detailed screening protocol, 32 papers left gleaming in the sun and obeying all specified requirements emerged. The entire selection process is documented in Figure 1 through a PRISMA Flow Diagram.

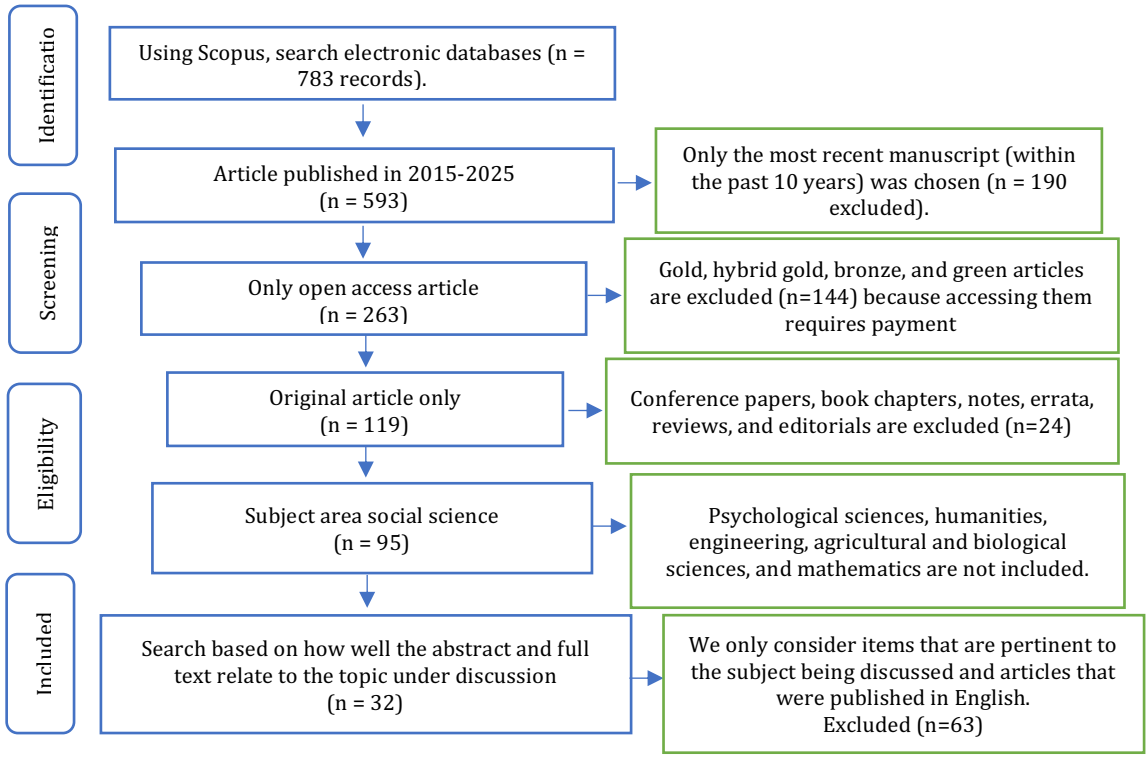

Figure 1. The SLR flow diagram (the PRISMA flow diagram for SLR shows the number of database

searches, abstracts screened, and full texts retrieved. (Produced through the PRISMA technique)

Methodological quality and the relevance of higher-quality studies to the research questions were rated using a comprehensive quality assessment across various domains (Shea et al., 2017). Clarity of research aims and parameters, appropriateness of the research design (e.g., case study, methodological, or survey-based), and data collection and analysis were considered in this categorization. Quality of Review ratings were similarly rated in each of the areas depicted above, which are relatively unique to considerations about 'study recognition' and methodological requirements for studies concluding a review (in this case, internal validity). Clear reporting was particularly emphasized as a means of assessing study findings. This comprehensive review strategy was designed to select high-quality studies that would inform and be relevant to the research questions and to ensure academic completeness.

Throughout the systematic analysis, the attributes of the implementation of design thinking in science education have been recorded. This process of looking for curriculum integration approaches that could, from the science syllabus and teaching framework's point of view, make sense of what design thinking is, but not only. Designing teaching methodologies for this field, such as Project-Based Learning (PBL) and co-design challenges, was also the focus. Furthermore, certain digital tools, as enabling technologies for design thinking in science education, could be emphasized, e.g., digital simulation. A somewhat multi-tiered approach also allows for more cautious and comprehensive documentation of all variables that potentially are processes across studies (Tricco et al., 2018).

This process of transparency enhances the stability of the systematic review to which we refer in the literature on design thinking and science teaching. The program qualifies as educational research of high standards and is replete with case studies of curriculum implementation, instructional methods, and technology utilization. The study is based on a solid, evidence-based foundation in science education research, characterized by high-quality electronic searching , evaluation, and extraction (Duschl, 2019; Yu et al., 2024).

Key results from the included studies in the SLR. The included studies in the SR presented aggregated results to address the research questions. The last step in performing the SLR is synthesizing the findings by presenting results that systematically and logically address the research questions. This overview should also clarify the design-thinking-based pattern in science education across the globe. The report also includes evidence-based recommendations for moving the organization and its members in a more productive direction, toward new research and science education practice. This comprehensive and detailed procedure is aimed not only at guaranteeing reproducibility but also at making its application in other learning scenarios (e.g., different school levels and reported subjects) easier. Our SLR also offers theoretical insights that may serve as a launch pad for future research and broaden the theoretical perspective to influence science education innovation, new hotspots, and contributions (Kijima et al., 2021; Ramírez-Montoya et al., 2024).

RESULTS AND DISCUSSION

Figure 2 shows a bibliometric diagram produced with VOSviewer, which visually illustrates the conceptual structure of design thinking research from a keyword co-occurrence perspective.

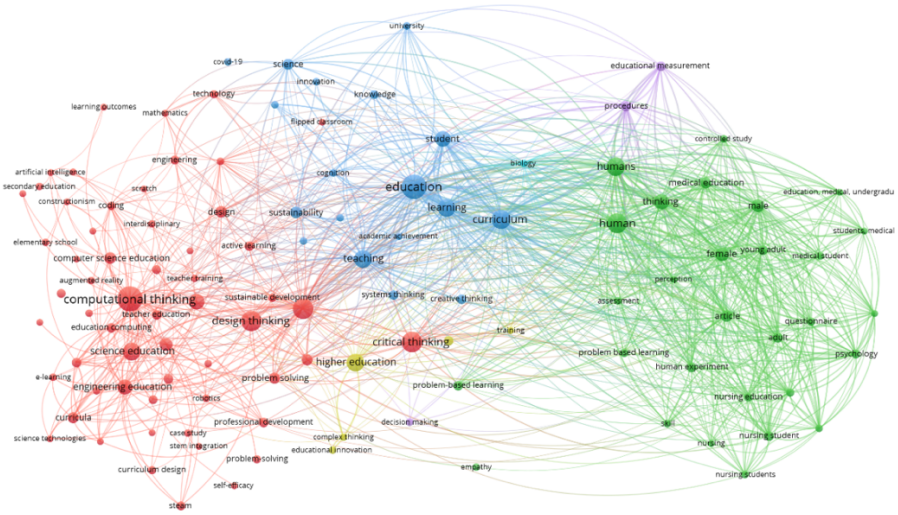

Figure 2. Authors' visualization of a VOSviewer co-occurrence keyword analysis on design thinking-related themes (Source: Authors' elaboration using VOSviewer software)

Figure 2 is a network analysis of the intellectual structure of a field, where terms are represented as nodes sized by frequency, and lines indicate relationships. Such visualization is especially useful for revealing: (1) core topics of the research, (2) emerging inter-disciplinary relationships and (3) gaps in the existing literature. The observed density and clustering patterns empirically reveal where design thinking converges with neighboring fields, providing a snapshot of current interest within the scholarship and an agenda for future research.

Figure 2 presents keyword trends, revealing two dominant conceptual domains: design thinking and computational thinking, as indicated by the significantly larger node sizes. This finding aligns with the recent recommendation for combining human-centered design and computation-based thinking in STEM education. Solution-oriented design thinking has a strong relationship with computational thinking. Design thinking, based on creativity and user needs, has two major elements: logic and algorithmic problem-solving, with a focus on the other side (the relationship). While these are based in different disciplinary paradigms, the tight internal connections within these central nodes suggest a desire to incorporate aspects of both into contemporary innovation and education, including science education.

The keyword clustering, color-coded, serves as a thematic grouping of similar concepts. Derived from the blue cluster are the basics: creativity frameworks and problem-solving. Meanwhile, the yellow and green nodes are associated with recent research trends, such as the dynamics of digital transformation in education. The red cluster comprises technology elements (such as data analytics) that provide a conceptual bridge between the human-centered orientation of design thinking and the method-oriented precision of computational thinking. The connected patterns exhibit an interesting feature: they are highly complementary, even though the sets are from different clusters. In digital product design, for example, we have the materialization of design thinking to elicit user-centric ideas and computational thinking to formulate the logical and technical rules for implementation in an educational context.

Interdisciplinarity is more relevant than ever in the digital era, where problem-solving demands effective innovation and a balance between human empathy and technological advancement. What is innovative about this bibliometric analysis is that the three emergent interdisciplinary groupings are not reported by the literature: 1) sustainability-based designing

education; 2) digital prototyping in STEM instruction; and 3) cognitive dimensions to design thinking in science education. These emerging themes show distinctive movement from previous work, but before the present piece, have focused predominantly on the general applications of design thinking alone, rather than these interdisciplinary connections.

Trends in publications over the past 10 years show a substantial increase in studies on the use of design thinking in science. Examination of such publication trends indicates that design thinking has been established as an integral part of science learning, with a pattern indicative of increasing development across three successive phases and within each new stage. The evolution of design thinking began with a pre-exploratory stage (around 2016–2018), during which researchers laid the conceptual groundwork and conducted preliminary case studies. In the later phase of expansion between 2019 and 2022, the massive expansion significantly diversified research methods. Since 2023, scaling up has developed into a mature academic field, with more sophisticated research designs, systematic reviews, and implementation frameworks published. This developmental trajectory from exploration to growth to maturation is clearly reflected in the publishing trend, as shown in Fig. 3, and hence design thinking becomes an established paradigm for science education research.

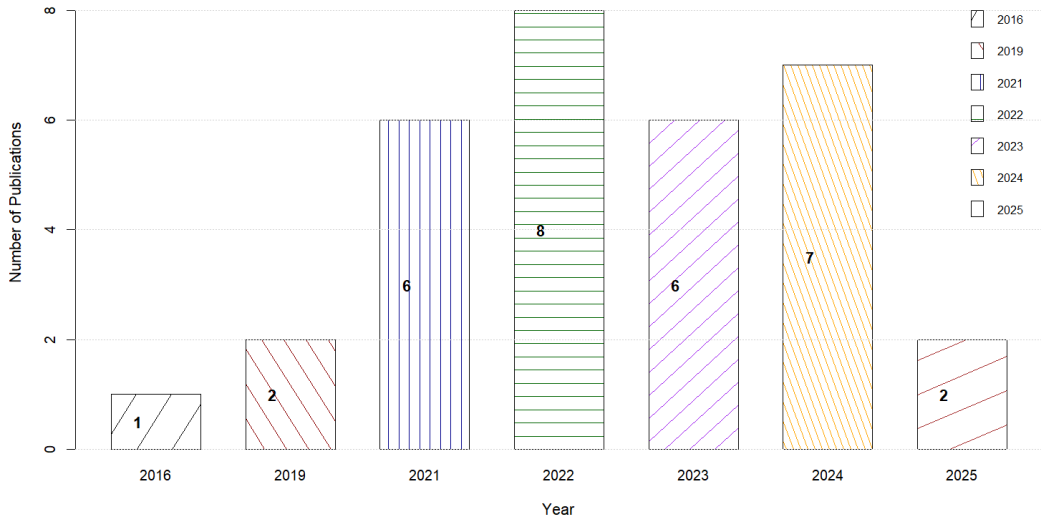

Figure 3. Trend of Publications in Design Thinking for Science Education (2016 to 2025)

The tide of design thinking in science education has continued to flow well in the past decade (2015-2025). Research publication productivity was relatively low during the 2016–2019 period (1-2 articles/year), reflecting an early stage of theoretical framework development and refinement of conceptualization. Science education, as it is currently practiced, can no longer ignore the growing interest in Design Thinking across all educational levels. The publications identified in Panke's (2019) study, which have increased between 2016 and 2019 around the subject of Design Thinking in general education settings, are opening the door and providing a theoretical underpinning for science education to take on this approach even more explicitly, as demonstrated by these impressive expansion estimates. A rapid increase in reports was evident during 2021-2024 (6-8 publications per year), with a peak in publication output in 2022, presumably indicating that design thinking's efficacy is increasingly recognized by experts and pedagogical communities, which in turn drives further use of creativity-based sciences. Although the initial 2025 data (2 articles) indicate a possible downward trend, this is more plausibly due to incomplete annual reporting (since data were collected up to April

2025), rather than rapid attenuation in academic interest, particularly as publications for the current year are still anticipated.

A typical progression in the evolution of this theme has been observed in the papers, from the conceptual inquiry to its realization in application domains. Preliminary studies (2016–2019) have focused on theoretical design and proof-of-principle. With the post-2020 studies, learning science and digital technology intervention began to be increasingly inflected, often framed in three interrelated areas: (1) digital technology integration for learning science; (2) teacher professional development programs; and (3) curricular design across the different content areas. The current situation also reflects that dominant design thinking in science education has become less theory-driven and more driven by claims and evidence regarding learning. The speed with which the original design thinking research agenda has widened and deepened perversely echoes its relevance to science education today, but also highlights several areas that need much deeper probing (long-term assessment of impact from such approaches, for one) and models for scaling some initiatives across learning contexts.

Collaborative design thinking has led to a global shift in the twenty-first century. We have witnessed our research on collaborative design thinking increasingly take a global form, with researchers and institutions from all corners of the world actively co-constructing knowledge. The field is increasingly taking shape as international collaboration, reflecting the interdisciplinary and transcultural significance of design thinking applications. Such dissemination has been found at varying levels across countries, illustrating the gap between what is possible and current disparities in research collaboration. By mapping these partnerships (Figure 4), we can visualize the size and make-up of research on design thinking as an international academic community and see how the relationships that structure the field now spread around the world.

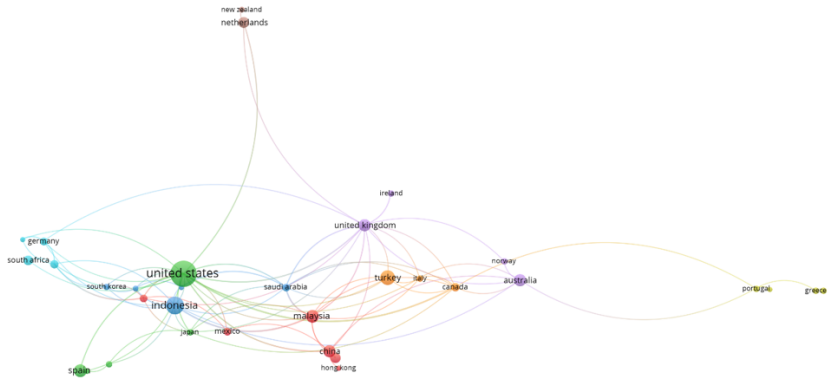

Figure 4. Transnational Collaboration Trends in Design Thinking Research

Figure 4 displays a network map of exclusive worldwide cooperation patterns in design thinking research. A few large nodes are for some of the most frequent countries, such as the US, UK, and Australia. Countries are depicted as nodes, and their sizes correspond to the volume of research output and impact related to design thinking. Lines between nodes depict the strength of collaboration (thicker lines indicate more links). The inter-node configuration also presents a core-periphery pattern, with the group of developed countries constituting the core and evolving as strong collaborative hubs in the evolution of design thinking. Most of the developing world, in contrast, serves as peripheral nodes on the network. These patterns of international collaboration affirm the interdisciplinary nature of the uptake of design thinking and its worldwide orientation in producing design thinking research. Such horizontal (developed-developed) and vertical developed-developing R&D cooperation takes place in advanced training systems and innovation hubs such as Germany and

the Netherlands. This trend indicates that knowledge about design thinking is shared and disseminated not only in advanced research-based economies but also through a multi-tiered collaborative structure. Variations in regional communities across Asian and European countries demonstrate that proximity and similarity also shape cooperation dynamics. This situation has clear implications for science policy regarding equitable research partnerships. North America (USA), Europe (UK and France), and Australia are research hotspots (Bahroun et al., 2023). On the other hand, Asian/African countries exhibit almost no production of new knowledge in sequence.

The diversity of methodologies in research studies on design thinking in science education is highlighted in Table 1. Method trends using qualitative and quantitative methods in comparable volumes, the nature of the work also varies across disciplines, with different method preferences. This variety of approaches is a testament to the fact that a complex research area, as it remains an academic discipline, is still evolving. Such a distribution reinforces a pattern, suggesting that some are interested in ruler-rich case-study tracking and recognition opportunities for the nuance found in implementation processes. Others, meanwhile, are proponents of experimental approaches to knowledge. These two methodological approaches also come together to account for the multifaceted adoption of design thinking in science education settings.

Table 1. Trends in Design Thinking Research Methodologies

Research Type	Specific Methods	References	f
Quantitative	Quasi-Experimental	(Hsu et al., 2023); (Dúo-Terrón et al., 2022); (Leonardou et al., 2022)	3
	Structural Equation Modeling (SEM)	(Avsec & Savec, 2022)	1
	Quantitative Survey	(Rahman, 2024)	1
	Experimental Study	(Liu, 2024) (Li et al., 2019)	2
Qualitative	Case Study	(Alhamdani, 2016), (Sigauke, 2020), (Ho & Pang, 2024), (Siew & Arifin, 2025)	4
	Design-Based Research (DBR)	(Charosky et al., 2022), (Brandão et al., 2024), (Högsdal & Grundmeier, 2021)	3
	Literature Analysis	(Dyer, 2019), (Nugraha et al., 2024)	2
	Sequential Explanatory	(Bayer et al., 2022)	1
	Position Paper	(Bush et al., 2024)	1
Mixed Methods	Mixed Methods	(Shakeel et al., 2024), (Galoyan et al., 2022), (Stevens et al., 2022), (Kijima et al., 2021), (Ladachart et al., 2022), (Fritzsche et al., 2021)	6
R&D	Design Science Research (DSR)	(Liu, 2023), (Villarrubia et al., 2024)	2
	Action Research	(Atchia, 2023), (Sulisworo et al., 2021)	2
	Participatory Design	(McGrath et al., 2024), (Chen et al., 2023)	2
	Service Design	(Fearn & Hook, 2023)	1
	Double Diamond	(Wren et al., 2025)	1

Design Thinking in science education research reveals a clear dominance of qualitative research (11 articles), predominantly case study approaches (4 articles), and, to a lesser extent, Design-Based Research studies (3 articles), with a focus on very detailed accounts of learning phenomena. For example, Ho and Pang (2024) utilized qualitative case studies to examine how design thinking is

implemented in early childhood education. Charosky et al. (2022) developed a new DBR model for managing student learning performance. At the same time, mixed-methods strategies (6 articles), such as those used by Galoyan et al. (2022) and Fritzsche et al. (2021), which integrate quantitative (survey) data with qualitative/semi-structured interviews, have become more desirable. This result indicates an increasing demand for evidence-based confirmation, with a background of contextual knowledge in the area examined. Recent applications of the DBR methodology, however, differ in that they emphasize scalable models for the implementation rather than stand-alone interventions (Khushk et al., 2023). On the other hand, mixed-methods designs (6 articles), in which qualitative and quantitative findings can be triangulated, have become a popular approach, indicating a growing trend towards empirical evidence grounded in context.

Quantitative studies (7 articles), such as quasi-experimental designs by Dúo-Terrón et al. (2022) and SEM analyses by Avsec & Savec (2022), demonstrate the growing trend toward the use of experimental studies to test independent variables and determine the design thinking effect statistically. Simultaneously, in the domain of R&D approaches (8 records) to petty rather than practical innovation, Liu's (2023) employment of Design Science Research for educational software development and Wren et al. (2025) deployment of the double diamond framework for managing wicked problems associated with current social issues, including climate change. The methodological becoming in investigating design thinking represents a change of paradigm: from mere exploration to a taxonomy and evidence-based solutions that are classroom-applicable (Al-Zahrani, 2024; Li et al., 2022). This condition provides an example of the growing potential of design thinking research as it transitions from theoretical examination to practical intervention. The implementation of design thinking in science education has been realized through diverse pedagogical strategies that prioritize student-centered processes. These implementation models illustrate how design thinking can serve as a framework for educational experiences across multiple learning environments. To present a complete picture of the instructional methods that incorporate design thinking, please see Table 2.

Table 2. Trend of Design Thinking Integration Based on Learning Approaches

Instructional Approach	Description	f	Authors
Project-Based Learning (PBL)	Real-world projects using DT stages	10	(Charosky et al., 2022), (Brandão et al., 2024), (Rahman, 2024), (Ladachart et al., 2022), (Sulisworo et al., 2021), (Siew & Arifin, 2025), (Villarrubia et al., 2024), (Bawaneh & Alnamshan, 2023), (Avsec & Savec, 2022), (Nugraha et al., 2024)
Collaborative Learning	Multidisciplinary/group collaboration	6	(Kijima et al., 2021), (Liu, 2024), (Högsdal & Grundmeier, 2021), (Alhamdani, 2016), (Bayer et al., 2022), (Ho & Pang, 2024)
Creative Pedagogy	Integration of arts, makerspace, or creative activities	5	(Stevens et al., 2022), (W.-T. Li et al., 2019), (Galoyan et al., 2022), (McGrath et al., 2024), (Dyer, 2019)
Intensive Workshops/Courses	Short-term training with DT methods	4	(Wren et al., 2025), (Chen et al., 2023), (Dúo-Terrón et al., 2022), (Sigauke, 2020)
Reflective Learning	Incorporates Schön's reflection or ethics	3	(Shakeel et al., 2024), (Hsu et al., 2023), (Fritzsche et al., 2021)
Experiential Learning	Direct experience-based learning	4	(Bush et al., 2024), (Fearn & Hook, 2023), (P. Liu, 2023), (Atchia, 2023)

As illustrated in Table 2, the use of DT in science education is overwhelmingly supported by real-world PBL projects. Charosky et al. (2022) in Challenge-Based Innovation (CBI) courses is a case in point. DT is used as a framework through empathize-define-ideate-prototype-test to address social issues in line with the SDGs, stimulating cross-disciplinary collaboration. A similar line can be found in Brandão et al. (2024), who use a 10-stage DTEL framework in Sustainable Animal Agriculture teaching projects in which students work in teams to provide sustainable solutions. These examples illustrate how DT can serve both as a problem-solving method and as a pedagogical device for teaching interdisciplinary collaboration skills.

The deployment spectrum reveals a remarkable lack of innovation and technological deviation from past designs. Li's 3-week Cultural Training Camp adopts the design thinking process, a mainstream approach at Stanford, to instruct trainees on how to help themselves develop culturally sensitive Chinese products (Li et al., 2019), indicating creativity and the incorporation of local wisdom. On the other hand, the digital focus on WeChat Mini Programs and Figma in the Fire Festival Software project by Ping Liu supports prototyping and teamwork (Liu, 2023). These case examples illustrate how adaptable or configurable DT can be to fit within different educational practices, whether experiential or practical, with digital technologies aligned with local curricular goals and resources.

There are many hints and tips on how to use technological media effectively to encourage the use of design thinking in learning. The multiplicity of these approaches reveals an immense variety of ways in which design thinking intersects with technology in different learning contexts. More advanced tech design-thinking facilitated learning activities are presented in Table 3.

Table 3. Trends in Learning Strategies: Empowering Design Thinking Supported by Learning Technology Usage

Main Category	f	References	Technology Support
Collaborative & Project-Based Learning	12	(Bush et al., 2024); (Hsu et al., 2023); (Alhamdani, 2016); (Dúo-Terrón et al., 2022); (Ho & Pang, 2024); (Kijima et al., 2021); (Rahman, 2024); (Villarrubia et al., 2024); (Ladachart et al., 2022) (Nugraha et al., 2024); (Siew & Arifin, 2025); (Fearn & Hook, 2023)	Robotic (LEGO, 3D printer) Collaboration Platform (Miro, SlideShare) Makerspace
Human-Centered & Participatory Methods	8	(Charosky et al., 2022); (Sigauke, 2020); (Wren et al., 2025); (Chen et al., 2023); (Bayer et al., 2022); (Stevens et al., 2022); (Liu, 2024); (Högsdal & Grundmeier, 2021)	Empathy tools (Mural, Figma); Hybrid learning (Zoom); Digital documentation
Gamification & Interactive Simulation	6	(Shakeel et al., 2024); (Atchia, 2023); (Liu, 2023); (Bawaneh & Alnamshan, 2023); (Sulisworo et al., 2021); (Fritzsche et al., 2021)	AR/VR (Google Expeditions); Game applications (Kahoot); Digital comics.
Rapid Prototyping & Experimentation	6	(Galoyan et al., 2022); (Avsec & Savec, 2022); (Brandão et al., 2024); (Li et al., 2019); (Dyer, 2019); (McGrath et al., 2024)	Physical prototypes (recycled materials); IoT/sensors; Tinkercad

Referring to Table 3, Collaborative and Project-Based Learning clearly emerges as a proposed strategy for translating such technological support and empowerment into Design Thinking. In

practice, the project-based collaborative approach uses multiple tools, including robotics (LEGO/3D printer), collaborative platforms (Miro/SlideShare), and makerspaces for immersive, hands-on project-based learning. Recent evidence from Bush et al. (2024) and Hsu et al. (2023) indicates that, in some cases, project-based teaching can lead to greater student involvement and substantially improve problem-solving skills. One interesting point to note is that, even though a technology-centric approach is used for learning support, the people-based principles and character of Design Thinking remain unchanged as students participate in every aspect of the training process.

Our review, therefore, also finds positive trends in the adoption of Human-Centered and Participatory methods. Digital platforms like Mural and Figma are not only used as tools. However, they are employed and refined with the aim of encouraging empathy and understanding of user needs. Several schools have already introduced digital tools and find that integrating these platforms into hybrid learning via Zoom makes classrooms more dynamic and fun. For instance, students who are usually passive will become more excited and engaged when allowed to express their thoughts using digital whiteboard features. On the other hand, with IoT/sensors (Atchia, 2023; Shakeel et al., 2024) and recycled materials, progress has been made in rapid prototyping and experimentation, allowing students to conduct rapid experimentation and iteration testing (Avsec & Savec, 2022; Galoyan et al., 2022). Therefore, the inclusion of technology in Design Thinking processes generally leads to more dynamic, student-centered learning scenarios.

Applying design thinking to schools has uncovered several key trends that highlight its flexibility as a pedagogical method. Project-based collaborative approaches leveraging human-centered design principles are particularly prevalent in current uses, accounting for almost two-thirds of the literature reviewed (Aifan, 2022; Zheng, 2018). These activities ultimately have students work together on real-life, problem-driven, user-needs-focused projects (Tsai et al., 2023). Increasingly, however, digital tools such as Miro are helping to bridge that distance and render empathy mappable. This finding offers an intriguing way forward, preserving the original principle of human-centeredness in design thinking while aligning with the traditional approach.

The latest and hottest applications on the electronics highway provide jewel-like models of versatility. At the more advanced end of the spectrum, sophisticated apps employ both vertical and responsive software, with VR simulator integration, to create an immersive learning experience (Shah et al., 2024). It is also exciting to observe that Design Thinking takes on a different shape in various educational settings. Based on preliminary results, we rank three situations in order: isolate schools with IoT (Internet of Things) and VR (Virtual Reality), and full facilities that adopt design thinking to create an immersive learning environment. However, Goldman and Kabayadondo (2016), challenge students creatively to solve real-life problems by having them build a prototype from cardboard, a waste material. This dichotomy demonstrates the power of design thinking to address resource constraints while preserving the core principles of education. More interesting, even, are those that show, in low fidelity, what learning results can be like , compared to higher-tech, where the value is not in the tool but in how it is used (Guaman-Quintanilla et al., 2025).

The main challenge on the horizon is reconciling innovation with simplicity and inclusivity, which are at the core of Design Thinking. Some scholars (e.g. Ng et al. (2021)) have started studying the opportunities generated by generative AI and the metaverse. However, others, such as Quintanilla et al. (2023) have developed instruments for schools with fewer resources. This rift implies, or perhaps undermines, the idea that what Design Thinking is has more to do with creative thinking and empathy than with technical aptitude. This condition is a threefold contribution, consisting of: the development of a comprehensive architecture for describing and restructuring design thinking across various educational contexts; best integration strategies that maintain the integrity of pedagogy; and an evidence-based implementation model that can scale in resource-deprived contexts. Finally, the

discussion showed how the research findings can address well problem formulation by establishing a clear link between study results and initial purpose; further work should focus on longitudinal studies for investigating more in-depth DT impact on scientific creativity and problem-solving abilities of individuals as future directions as well culturally responsive adaptations of the DT framework elsewhere in non-Western education settings due to their global applicability.

CONCLUSION

A recent systematic literature review of scholarly work from 2015 to 2025 organized key data on the implementation of design thinking (DT) in science education, identifying important trends and outcomes. The bibliometric analysis revealed two blocks of concepts, design thinking, and computational thinking, indicating an increasing interdisciplinarity in the field of science education research. The study revealed three development periods: exploratory phase (2016-2018), fast expansion (2019-2022), and current consolidation (2023-2025), where a maximum peaked at 6 to 8 papers per year in 2022, with an initial slight reduction according to preliminary 2025 data that probably reflects incomplete reporting rather than a reduction of scientific interest. In terms of regional implementation and coordination, the developed countries have been at the forefront, notably the US, the UK, and Australia. Methodologically, qualitative approaches (notably case studies and design-based research) were the most frequently used in the field, while mixed-method designs increased notably (from 15% of the pre-2020 works to 35% of recent papers). Specifically, in the literature, PBL has been identified as the best practice for integrating DT and technology-enabled strategies through digital platforms, AR/VR, and gamification, with applications across various educational areas. Implications for the use of these findings include flexible implementation frameworks as educators work with varying resource levels, evidence-based strategies for assessing DT outcomes, and models to guide professional development targeting teacher competencies. These outputs fill a significant gap in theoretical and practical knowledge and have the potential to materially improve students' metacognitive skills for creative thinking and problem-solving in the 21st century. We suggest that further research should focus on longitudinal studies of DT's sustained influence on scientific creativity and on the cultural responsiveness of DT frameworks for application in non-Western schooling systems, to ensure global transferability.

DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

CONFLICTING INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

FUNDING INFORMATION STATEMENT

Satya Wacana Christian University supports this publication through the Writers Camp 2025 program.

REFERENCES

Aifan, H. (2022). Implementing a Project-Based Collaborative Learning Approach Using PowerPoint to Improve Students' 21st-Century Skills. *E-Learning and Digital Media, 19*(3), 258–273.

Al-Zahrani, A. M. (2024). Unveiling the Shadows: Beyond the Hype of AI in Education. *Heliyon, 10*(9), e30696.

Alhamdani, W. A. (2016). Teaching Cryptography Using Design Thinking Approach. *Journal of Applied Security Research, 11*(1), 78–89.

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-Tool for Comprehensive Science Mapping Analysis. *Journal of Informetrics, 11*(4), 959–975.

Arifin, N. R., & Mahmud, S. N. D. (2021). A Systematic Literature Review of Design Thinking Application in STEM Integration. *Creative Education, 12*(07), 1558–1571.

Atchia, S. M. C. (2023). Integration of 'Design Thinking' in a Reflection Model to Enhance the Teaching of Biology. *Journal of Biological Education, 57*(2), 386–400.

Avsec, S., & Savec, V. F. (2022). Mapping the Relationships Between Self-Directed Learning and Design Thinking in Pre-Service Science and Technology Teachers. *Sustainability, 14*(14), 8626.

Bahroun, Z., Anane, C., Ahmed, V., & Zacca, A. (2023). Transforming Education: A Comprehensive Review of Generative Artificial Intelligence in Educational Settings Through Bibliometric and Content Analysis. *Sustainability, 15*(17).

Bawaneh, A. K., & Alnamshan, M. M. (2023). Design Thinking in Science Education: Enhancing Undergraduate Students' Motivation and Achievement in Learning Biology. *International Journal of Information and Education Technology, 13*(4), 621–633.

Bayer, I., Elma, A., Nasser, M., & Grierson, L. (2022). Empathy for the Health Professional in Online Asynchronous Graduate Education: An Initial Design Thinking Approach to Program Improvement. *Discover Education, 1*(1).

Beligatamulla, G., Rieger, J., Franz, J., & Strickfaden, M. (2019). Making Pedagogic Sense of Design Thinking in the Higher Education Context. *Open Education Studies, 1*(1), 91–105.

Brandão, A. P., Donaldson, J. P., Dunlap, K. A., Wiegert, J. G., Kao, S., & Paudyal, S. (2024). Design Thinking for Engaged Learning in Animal Science: Lessons From Five Semesters of a Senior Capstone Course. *Translational Animal Science, 8*.

Bush, S. B., Edelen, D., Roberts, T., Maiorca, C., Ivy, J. T., Cook, K. L., ... & Cox Jr, R. (2024). Humanistic STE(A)M Instruction Through Empathy: Leveraging Design Thinking to Improve Society. *Pedagogies: An International Journal, 19*(1), 60–79.

Charosky, G., Hassi, L., Papageorgiou, K., & Bragós, R. (2022). Developing Innovation Competences in Engineering Students: A Comparison of Two Approaches. *European Journal of Engineering Education, 47*(2), 353–372.

Chen, K., Chen, J., & Wang, C. (2023). The Effects of Two Empathy Strategies in Design Thinking on Pre-Service Teachers' Creativity. *Knowledge Management and E-Learning, 15*(3), 468–486.

Couzens, A. J., & Cattoni, J. (2023). Redesigning Screen Production Pedagogy for Hybrid Learning Models. *Media Practice and Education, 24*(1), 4–20.

Dotson, M. E., Alvarez, V., Tackett, M., Asturias, G., Leon, I., & Ramanujam, N. (2020). Design Thinking-Based STEM Learning: Preliminary Results on Achieving Scale and Sustainability Through the IGNITE Model. *Frontiers in Education, 5*.

Dúo-Terrón, P., Hinojo-Lucena, F. J., Moreno-Guerrero, A. J., & López-Belmonte, J. (2022). Impact of the Pandemic on STEAM Disciplines in the Sixth Grade of Primary Education. *European Journal of Investigation in Health, Psychology and Education, 12*(8), 989–1005.

Duschl, R. A. (2019). Learning Progressions: Framing and Designing Coherent Sequences for STEM Education. *Disciplinary and Interdisciplinary Science Education Research, 1*(1), 4.

Dyer, M. (2019). STEAM Without Hot Air: Strategy for Educating Creative Engineers. *Australasian Journal of Engineering Education, 24*(2), 74–85.

English, L. D., & King, D. (2019). STEM Integration in Sixth Grade: Designing and Constructing Paper Bridges. *International Journal of Science and Mathematics Education, 17*(5), 863–884.

Fallin, L. (2025). The Transformative Potential of Design Thinking in Learning Development. *Journal of Learning Development in Higher Education, 34*.

Fatkhurrohman, M. A. (2023). A Systematic Review on Design Thinking in Science Education Research (DTiSER) on 21st Century Skills. *Journal of Advanced Sciences and Mathematics Education, 5*(1), 123–135.

Fearn, W., & Hook, J. (2023). A Service Design Thinking Approach: What Are the Barriers and Opportunities of Using Augmented Reality for Primary Science Education? *Journal of Technology and Science Education, 13*(1), 329–351.

Fritzsche, H., Barbazzeni, B., Mahmeen, M., Haider, S., & Friebe, M. (2021). A Structured Pathway Toward Disruption: A Novel HealthTec Innovation Design Curriculum With Entrepreneurship in Mind. *Frontiers in Public Health, 9*.

Galoyan, T., Barany, A., Donaldson, J. P., Ward, N., & Hammrich, P. (2022). Connecting Science, Design Thinking, and Computational Thinking Through Sports. *International Journal of Instruction, 15*(1), 601–618.

Goldman, S., & Kabayadondo, Z. (2016). *Taking Design Thinking to School: How the Technology of Design Can Transform Teachers, Learners, and Classrooms* (1st ed.). Routledge.

Grönman, S., Lindfors, E., & Rönkkö, M. L. (2025). Design Thinking in Early Childhood Education and Care. A Literature Review and Consideration From the Perspective of Young Learners' Craft, Design, and Technology Education. *International Journal of Technology and Design Education, 35*(3), 857–877.

Guaman-Quintanilla, S., Alcivar, I., Caicedo, G., Everaert, P., & Chiluiza, K. (2025). How to Set Up a Formal Design Thinking Course That Works? A Practical Guide for Higher Education Settings. *Thinking Skills and Creativity, 56*, 101759.

Gusenbauer, M. (2024). Beyond Google Scholar, Scopus, and Web of Science: An Evaluation of the Backward and Forward Citation Coverage of 59 Databases' Citation Indices. *Research Synthesis Methods, 15*(5), 802–817.

Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R Package and Shiny App for Producing PRISMA 2020-Compliant Flow Diagrams, With Interactivity for Optimised Digital Transparency and Open Synthesis. *Campbell Systematic Reviews, 18*(2), e1230.

He, W., Zheng, Y., Zhang, X., Liao, L., & Hu, X. (2025). Application of Design Thinking Model for the Improvement in Engagement Among Primary Students for STEM Courses. *The Asia-Pacific Education Researcher*.

Henriksen, D., Gretter, S., & Richardson, C. (2020). Design Thinking and the Practicing Teacher: Addressing Problems of Practice in Teacher Education. *Teaching Education, 31*(2), 209–229.

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design Thinking: A Creative Approach to Educational Problems of Practice. *Thinking Skills and Creativity, 26*, 140–153.

Ho, T. E., & Pang, V. (2024). Outcomes of an Integrated STEM With Design Thinking Module on Preschoolers' Engineering Practices. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(4).

Högsdal, S., & Grundmeier, A. M. (2021). Integrating Design Thinking in Teacher Education: Student Teachers Develop Learning Scenarios for Elementary Schools. *International Journal of Design Education, 16*(1), 1–26.

Hsu, T. C., Chang, Y. S., Chen, M. S., Tsai, I. F., & Yu, C. Y. (2023). A Validity and Reliability Study of the Formative Model for the Indicators of STEAM Education Creations. *Education and Information Technologies, 28*(7), 8855–8878.

Khushk, A., Zhiying, L., Yi, X., & Zengtian, Z. (2023). Technology Innovation in STEM Education: A Review and Analysis. *International Journal of Educational Research and Innovation, 2023*(19), 29–51.

Kijima, R., Yang-Yoshihara, M., & Maekawa, M. S. (2021). Using Design Thinking to Cultivate the Next Generation of Female STEAM Thinkers. *International Journal of STEM Education, 8*(1), 14.

Ladachart, L., Khamlarsai, S., & Phothong, W. (2022). Cultivating a Design Thinking Mindset in Educationally Disadvantaged Students Using a Design-Based Activity. *International Journal of Innovation in Science and Mathematics Education, 30*(4), 1–14.

Leonardou, A., Rigou, M., Panagiotarou, A., & Garofalakis, J. (2022). Effect of OSLM Features and Gamification Motivators on Motivation in DGBL: Pupils' Viewpoint. *Smart Learning Environments, 9*(1).

Li, R., Zhang, H., Liu, C., Qian, Z. C., & Zhang, L. (2022). Bibliometric and Visualized Analysis of User Experience Design Research: From 1999 to 2019. *SAGE Open, 12*(1).

Li, T., & Zhan, Z. (2022). A Systematic Review on Design Thinking Integrated Learning in K-12 Education. *Applied Sciences, 12*(16).

Li, W. T., Ho, M. C., & Yang, C. (2019). A Design Thinking-Based Study of the Prospect of the Sustainable Development of Traditional Handicrafts. *Sustainability, 11*(18).

Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2019). Design and Design Thinking in STEM Education. *Journal for STEM Education Research, 2*(2), 93–104.

Liang, J. (2024). A Systematic Literature Review of the Design Thinking Application in the Early Childhood Integrated STEM Education. *International Journal of Learning and Teaching, 10*(5), 643–646.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Healthcare Interventions: Explanation and Elaboration. *BMJ, 339*, b2700.

Lin, L., Shen, S., Shadiev, R., & Yu, M. (2025). Review of Research on Design Thinking in K-12 Education. *Educational Research Review, 47*, 100682.

Liu, H. Y. (2024). Effects of the Design Thinking Pedagogy on Design Thinking Competence of Nursing Students in Taiwan: A Prospective Non-Randomized Study. *Nurse Education Today, 138*.

Liu, P. (2023). An Entrepreneurship Incubation Process Model and Gamified Educational Software Designed for Sustainable Education. *Sustainability, 15*(19).

McGrath, K., Regan, Á., & Russell, T. (2024). A User-Centred Future for Agricultural Digital Innovation: Demonstrating the Value of Design Thinking in an Animal Health Context. *Journal of Agricultural Education and Extension*, 1–19.

Munn, Z., Stern, C., Aromataris, E., Lockwood, C., & Jordan, Z. (2018). What Kind of Systematic Review Should I Conduct? A Proposed Typology and Guidance for Systematic Reviewers in the Medical and Health Sciences. *BMC Medical Research Methodology, 18*(1), 5.

Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI Literacy: An Exploratory Review. *Computers and Education: Artificial Intelligence, 2*, 100041.

Nguyện, L. C., Hoa, H. Q., & Hien, L. H. P. (2025). Integrating Design Thinking Into STEM Education: Enhancing Problem-Solving Skills of High School Students. *Eurasia Journal of Mathematics, Science and Technology Education, 21*(4), 1–11.

Nugraha, M. G., Kidman, G., & Tan, H. (2024). Interdisciplinary STEM Education Foundational Concepts: Implementation for Knowledge Creation. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(10).

Ogegbo, A. A., & Ramnarain, U. (2022). Teachers' Perceptions of and Concerns About Integrating Computational Thinking Into Science Teaching After a Professional Development Activity. *African Journal of Research in Mathematics, Science and Technology Education, 26*(3), 181–191.

Orozco, M., Boon, M., & Arce, A. S. (2023). Learning Electrochemistry Through Scientific Inquiry. Conceptual Modelling as Learning Objective and as Scaffold. *European Journal of Engineering Education, 48*(1), 180–196.

Oshima, J., Oshima, R., & Kayagi, T. (2024). University Students' Knowledge Creation Practices in Face-to-Face and Hybrid Blended Learning: Development of Epistemic Views and Perceptions of the Community of Inquiry. *Journal of Science Education and Technology*.

Öztürk, A., & Korkut, F. (2023). Design Thinking Customized to Support STEM Teachers: Co-Developing and Implementing STEM Activities for Fifth Graders in Turkey. *International Journal of Technology and Design Education, 33*(4), 1409–1447.

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & McKenzie, J. E. (2021). PRISMA 2020 Explanation and Elaboration: Updated Guidance and Exemplars for Reporting Systematic Reviews. *BMJ, 372*.

Panke, S. (2019). Design Thinking in Education: Perspectives, Opportunities and Challenges. *Open Education Studies, 1*(1), 281–306.

Piwowar, H., Priem, J., Larivière, V., Alperin, J. P., Matthias, L., Norlander, B., ... & Haustein, S. (2018). The State of OA: A Large-Scale Analysis of the Prevalence and Impact of Open Access Articles. *PeerJ, 6*, e4375.

Quintanilla, S. G., Everaert, P., Chiluiza, K., & Valcke, M. (2023). Impact of Design Thinking in Higher Education: A Multi-Actor Perspective on Problem Solving and Creativity. *International Journal of Technology and Design Education, 33*(1), 217–240.

Rahman, S. M. M. (2024). Digital K–12 STEM Education Through Human–Robot Interaction: Investigation on Prerequisites. *Digital, 4*(2), 461–482.

Ramírez-Montoya, M. S., Quintero Gámez, L., Sanabria-Z, J., & Portuguez-Castro, M. (2024). Exploring Complex Thinking in Latin American Universities: Comparative Analysis Between Programs and Alternative Credentials. *Journal of Latinos and Education, 23*(5), 1744–1765.

Ramos-Mejía, A., & Padilla, K. (2025). A Problem-Based Learning Electrochemistry Course for Undergraduate Students to Develop Complex Thinking. *Education Sciences, 15*(3).

Rethlefsen, M. L., Kirtley, S., Waffenschmidt, S., Ayala, A. P., Moher, D., Page, M. J., & Koffel, J. B. (2021). PRISMA-S: An Extension to the PRISMA Statement for Reporting Literature Searches in Systematic Reviews. *Systematic Reviews, 10*(1), 39.

Shah, S. F. A., Mazhar, T., Shahzad, T., Ghadi, Y. Y., & Hamam, H. (2024). Integrating Educational Theories With Virtual Reality: Enhancing Engineering Education and VR Laboratories. *Social Sciences & Humanities Open, 10*, 101207.

Shakeel, M. C. A., Chummun, D., & Luckho, S. (2024). Use of Design Thinking as a Strategy to Identify and Clear Students' Misconceptions in Photosynthesis: A Case Study. *Journal of Biological Education, 58*(3), 666–683.

Shanmugam, S., Veloo, A., Ng, S. B., & Revindran, S. (2025). Exploring the Barriers to Implementing Hybrid Learning in Rural Primary Schools. *Cogent Education, 12*(1).

Shea, B. J., Reeves, B. C., Wells, G., Thuku, M., Hamel, C., Moran, J., ... & Henry, D. A. (2017). AMSTAR 2: A Critical Appraisal Tool for Systematic Reviews That Include Randomised or Non-Randomised Studies of Healthcare Interventions, or Both. *BMJ, 358*.

Siew, N. M., & Arifin, S. (2025). Fostering Creative Thinking in Entrepreneurship Among Socio-Scientific Issues and Design Thinking Integration in Science Education. *Journal of Baltic Science Education, 24*(1), 169–186.

Sigauke, E. (2020). Connecting Urban Agriculture With Design Thinking: A Case Study From Zimbabwe. *Journal of Environmental Education, 52*(1), 53–68.

Situmorang, R. P., Suwono, H., Susanto, H., Chang, C. Y., & Liu, S. Y. (2024). Learn Biology Using Digital Game-Based Learning: A Systematic Literature Review. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(6), em2459.

Snyder, H. (2019). Literature Review as a Research Methodology: An Overview and Guidelines. *Journal of Business Research, 104*, 333–339.

Stammes, H., Henze, I., Barendsen, E., & de Vries, M. (2025). Monitoring Multiple Aspects of Learning When Design-Based Learning Meets Science Education. *International Journal of Technology and Design Education*.

Stevens, L. L., Whitehead, C., & Singhal, A. (2022). Cultivating Cooperative Relationships: Identifying Learning Gaps When Teaching Students Systems Thinking Biomimicry. *Biomimetics, 7*(4).

Sulisworo, D., Drusmin, R., Kusumaningtyas, D. A., Handayani, T., Wahyuningsih, W., Jufriansah, A., ... & Prasetyo, E. (2021). The Science Teachers' Optimism Response to the Use of Marker-Based Augmented Reality in the Global Warming Issue. *Education Research International, 2021*(1), 7264230.

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., … Straus, S. E. (2018). PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Annals of Internal Medicine, 169*(7), 467–473.

Tsai, C. A., Song, M. Y. W., Lo, Y. F., & Lo, C. C. (2023). Design Thinking With Constructivist Learning Increases the Learning Motivation and Wicked Problem-Solving Capability—An Empirical Research in Taiwan. *Thinking Skills and Creativity, 50*, 101385.

Villarrubia, C., Vara, J. M., Granada, D., Gómez-Macías, C., & Pérez-Blanco, F. J. (2024). DesignScrum–An Agility Educational Resource Powered by Creativity. *Software: Practice and Experience, 54*(6), 985–1009.

Wang, C. C. (2024). Using Design Thinking for Interdisciplinary Curriculum Design and Teaching: A Case Study in Higher Education. *Humanities and Social Sciences Communications, 11*(1), 1–13.

Wren, H., Hetherington, L., Chappell, K., O'Kane, E., Sotiriou, M., Quacinella, D., ... & Duca, E. (2025). Conceptualising and Exploring Creative Pedagogies and Design Thinking in Transdisciplinary STEAM Higher Education Courses. *Research Papers in Education*, 1–30.

Yu, Q., Yu, K., & Lin, R. (2024). A Meta-Analysis of the Effects of Design Thinking on Student Learning. *Humanities and Social Sciences Communications, 11*(1), 742.

Yüksel, A. O. (2025). Design-Based STEM Activities in Teacher Education and Its Effect on Pre-Service Science Teachers' Design Thinking Skills. *Journal of Science Education and Technology, 34*(4), 904–918.

Zheng, J. (2018). Analysis of Collaborative Design and Construction Collaborative Mechanism of Cloud BIM Platform Construction Project Based on Green Computing Technology. *Journal of Intelligent & Fuzzy Systems, 34*(2), 819–829.

Zupic, I., & Čater, T. (2015). Bibliometric Methods in Management and Organization. *Organizational Research Methods, 18*(3), 429–472.