

Repositioning of Design Thinking in Science Education Research: Systematical Review

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Abstract: 21st century science learning is design-based learning that can be applied with design thinking. Design Thinking in science education needs to be repositioned so that all stages can be applied to science learning. A more in-depth review of design thinking research needs to be carried out to identify research opportunities. The aim of this research is to determine the trends and focus of design thinking research, the fields of study and competencies measured by researchers in design thinking research, as well as the types of design thinking chosen by researchers. The method used in this research uses bibliometric analysis and literature review. The publications are from the last 10 years (2013-2022) from the Crossref, Google Scholar, and Scopus databases. Based on these results, it was concluded that there will be an increase in the trend of design thinking research in 2022. Eight design thinking research focuses were found with themes that are rarely researched. The field of design thinking research that is most widely applied is in the field of education, where the most researched competency is the design thinking process, but in the field of science education it is still not applied. There is a need to reposition every aspect of design thinking in science learning.

Keywords: Design Thinking; Science Education; Systematical Review

Introduction

21st century learning is a need to guide present and future life through technology (Caena et al, 2019) y. One of the current education considered important for creating scientifically literate citizens is science learning because it introduces important 21st century skills such as adaptability or problem-solving (Kalogiannakis et al., 2021). Even though the teacher in learning science focuses more on remembering concepts by memorizing rather than the learning process that is by the demands of the 21st century (Sigit et al., 2022). The importance of the science process in learning, students can understand it better than just memorizing (Usman & Faradina, 2023). By understanding science as a process, students can also avoid misconceptions or mistakes in understanding scientific concepts (Listiani, 2023). Mastery of the process in science learning requires students to have a scientific attitude (Rizaldi et al., 2023).

The development of knowledge in the field of education requires students to have skills to improve their quality (Amala et al., 2023). In 21st century science learning, teachers need to master basic teacher-teaching skills (M. H. Usman et al., 2021). Prospective science teachers must have an understanding of the concepts being taught (Putra et al., 2021)). Science learning is carried out with learning strategies to facilitate the learning process (Rudi et al., 2023). Science learning students' skills can be developed with the right learning model (Lestari et al., 2020)

Increasing competence in the 21st century by introducing design thinking to primary and secondary students has increased in popularity by integrating design thinking into education (Li & Zhan, 2022). An effective pedagogical approach to enable students to acquire the skills needed to solve real-world problems adopted in several higher education disciplines is Design Thinking (Bene et al, 2020). Design thinking competency in students shows opportunities to help

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students with lower competency (Liu, 2023). In the 21st century, design-based learning in undergraduate education is through a design thinking mindset, but the design thinking mindset has not been implemented when engaging in design-based activities (Ladachart & Phothong, 2022).

Design thinking will elaborate various strategies that can foster curiosity, and exploration, and improve the design thinking process to obtain optimal solutions (Pressman, 2018). Design thinking offers creative problem-solving solutions for a variety of topics by emphasizing integrated team communication and collaboration and exchange between interdisciplinary talent (J. C. Tu et al., 2018). However, the lack of design thinking from the perspective of teachers in Slovakia is the limited time at certain stages and the prototyping and testing phases are limited according to university conditions (Sádorová et al., 2020). So it is necessary to reposition each stage of design thinking so that it can be applied to all conditions in higher education.

Based on the description above, to reposition design thinking in Science Education, a study of various design thinking research was carried out. Several methods can be used, namely bibliometric analysis and literature reviews. This research analysis study includes trends and focus of design thinking research, fields of study and competencies measured by researchers in design thinking research, and types of design thinking chosen by researchers.

Method

We conducted this research as a systematic review using bibliometric visualization and literature review methods. The aim of using the bibliometric visualization method is to obtain information regarding trends and focus of design think research, while the use of literature reviews is to obtain information on areas of study, design thinking competencies, and types of design think. According to (Erpin., 2022) bibliometric research can describe and examine literature in fields of study with science learning. The publications are selected from the last 10 years (2013-2022). The bibliometric analysis process follows Figure 1.

Bibliometric analysis was obtained using Vosviewer software to find out the mapping of trends, patterns, and gaps for further research related to design thinking. VOSviewer visualizes data in the form of a map of variables related to keywords and opportunities for development (Muhammad et al., 2022).

Based on Crossref, Google Scholar, and Scopus databases through data collection using POP (Publish or Perish). The sample in this research's bibliometric analysis was 2649 publications obtained from a database

with the keyword design thinking. Most come from articles, and some from book reviews. The sample for the literature review analysis was 2147 articles in the Science Direct database, 1176 articles in Springer, and 10931 articles in ERICS.

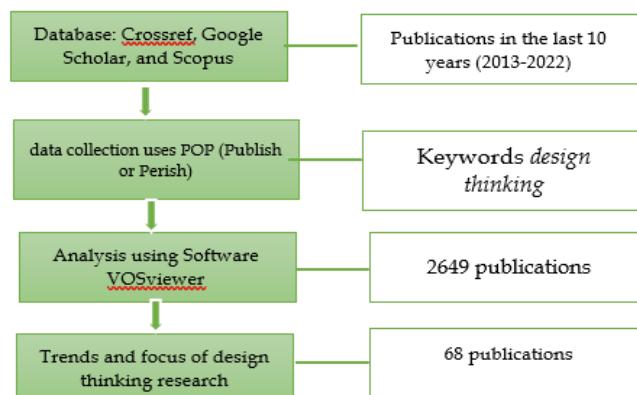


Figure 1. Bibliometric analysis process schematic

Apart from the bibliometric analysis above, searches were also carried out through literature reviews. The literature review process follows Figure 2.

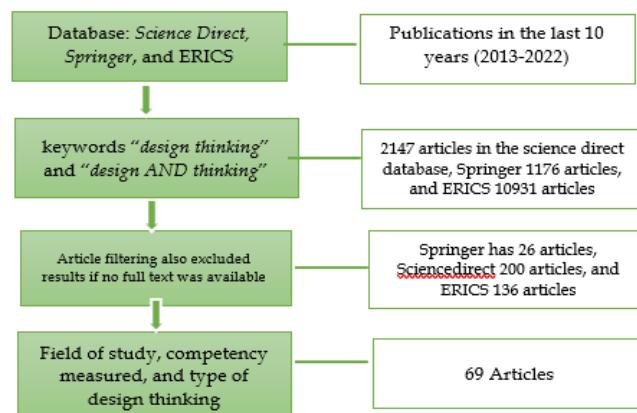


Figure 2. Schematic of the literature review process

The keywords used are "design think" and "design AND think" in the Science Direct, Springer, and ERICS databases. The main reason for selecting this database is to retrieve quality research articles and draw conclusions from a literature review that is reliable and more representative. When keywords were used in the search, 2147 articles were obtained in the Science Direct database, 1176 articles in Springer, and 10931 articles in ERICS. Articles were investigated based on quality, and relevance to the research. Article filtering also excludes results if no full text is available. Springer's initial review found 26 relevant articles, ScienceDirect 200 articles, and ERICS 136 articles. The final review of articles used for analysis totaled 69 articles.

Result and Discussion

Question number 1: In design thinking research, what are the trends and research focuses?

Data from search results for articles related to design thinking trends in the last 10 years, namely 2013-2022, is presented in Figure 1. Based on the data in Figure 1. since 2013-2022 there has been an increase in publications meaning that there has been a trend in design thinking research in 2022. Especially significant increases have occurred in 2014 and 2021. Design thinking shows the great potential of 21st-century education (Li & Zhan, 2022). While the data for article search results using POP shows the number of article citations that are relevant to design thinking with the 10 most citations since 2005 presented in Table 1.

Table 1. Articles with the Most Design Thinking Citations

Author's Name	Article Title	Year	Journal Name	Number of Citations
C.L. Dym	Engineering design thinking, teaching, and learning	2005	Journal of Engineering Education	2258
T. Brown	Design thinking	2008	Harvard Business Review	2242
K. Dorst	The core of 'design thinking and its application	2011	Design Studies	881
U. Johansson-Sköldberg	Design thinking: Past, present and possible futures	2013	Creativity and Innovation Management	520
R. Razzouk	What Is Design Thinking and Why Is It Important?	2012	Review of Educational Research	518
D. Dunne	Design thinking and how it will change management education: An interview and discussion	2006	Academy of Management Learning and Education	441
S.L. Beckman	Innovation as a learning process: Embedding design thinking	2007	California Management Review	426
E. Bjögvinnsson	Design things and design thinking: Contemporary participatory design challenges	2012	Design Issues	378
J. Liedtka	Perspective: Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction	2015	Journal of Product Innovation Management	376
D.S. Yeager	Using design thinking to improve psychological interventions: The case of the growth mindset during the transition to high school	2016	Journal of Educational Psychology	363

The article data in Table 1 above can be used as a reference source for research on design thinking. The greater the number of citations or citations from an article, means that the research results have been used as references in other studies (Supinah & Soebagyo, 2022). POP data related to design thinking from the Google Scholar database, and Scopus are stored in the RIS form which is then used in the VOSviewer software to obtain 2649 terms with the closest 68 terms and repeated occurrences using 8 terms, the display is shown in Figure 4.

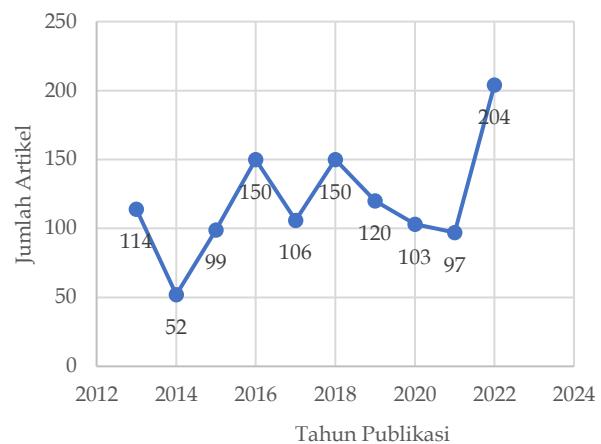


Figure 3. Design Thinking Article Publication Trends

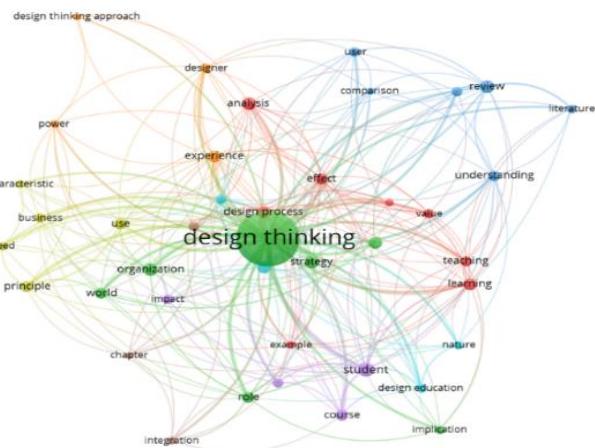


Figure 4. Network visualization results

The image above shows a network visualization of the use of design thinking. The size of the circle shows that researchers have used design thinking a lot. The network visualization results in Figure 4 show that 8 clusters are the focus of design thinking research, namely:

Table 2. Network Visualization Design Thinking Cluster

Cluster	Focus
Cluster 1:	analysis, design process, effects, engineering design, examples, learning, teaching, value.
Cluster 2:	design thinking, implications, management, organization, rules, strategy, world
Cluster 3:	comparison, terrain, literature, review, understanding, users
Cluster 4:	business, characteristics, needs, principles, use
Cluster 5:	course, creativity, consequences, students
Cluster 6:	challenges, educational design, nature, opportunities
Cluster 7:	design thinking approach, designers, experience, strengths
Cluster 8:	aspects, parts, integration

Based on the network visualization results, shows that the 8 research focuses above can be used as a reference for further research to determine research themes in the field of design thinking. There are research opportunities between the themes of design thinking and engineering design process, design thinking approach, and educational design because these keywords are not in the same cluster or are not connected. Furthermore, the density of the focus of design thinking research is shown by density visualization. The yellow color indicates the density of a journal. A solid yellow color indicates more publications. The following is the result of density visualization on design thinking.

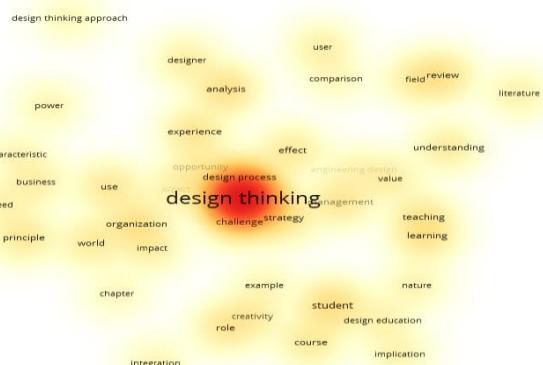


Figure 5. Density Visualization Results

The density visualization results in Figure 5 are shown in dim colors which indicate that these themes

are rarely researched, namely management, engineering design, opportunities, and aspects, so these themes can become opportunities for further design thinking research.

Question number 2: What areas of study and competencies do researchers measure in design thinking research?

Based on the analysis of several articles through literature review, design thinking is widely applied in the field of education as shown in Figure 6.

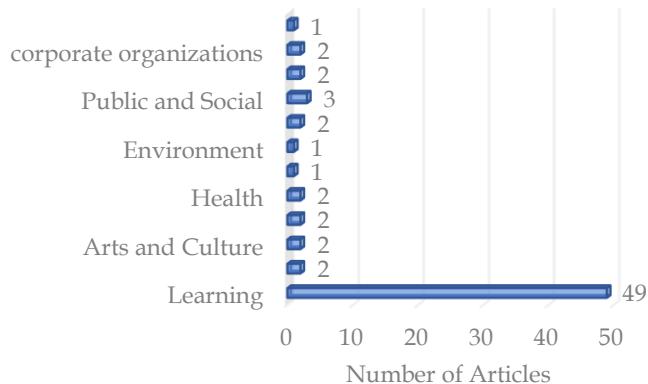


Figure 6. Field of Design Thinking Study

The effectiveness of the application of design thinking in education is the most widely studied area of design thinking research. The design thinking approach has proven to be a great tool for improving the teaching and learning process, especially in terms of cultivating 21st Century Skills among students (Razali et al., 2022). The quality of student learning has a positive relationship with the STEM-based learning process in science process skills (Akbariah et al., 2023). Science learning in Indonesia needs to apply STEM (Zulyusri et al., 2023). Applying design thinking to educational research from the results of the literature review, the fields of science shown in Figure 5.

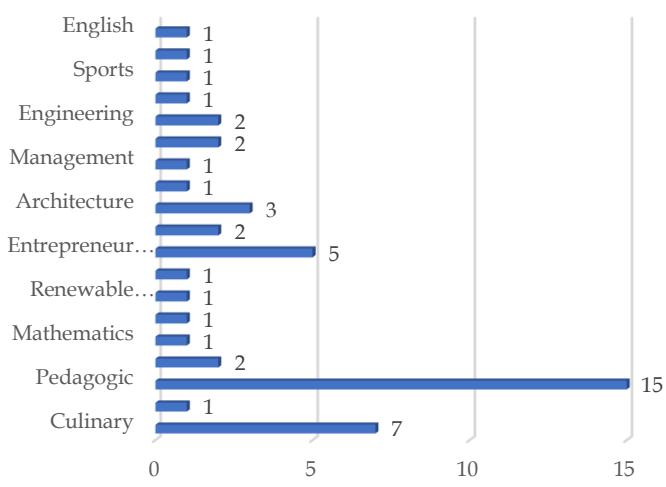


Figure 7. Fields of Educational Research

Based on Figure 7, most design thinking research is applied to the pedagogic field, but the science field has not yet been carried out so that it can be used as an opportunity for further research. Several reasons why the field of pedagogy is widely applied to design thinking. In the pedagogical field, design thinking is applied in 21st-century education to promote collaborative and creative problem-solving among students across the curriculum (Goldman et al., 2009). Design Thinking as a pedagogy can be conducive to digital transformative learning (Taimur & Onuki, 2022). There is a need for learning that can link science, technology, and society (Astuti et al., 2023). In the context of educational research, the competencies examined in the research are as follows.

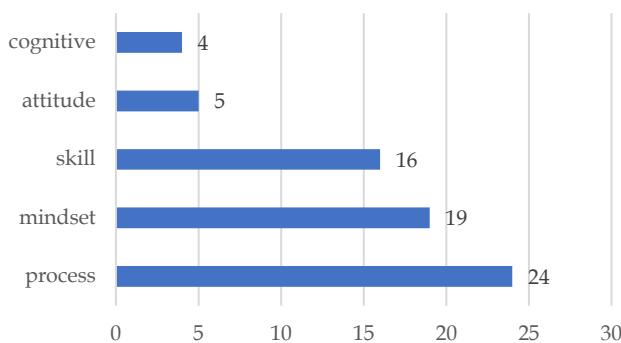


Figure 8. Researched Design Thinking Competencies

The process of developing each student's knowledge, skills, or attitudes is a component of learning (Budiarti & Istiyono, 2023). The most researched design thinking competencies are the design thinking process in 24 articles, mindset in 19 articles, and skills in 16 articles. The design thinking process makes people "think and do" during the design process using a pedagogical approach (Parker et al., 2021). Design thinking refers to a series of cognitive processes and methods through design that aim to identify and solve complex problems (Felder et al., 2023). Design Thinking is a creative thinking pattern that can be applied to design learning (Kartika Dewi et al., 2018). Meanwhile, the design thinking competency indicators are shown in Table 3.

Table 3. Indicators of Design Thinking Competency

Attitude	Mindset	Skills
empathetic	motivational	collaboration
Ethical	Interest	Collaboration
creative	design thinking	interest
confidence	problem-solving	
mind mapping		
communication		
finding solutions		
Synthesis		

Design thinking skills are largely augmented through experiential learning education or the application of design tools (Lyu et al., 2023). Collaborating to solve complex problems requires new ways of thinking with a positive, forward-moving, and innovative mindset to achieve impactful solutions (Cleckley et al., 2021). In design thinking skills communication, feedback and additional information occur as an investigation to solve problems (Albright et al., 2022). In attitudinal competence, the empathy phase is used to find out the user's needs, desires, goals, ways of acting and thinking (Albay et al., 2021). Empathy is the foundation of the human-centered design process (Avsec et al 2021). Competency indicators other than those listed above can be an option for opportunities for further design thinking research.

Question number 3: What type of design thinking does the researcher choose?

Based on the types of design thinking applied to research, Figure 9.

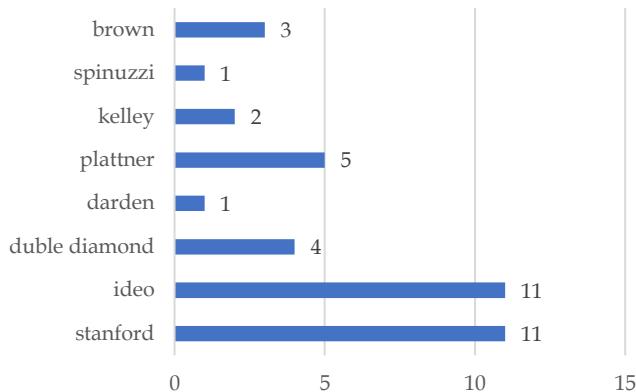


Figure 9. Types of Design Thinking

The choice of using design thinking in learning from several design thinking needs to be considered. According to Stanford and IDEO, design thinking is most often used in research. Design Thinking according to Stanford is a human-oriented problem-solving method that departs from human needs and offers creative solutions for various topics (J.-C. Tu et al., 2018). IDEO describes the design process as the stages of problem definition, understanding users, generating ideas, and creating and testing prototypes (Parker et al., 2021). One of the research opportunities is design thinking according to Brown. The difference from the various types of design thinking according to (Öztürk, 2021) is the design thinking approach by Brown which only has an implementation stage. The components of design thinking include inspiration, ideas, and implementation (Brown, 2008). However, these three elements can overlap and not be sequential (Bender-Salazar, 2023). So it is necessary to define and create a

systematic sequence for each aspect of Brown's design thinking.

Conclusion

Based on the overall description above, it can be concluded that there are themes that are rarely researched, namely management, engineering design, opportunities and aspects. The field of design thinking research that is most widely applied is in the field of education, but in the field of science education it is still not applied. One of the research opportunities is design thinking according to Brown. The need to reposition every aspect of design thinking proposed by Brown in science learning. Some of the opportunities above can be suggested for use in further design thinking research.

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Author Contributions

The investigation, H.H and S.; data curation, H.H and P.D.A.; funding acquisition, H.H and S. and P.D.A. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

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