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Design Thinking as an Effort to Enhance Critical Thinking and Science Literacy in Chemistry Learning: A Systematic Review

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Abstract: Critical thinking skills and science literacy represent two pivotal aspects within education, seeking to cultivate students into knowledgeable, analytical individuals proficient in critical thinking when confronting diverse challenges and life circumstances. In the pursuit of enhancing critical thinking abilities, four fundamental aspects come into play, encompassing the capacity for problem-solving, decision-making, assumption analysis, as well as evaluation and inquiry skills. On the other hand, the literacy aspect comprises the articulation of phenomena through the application of chemical concepts, the resolution of problems through the utilization of chemical comprehension, and the critical analysis of strategies and benefits derived from chemistry education. The primary objective of this study are to analyze research trends on the influence of design thinking strategies in improving students' critical thinking and literacy skills through bibliometric analysis and to ascertain the impact of design thinking strategies on the augmentation of students' critical thinking skills and literacy. The data sources used came from reputable journals from 2017-2023. The data obtained is secondary data analyzed with VOSviewer on research trends in critical thinking skills and scientific literacy, the number of publications, the type of research, and the samples used. The data analysis technique employed is Miles and Huberman's method, which consists of four stages: data collection, data reduction, data display, and conclusion drawing. The findings of this research indicate that the utilization of design thinking strategies exerts a significant influence on students' critical thinking skills and literacy, employing 13 aspects applicable during the implementation of chemistry learning processes.

Keywords: Critical thinking skills; Design thinking; Science literacy

Introduction

The ability of students to respond to or confront a given complex problem presented by the teacher requires pedagogical skills. One of the elements of this pedagogical knowledge is critical thinking skills (Shaw, 2020). With students' critical thinking abilities, it will facilitate the process of identifying essential issues from each phenomenon, conducting evaluations, and drawing appropriate conclusions. According to Bloom's Taxonomy, the ability of critical thinking can be identified at the levels of analysis, synthesis, and evaluation through rational and decision-oriented reflective thinking (Ananda, 2023). Critical thinking ability is crucial in implementing learning as it requires a profound understanding, thus aiding students in comprehending both abstract and concrete concepts. This is driven by educators to assist students in achieving learning objectives.

The enhancement of students' critical thinking abilities can be trained and applied through the utilization of *design thinking*. *Design thinking* is a strategy that can be employed to improve students' critical

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thinking skills. Through design thinking, students will strive to generate ideas obtained during the initial stages, assess, and select appropriate actions. This design can assist students in developing new ideas that can transform their way of thinking, including critical thinking skills. The stages of design thinking consist of five steps, namely introduction, defining, generating ideas, prototyping, and evaluation, which can be measured using various indicators (Lin, 2020).

Critical thinking skills will become meaningful for students if supported by project-based learning or learning through direct investigation. With the presence of investigative processes carried out by students, they will apply independent learning skills that enhance students' intellectual abilities in solving given problems. To facilitate this understanding, students need scientific literacy before undertaking the investigation process and to ease the generation of ideas until the final stage of design thinking (Opeyemi, 2022).

The purpose of literacy in education is twofold. Firstly, it aids students in developing accurate scientific knowledge, complemented by their ability to make informed decisions about the given issues (Yiannis, 2023) Secondly, it facilitates the attainment of sustainable educational contexts, particularly in chemistry learning (van Harskamp, Knippels, & Joolingen, 2022). The importance of students' scientific literacy skills has a significant impact on their critical thinking abilities. When students are capable of generating ideas obtained through accurate ideation in exploring scientific literacy on a given subject, it enhances their critical thinking. Secondly, through the practice of scientific literacy, students develop critical thinking skills that are evident in their discussions as they carefully consider each idea put forward. Thirdly, this literacy emphasizes the attainment of educational objectives in problem-solving (Sjöström & Eilks, 2018).

Based on research findings (OECD, 2018) stated that students' literacy skills are low in three aspects: content, process, and context. This is supported by the results of PISA 2018 for scientific literacy, where Indonesia ranks 62 out of 71 participating countries. When looking at the national level of scientific literacy, only 25.38% are considered to have adequate scientific literacy, while 73.61% are deemed to have insufficient scientific literacy (Citra A. D., 2021). The lack of scientific literacy among students can be determined through their behavioral competencies during the learning process. The learning process, accompanied by effective strategies, relies on educators' ability to encourage students to act as facilitators within it. There are various ways and steps to enhance students' critical thinking abilities and literacy. These include utilizing various technologies such as Google Classroom in online learning, implementing different teaching models in both online and offline settings, using appropriate media, and so forth. All of these refer to the importance of effective information management knowledge and skills, which are crucial for understanding the logic behind the process of information gathering, synthesis, analysis, interpretation, and evaluation of relevant information (Citra A. D., 2022).

With the presence of literacy skills possessed by students, it will facilitate their improvement in critical thinking abilities due to the literacy process that enables them to generate ideas in examining a problem, thereby aiding their comprehension of concepts. The use of design thinking will assist students in enhancing their critical thinking abilities and literacy. This is because critical thinking skills are closely related to literacy skills. With the presence of scientific literacy or prior knowledge possessed by students, it will facilitate the attainment of various desired skills, including critical thinking skills. The purpose of this research is to investigate the influence of the design thinking strategy, consisting of five stages: introduction, defining, generating ideas, prototyping, and evaluation, on enhancing students' critical thinking abilities and literacy and analyzing research trends on the influence of design thinking strategies in improving students' critical thinking and literacy skills through bibliometric analysis.

Method

Literature review, also known as a literature study, is a series of actions related to reading, taking notes, and processing research materials. Literature review is not just about reading and taking notes on the collected information. To assist academics in finding scientific literature more easily, characterization of digital databases must be conducted. This literature review aims to provide a description and characterization of research trends, methodologies, and the scope of research areas related to scientific literature databases. In this study, a systematic literature review method is applied. This is carried out to analyze and identify previous research related to this topic (Yanti, 2022).

The data used in this study are secondary data consisting of 48 articles sourced from reputable scientific articles and indexed by Scopus. The stages of this research consist of 4 stages, namely: 1) data collection, where data collected through literature studies through scopus consisting of 613 articles on analytical thinking skills and science literacy in various fields of science. 2) filtering, data obtained 348 articles that are not from books, book chapters, and proceedings. 3) Selection (inclusion and exclusion), data selection by setting clear and specific criteria on studies to be included (inclusion) and excluded studies (exclusion) based on criteria such

as the number of publications, type of research, research methods, and research subjects. The inclusion/exclusion process was carried out by screening the titles/abstracts of articles resulting in 68 excluded articles and 50 selected articles in the inclusion selection, which were then subjected to data extraction. 4) Drawing conclusions, based on the results of the analysis analyzed (Lia Ernawati, 2022). The stages of this research are presented in Figure 1 (Hendratmoko et al., 2023). The literature research was systematically extended with bibliometric analysis and evaluation with the help of VOSviewer and excel software, which aimed to analyze the research trends of the influence of design thinking strategies in improving students' critical thinking and literacy skills.

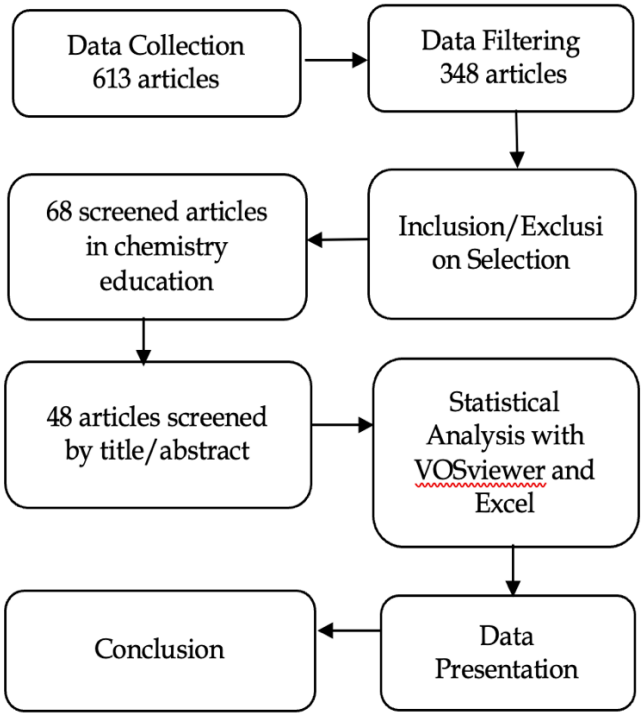

Figure 1: Stages of literatur review with bibliometric analysis

Result and Discussion

Abstract chemistry learning requires comprehensive understanding due to the interconnectedness between prior and upcoming topics. Therefore, the application of design thinking is necessary to enhance students' literacy skills in analyzing, synthesizing, and drawing conclusions from a subject matter. This approach can improve students' critical thinking abilities. Based on the research conducted by (Ananda, 2023) students' critical thinking abilities were assessed using several indicators, namely framing the problem, solution finding, self-regulation, and reflection, which were accomplished through five stages of design thinking.

As for the stages of design thinking, the first one is empathy (Empathize), which begins with understanding students deeply. Conduct observations, interviews, or activities that allow you to explore their needs, interests, and challenges. Interact with students to gain their perspectives. Secondly, the definition (Define) stage involves using insights obtained from the empathy phase to formulate specific learning challenges. Fourthly, Ideation (Ideate) entails engaging students in the ideation process. Utilize creative techniques such as brainstorming or mind mapping to generate various learning ideas and solutions. Encourage students to think "out of the box" and consider various different approaches. Fourthly, the prototype (Prototype) stage involves inviting students to design learning prototypes. This can take the form of a lesson plan, interactive activities, or even real projects. Fifthly, the testing (Test) stage involves conducting tests on the designed learning prototype. Observe how students interact with the learning solutions. Obtain feedback from students to understand the effectiveness and usefulness of these solutions (Wrigley, 2017).

The research findings revealed that the utilization of design thinking can enhance students' critical thinking abilities. With the improvement in students' critical thinking skills, there will be a necessity for literacy to be possessed by students when the design thinking strategies are applied. This is in line with the research by (Opeyemi, 2022) which utilizes project-based learning to enhance students' critical thinking skills. The utilization of design thinking to improve students' critical thinking skills is essential in developing new ideas, and its implementation through project-based learning will support this enhancement. Students will engage actively in project-based learning, leading to active exploration and involvement.

Based on the literacy analysis, it is evident that it is crucial to connect chemical concepts in the learning process with everyday life phenomena to make abstract chemical concepts more tangible. Therefore, chemistry education should address everyday problems, technology, as well as social and environmental issues. This enables students to understand the relationship between chemistry and everyday life and apply it to decision-making; in other words, students become familiar with chemical concepts and are encouraged to enhance their critical thinking abilities (Apriliya, 2021).

The activities conducted to enhance students' critical thinking abilities encompass asking questions, formulating inquiries, making appropriate choices, and drawing conclusions from conducted experiments (Ani, 2021). Scientific literacy is related to the guidance and support of learning resources because it involves how a

student is capable of understanding, evaluating, and applying scientific information effectively in daily life (Persky, 2019). Scientific literacy supports students in making decisions to solve problems by utilizing previously acquired scientific knowledge, cognitive skills, scientific attitudes, and other relevant aspects (Tal, 2014). In chemistry education, it is crucial to relate abstract chemical phenomena to more concrete concepts that are relevant to everyday life (Yapicioglu, 2018). Therefore, critical thinking skills and scientific literacy are two interconnected aspects that support the chemistry learning process.

The implementation of design thinking to enhance students' critical thinking skills and scientific literacy necessitates the presence of an assessment method. With the incorporation of design thinking, students can discover new ideas more efficiently, thereby aiding in the improvement of their understanding of chemical concepts through the assessment aspect of design thinking (Roberts, 2020). The assessment conducted, considering 13 aspects, is a combination of the frameworks proposed by (Facione, 2013), (Bowell, 2005), and (Watson, Critical thinking appraisal: Short form, 2008) as presented in Table 1

Tabel 1. Aspek Berpikir Kritis dan Literasi Sains

Aspects of Chemical Literacy	Aspects of Critical Thinking	Integrated Skill
Explain the phenomenon by using the chemical concept	Draw a conclusion	Drawing conclusions based on phenomena by utilizing the chemical concept
Explain the phenomenon by using the chemical concept	Evaluate arguments	Evaluate arguments based on phenomena by utilizing the chemical concept
Solve a problem using a chemical understanding	Identifying problems	Identify problems by utilizing chemical understanding
Solve a problem using a chemical understanding	Evaluate arguments	Evaluate arguments by utilizing chemical understanding
Explain the phenomenon by using the chemical concept	Draw a conclusion	Drawing conclusions based on phenomena by utilizing the chemical concept
Solve a problem using a chemical understanding	Draw a conclusion	Drawing conclusions based on phenomena by utilizing the chemical concept
Explain the phenomenon by using the chemical concept	Identifying problems	Identify problems based on phenomena by utilizing chemical understanding
Solve a problem using a chemical understanding	Identifying problems	Identify problems by utilizing chemical understanding
Solve a problem using a chemical understanding	Draw a conclusion	Drawing conclusion by exploiting the understanding of chemistry
Analyze the strategies and benefits of chemical applications	Identifying problems	Identify problems from chemical application instances
Explain the phenomenon by using the chemical concept	Draw a conclusion	Drawing conclusions based on phenomena by utilizing the chemical concept
Analyze the strategies and benefits of chemical applications	Determining solution	Determine the solution of the chemical application example
Analyze the strategies and benefits of chemical applications	Reconstructing arguments	Reconstruct arguments from chemical app instances

The table above represents a framework of critical thinking combined with the chemistry literacy skills developed from several experts: (Facione, 2013), (Bowell, 2005), and (Watson, 2008). The aspects of critical thinking consist of the ability to identify problems, construct arguments, evaluate arguments, determine appropriate solutions, and draw conclusions. According to (Agustin, 2020), students' critical thinking skills encompass four aspects: problem-solving, decision-making, analyzing assumptions, and evaluating and conducting investigations. Meanwhile, the aspects of literacy include explaining phenomena using chemical concepts, solving problems using chemical understanding, and analyzing the strategies and benefits of chemistry learning, such as applications, models, and media used (Satya, 2018). Based on the research findings, it is stated that the 13 aspects used for assessment are suitable for measuring students' critical thinking skills and chemistry literacy. These aspects in critical thinking and students' literacy skills can be implemented using design thinking since this approach allows the incorporation of these aspects into chemistry learning.

The application of design thinking in enhancing students' critical thinking skills and literacy can be implemented through various learning models, as demonstrated in the research conducted by (Maria, 2019) The study focused on improving scientific literacy using a problem-based learning approach with a flipped

classroom approach, which influenced the enhancement of students' critical thinking and literacy skills. The usage of this model resulted in an increase in students' critical thinking abilities. Furthermore, in the study conducted by (Yiannis, 2023) the utilization of the Socio Scientific Inquiry Based Learning (SCIBL) model was able to enhance students' literacy, supporting their understanding that humans are responsible for every development in science and technology. To achieve this, students start by deeply understanding the chemistry learning process to generate new ideas for conducting investigations that impact students' critical thinking abilities. This approach can assist students in finding the best alternatives in the problem-solving process (Priatna, Lorenzia, & Widodo, 2020).

By using such a learning model, it will aid teachers in observing students' activities by providing space for enhancing students' critical thinking and scientific literacy skills (Hafni, Herman, Nurlaelah, & Mustikasari, 2020). The study (Citra A. D., 2021) utilized collaborative learning to enhance students' literacy skills based on ethnosciences. Subsequently, (Ani, 2021) employed inquiry-based learning, and (Ananda, 2023) utilized STEAM-PJBIL. All types of learning models and approaches can be utilized to enhance students' critical thinking and literacy skills, but it all depends on how the implementation of these learning models can be applied appropriately and how the characteristics of the students who will undergo the learning process are determined. One way that can be used as an initial stage in implementing learning is by applying design thinking to students first. By applying it, educators will find it easier to determine the learning models that will be used, taking into account the aspects and components of students' critical thinking and literacy skills (Hamdu, Fuadi, Yulianto, & Akhirani, 2020). Although one of the challenges that students will face is the ability to think critically and make decisions in a short period of time, by encouraging scientific literacy and implementing various learning models with design thinking, it will facilitate the implementation of chemistry learning (Bağ, 2021).

The research trend of design thinking critical thinking ability and science literacy through an initial search there are 613 indexed articles in various fields of education. The literature was then filtered only in the form of reputable articles not from book chapters, proceedings and others, so that 348 articles were obtained. At the next stage, inclusion / exclusion selection was carried out which focused on chemical education, so that 48 articles were obtained to analyze this research trend (Dewi & Wardani, 2020; Suardana et al., 2018). Based on the results of the study, there is a tendency for research related to critical thinking skills and scientific literacy in 2021 and 2023. The highest number of publications was in 2021 and 2023. The following graph of the number of publications from 2017-2023 is shown in Figure 2.

The tendency of the material used in research on critical thinking skills and science literacy is chemical calculation material. Based on the 48 articles analyzed, there are several materials used in chemical education research, namely: salt hydrolysis, chemical equilibrium, reaction rate, colligative properties of solutions, acid base, redox reactions and electrochemistry. Based on the results of VOSviewer with 85 keywords from articles in 2017-2023 there is material that is often used in chemical education research, namely acid-base material. (Arisa et al., 2021; Badrun et al., 2021, 2021; Pertiwi et al., 2022) and chemical equilibrium (Irwanto, 2023; Rizki et al., 2021) that can be seen in Figure 3.

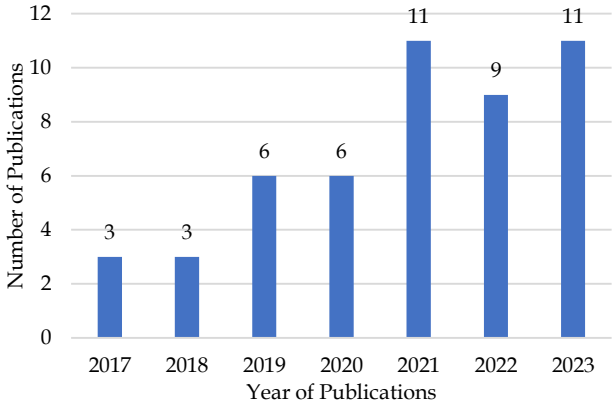

Figure 2. Number of critical thinking and science literacy publications

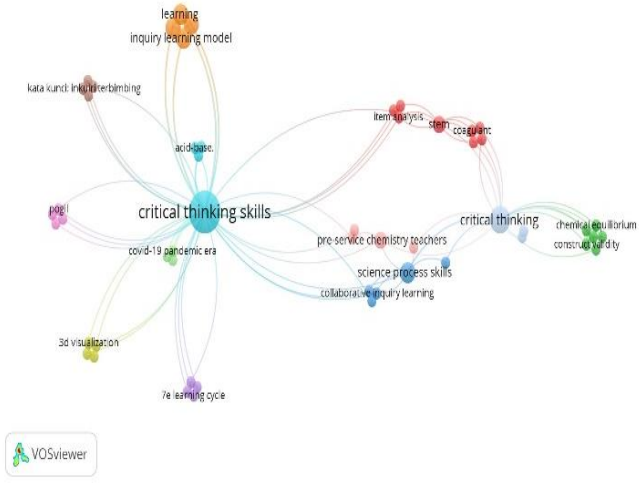

Figure 3. Results of VOSviewer Network Visualization

Based on Figure 1, it can also be seen that the relationship between critical thinking skills and science literacy is the main topic associated with various other keywords. The main topics in 2022 are acid-base,

collaborative inquiry learning, design thinking and the covid 19 pandemic. In 2021 regarding STEM and item analysis using Rasch analysis techniques. Detailed information regarding the main research topics can be seen in Figure .

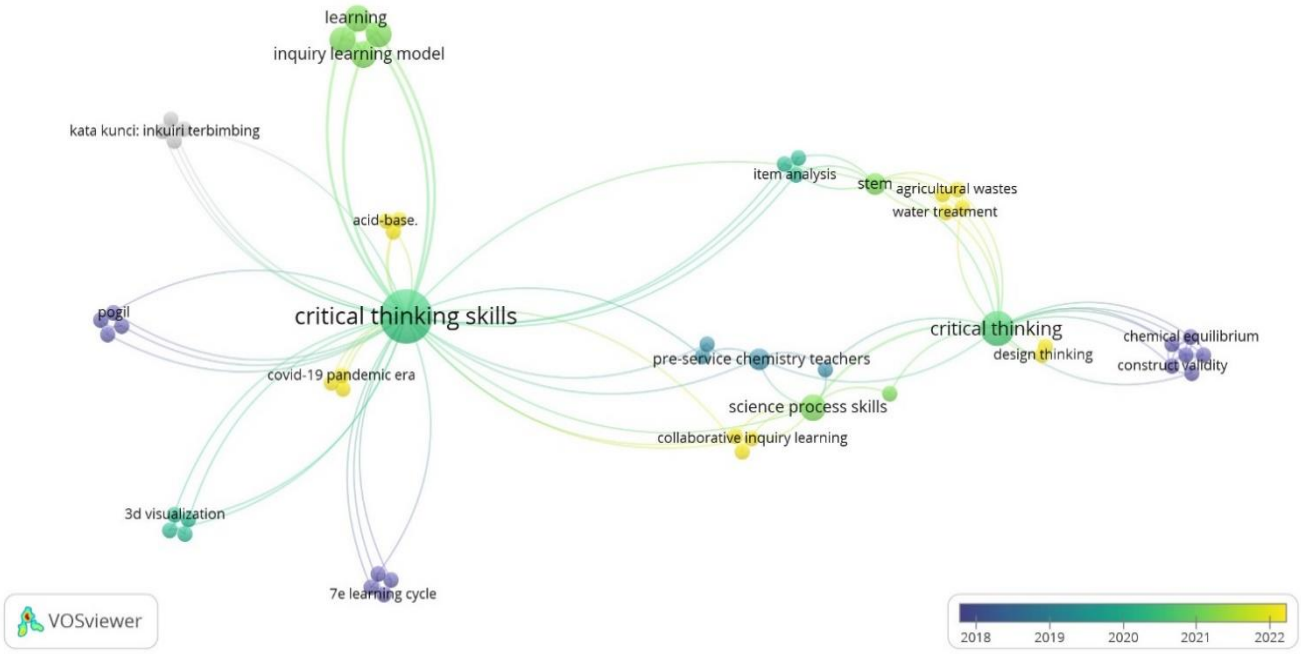

Figure 4. Results of Overlay Visualization

The design thinking on students' analytical thinking skills and science literacy has several samples used in several studies related to this research trend. Based on the results of the analysis, there are three samples used in the research, namely, students, students and teachers. However, the number of research samples used is still small for teachers, while 33 students and 13 students were studied. This is influenced by several factors such as time constraints, school policies, variable complexity and others. The following results of the analysis of the number of samples used in the study are in Figure 5.

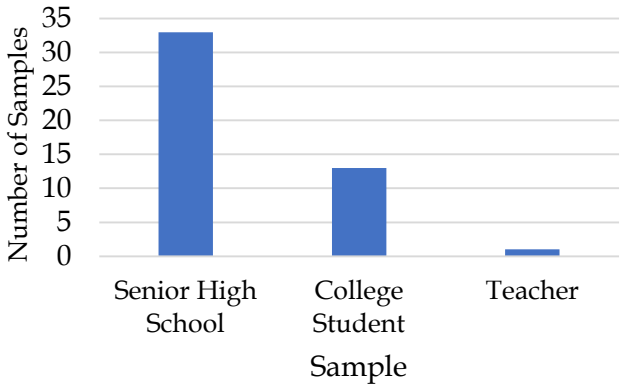

Figure 5. Results of Analysis of the Number of Samples in the Research

Different types of research were used in the various articles analyzed. There are 4 types of research used, namely, quantitative, qualitative, R&D, and mixed research (quantitative and qualitative). In this article analysis, the dominant type of research is quantitative research with various data collection and analysis techniques used. (Choo et al., 2022; E. Dewi et al., 2020; Priyambodo et al., 2022; Purba, 2022)(Dewi & Wardani, 2020; Khusna et al., 2023; Pratiwi et al., 2023). The use of this type of research is widely used as experimental research. While the research with the least type of research is qualitative research (Ananda et al., 2023; Asikin & Yulita, 2019; López-Fernández et al., 2022; Pertiwi et al., 2022; Purwanto et al., 2022; Tuysuz & Tuzun, 2020). To apply trends in research on analytical thinking skills and students' literacy skills, further research can be used mix methods which is a mixture of quantitative and qualitative research. In analyzing the trend of this research, using the same data collection techniques, namely the critical thinking skills test, questionnaire and observation sheet (Novitasari et al., 2022; Rahayu et al., 2022; Rahayu & Sari, 2023; Safitri et al., 2021). The following graph of the type of research used as a trend in this study is shown in Figure 6.

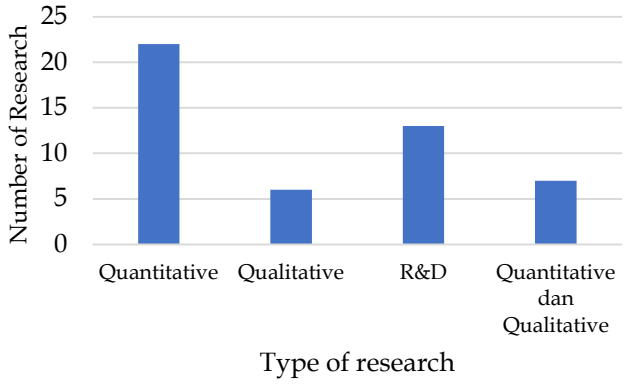

Figure 6. Results of Analysis of Research Type Used

Conclusion

Design thinking is an approach that encourages students to think critically, creatively, and collaborate in solving complex problems. In this context, the use of design thinking in teaching and learning can provide significant benefits to students in developing critical thinking skills and student literacy. By using design thinking, students are invited to identify problems, gather information, analyze data, and generate innovative solutions. This process involves critical thinking skills, namely problem-solving, decision-making, analyzing assumptions, evaluating, and conducting investigations. By integrating design thinking, students can develop critical thinking skills in contexts that are relevant to the real world. Students learn to see problems from various perspectives, think creatively in generating solutions, and use technology effectively to expand their understanding and communication. The use of design thinking also enhances students' literacy skills, making them more proficient in seeking, evaluating, and using information accurately. Therefore, the use of design thinking strategies will have an influence on students' critical thinking skills and literacy.This research trend analysis is based on the number of publications from the most critical thinking and science literacy thinking designs in 2023 and 2021, with the selection of materials in chemistry learning on acid-base materials and chemical equilibrium. Based on the VOSviewer results displayed, students' critical thinking and science literacy skills are the main focus of the research. Then the type of sample that is most widely used is high school students with quantitative research.

Authors Contribution

Conceptualization; S.S & S., methodology; S.S & L.A., analysis; S.S., S., D.R.S., writing original draft preparation; S.S., S & E.P. Revised; S.S., & S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interests

There are no conflicts or interests.

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