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Trend of Creative Thinking Researches in Chemistry Education from Research Design to Data Analysis: A Literature Review

Baiq Miftah Azumi [1*], Siti Aisyah[1], Eli Rohaeti[1]

[1] Department of Chemistry Education Program, Faculty of Science and Mathematics, Yogyakarta State University, Yogyakarta, Indonesia.

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Corresponding Author:
Baiq Miftah Azumi
baiqmiftaha@gmail.com

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Abstract: Creative thinking is a skill needed to meet the demands of the 21st century. The complexity of learning chemistry requires students to have creative thinking skills to solve the problems they will face. This research aims to gather information about various studies that discuss creative thinking skills. The research method employed in this study involves a literature review with content analysis of several articles, focusing on the entirety of articles published from 2015 to 2024, all of which are indexed by Scopus. A total of 15 articles were reviewed after a screening process according to the inclusion criteria. The results showed that among these publications, the predominant research design was quantitative. The majority of the research subjects were undergraduate students, with biochemistry being the most frequently observed topic. The problem-based learning (PBL) method was the most commonly used, with tests, observation sheets, and interview sheets as the most common data collection instruments, along with t-tests for data analysis.

Keywords: Creative thinking; Chemistry education; Creative thinking skills; Literature review

Introduction

The 21st century is known as the age of knowledge, marked by social and cultural changes due to globalization and information flows (Soh et al., 2010). The learning process must develop 21st-century skills, with flexible processes and dynamic learning resources. Therefore, education must be able to meet the skills and challenges of the 21st century (Rawung et al., 2021). The most important 21st-century skills that every individual must have to face these challenges are creative thinking, critical thinking, collaboration, and communication (Chusni *et al*. 2020). Creative thinking is one of the important educational outcomes in the 21st century because innovation drives economic growth today. Schools are expected to teach and familiarize students with creative thinking as a provision for their future (Robinson, 2012; Voogt & Roblin, 2012).

Students' creative thinking skills cannot develop optimally if learning only emphasizes convergent thinking training without providing challenges or problems that they need to solve (Dewi & Mashami, 2019). Studies in India report that creative thinking skills are still relatively low; this is due to their learning system that only focuses on competence in core subject areas (Acharya & Bhattacharya, 2024), Similarly, conditions in Indonesia report that students' creative thinking skills tend to be very low to moderate (Putri & Alberida, 2022; Sumarni *et al*. 2021; Herdiawan *et al*. 2019). Although creativity is considered an important and widely discussed skill in various fields of science and is recognized as essential in modern education, Polish teachers tend to ignore it and lack commitment to developing this skill among their students (Mróz & Ocetkiewicz, 2021). In fact, creative thinking skills are very important to develop because creativity is one of

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the key competencies for individuals in solving existing and unknown problems.

Creative thinking in chemistry learning is a skill that individuals must have because it is very useful for learning and understanding various aspects, including chemical representations in macroscopic, microscopic, symbolic, and mathematical forms (Wiyarsi et al., 2018). Student-centered and contextual learning can be a means to develop creative thinking skills (Sihaloho et al., 2022; Suradika et al., 2023). Therefore, the selection of learning models should encourage students to learn independently and actively discover their own knowledge (Dewi & Mashami, 2019; Sumarni & Kadarwati, 2020; Nuswowati et al., 2017). In addition to focusing on the applied treatments, the use of appropriate instruments is also very important in analyzing data in accordance with the proposed hypothesis. Therefore, there is a need for research that examines information about content, research design, and data analysis.

This research aims to gather information about various studies that address creative thinking skills. Some aspects of this research differ from previous studies related to creative thinking skills. This research focuses on all articles published from 2015 to 2024, all of which are accredited by Scopus. It specifically investigates a number of articles that focus on creative thinking skills and uses various parameters as the basis for content analysis. Specifically, this study is designed to answer the following questions: (a) What variations in research design are used to study creative thinking skills?; (b) How has the trend in the number of studies on creative thinking skills changed over the years?; (c) What research subjects are commonly used in studies on creative thinking skills?; (d) What topics are most frequently used to examine creative thinking skills?; (e) What treatments are applied by researchers to enhance creative thinking skills?; (f) What instruments are used by researchers to measure creative thinking skills?; (g) What data analysis techniques are employed by researchers to analyze creative thinking skills?

Method

This research type is a scoping literature review in information of creative thinking skills in chemistry. The steps for the literature review are as follows. creating research questions; determining where to search a database for research findings; selecting relevant research data; selecting relevant research findings; extracting information from primary research results; synthesizing research results; and presenting the research findings (Moher et al., 2009; Snyder, 2019). The review focuses on content analysis of articles published in journals related to creative thinking skills. The research method applied is followed the method used by Susetyarini & Fauzi, (2020).This selection is determined based inclusion criteria: (1) focusing on creative thinking skills in the context of chemistry education, (2) published in the last 10 years (2015-2024), (3) using quantitative, qualitative, or mixed research methods, and (4) published in Scopus-indexed journals (Q1-Q4).

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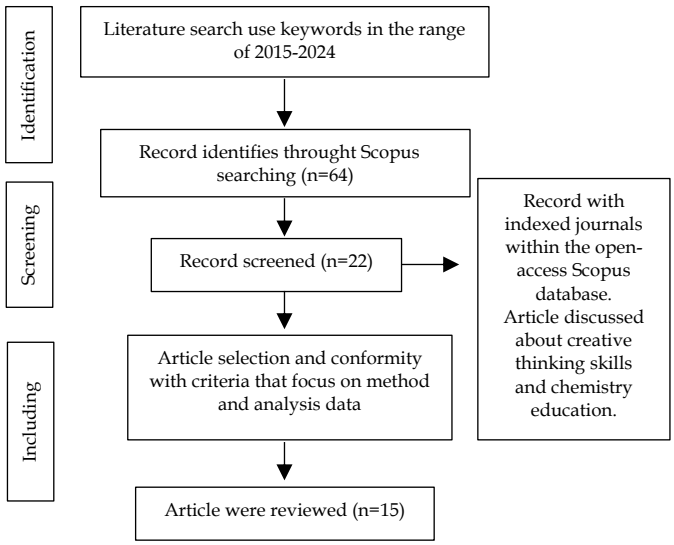

Figure 1. The literature flowchart adapted from (Moher et al., 2009)

Data were collected by identifying relevant articles through a search in the Scopus database using the keywords "creative thinking skills" and "chemistry education," resulting in the selection of 22 articles. Following data charting, qualitative data is synthesized and interpreted by materially sorting, organizing, and graphing it in accordance with major themes and topics. The Excel application was used to enter the data (Arksey & O'Malley, 2005). Data analysis was conducted using content analysis method to identify (a) the research design used; (b) the number of studies; (c) the research subjects; (d) frequently discussed topics; (e) applied treatments; (f) data collection methods; and (g) data analysis techniques used.

Result and Discussion

This study was conducted using the literature review method by selecting 15 articles that met the relevance and predetermined criteria. The screening of

journals from 2015-2024 was then adjusted to the predetermined inclusion criteria and categorized to assess the feasibility of the articles. The following is a list of selected articles presented in Table 1

Tabel 1. Results of article selection

Article	Index	IC1	IC2	IC3	IC4
Ryzal Perdana[1], Budiyono[2], Sajidan[2], Sukarmin[2] (2019). Analysis of Student Critical and Creative Thinking (CCT) Skills on Chemistry: A Study of Gender Differences	Q3	✓	✓	✓	✓
M. D. W. Ernawati*[1], S. Sudarmin[2], A. Asrial[3], D. Muhammad[4], H. Haryanto[5] (2022). Creative Thinking of Chemistry and Chemistry Education Students in Biochemistry Learning Through Problem Based Learning with Scaffolding Strategy	Q3	✓	✓	✓	✓
Nuswowati[1], M. Taufiq[2] (2015). Developing Creative Thinking Skills and Creative Attitude Through Problem Based Green Vision Chemistry Environment Learning	Q3	✓	✓	✓	✓
Dwi Wiwik Ernawati*, M. Damris M., Asrial, Muhaimin (2019). Development of Creative Thinking Skill Instruments for Chemistry Student Teachers in Indonesia	Q2	✓	✓	✓	✓
Dwi Wiwik Ernawati[1], M. Yusnidar[2], Haryanto[3], Endah Febri Setiya Rini[4], Febri Tia Aldila[5], Tri Haryati[6], Rahmat Perdana[7] (2023). Do creative thinking skills in problem-based learning benefit from scaffolding?	Q1	✓	✓	✓	✓
M. Nuswowati*[1], E. Susilaningsih[1], Ramlawati[2], S. Kadarwati[3] (2017). Implementation of Problem-Based Learning with Green Chemistry Vision to Improve Creative Thinking Skill and Students' Creative Actions	Q3	✓	✓	✓	✓
M. Dwi Wiwik Ernawati, Sudarmin, Asrial, Muhammad Damris, Haryanto, Eko Nevriansyah, Riska Fitriani dan Wita Ardina Putri (2022). How Scaffolding Integrated with Problem Based Learning Can Improve Creative Thinking in Chemistry?	Q3	✓	✓	✓	✓
T. Rahmawati*[1], T. Mulyaningsih[2], N. Nahadi[3], H. Suhanda[4], W. K. Lee[5], H. A. Aziz[6], S. Anwar[7] (2023). Electronic Portfolio Assessment Instruments in Improving Students' Creative Thinking Skills	Q3	✓	✓	✓	✓
M. Dwi Wiwik Ernawati[1], Damris Muhammad[2], Asrial Asrial[3], Muhaimin Muhaimin[4] (2019). Identifying creative thinking skills in subject matter bio-chemistry	Q3	✓	✓	✓	✓
D. K. Sari1 *, A. Permanasari2, F. M. T. Supriyanti2 (2017). Profile Of Students' Creative Thinking Skills on Quantitative Project-Based Protein Testing Using Local Materials	Q3	✓	✓	✓	✓
Arunrat Khamhaengpol*, Sunti Phewphong, and Porntip Chuamchaitrakool (2022). STEAM Activity on Biodiesel Production: Encouraging Creative Thinking and Basic Science Process Skills of High School Students	Q2	✓	✓	✓	✓
W. Apriwanda*[1] & C. Hanri[2] (2022). Level of Creative Thinking Among Prospective Chemistry Teachers	Q3	✓	✓	✓	✓
Citra Ayu Dewi[1], Ratna Azizah Mashami[2] (2019). The Effect of Chemo-Entrepreneurship Oriented Inquiry Module on Improving Students' Creative Thinking Ability	Q1	✓	✓	✓	✓
Ryzal Perdana, Ratu Betta Rudibyani, Budiyono, Sajidan. Sukarmin (2020). The Effectiveness of Inquiry Social Complexity to Improving Critical and Creative Thinking Skills of Senior High School Students	Q2	✓	✓	✓	✓
W. Sumarni*[1] and S. Kadarwati[2] (2020). Ethno-Stem Project-Based Learning: Its Impact to Critical and Creative Thinking Skills	Q3	✓	✓	✓	✓

Research on creative thinking in chemistry education has been widely conducted both domestically and internationally. A total of 64 articles were obtained using the keywords "creative thinking skills" and "chemistry education." From these, 22 articles were selected based on their publication in indexed journals within the open-access Scopus database. The subsequent selection of articles, based on predetermined criteria, resulted in 15 articles being chosen for analysis. According to Table 1, which outlines the results of research on creative thinking in chemistry education, of

the 15 articles studied, 2 are indexed in Q1, 3 are indexed in Q2, and 10 are indexed in Q3.

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Types of Research

The type of research reflects the purpose or main focus of a study. Based on the graph in Figure 2, articles with quantitative research are most often used by researchers in examining creative thinking skills, followed by quantitative-qualitative (mixed methods) research. This high number of quantitative studies aligns with research by Kocatepe (2017), which states that in the field of education, quantitative research designs are still predominantly used. However, other findings reveal a growing need for more qualitative and mixed-method studies.

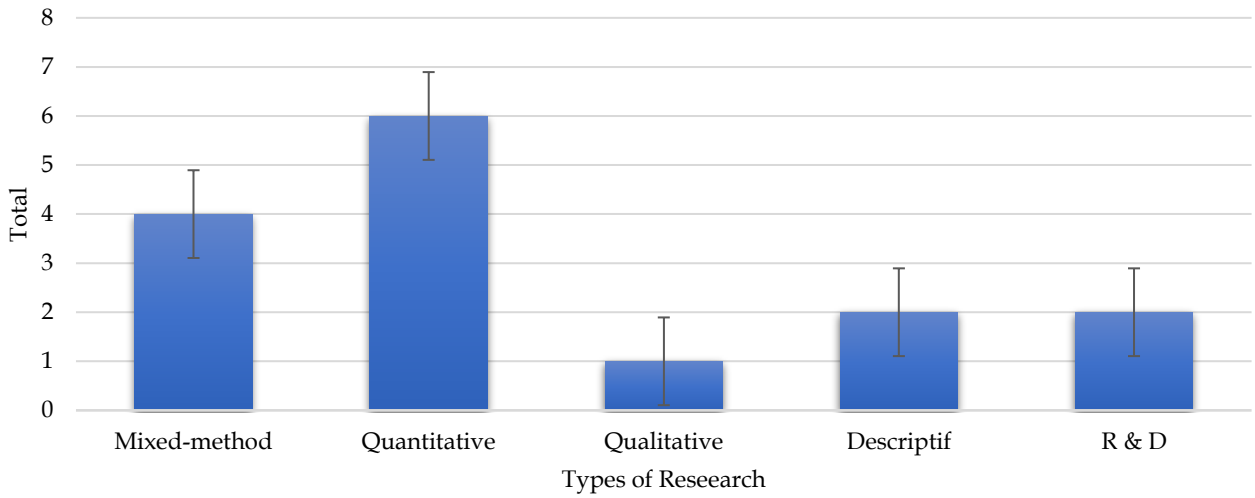

Figure 2. Distribution of Research Focusing on Creative Thinking in Chemistry Education by Research Type

Other information in this study includes the distribution of quantitative research used by researchers. Based on the analysis of 15 articles, the design most often used in quantitative research is the quasi-experimental design. The quasi-experimental design is the best alternative approach for exploring educational topics that do not allow for RCTs, as it mimics experimental conditions and applies statistical techniques to reduce bias from variables not included in the empirical model (Kim & Clasing-Manquian, 2023). In quasi-experimental research, researchers attempt to compare the effectiveness of various approaches in improving creative thinking skills. A salient point of this type of research is that researchers can involve an entire class of students as the control group while assigning another group in a different class (or more) as the experimental group. This distinguishes it from experimental research, which is difficult to implement. Meanwhile, pre-experimental designs, according to Knapp (2016), are rarely used compared to other experimental designs, and this result only appeared in one article.

Number of Publications

The number of article publications reflects the frequency of research conducted in a particular period. Based on the graph in Figure 3, articles published on Scopus discussing creative thinking skills in chemistry education can be found starting from 2015. The graph shows no specific pattern, as there are fluctuations in the number of publications each year. However, the highest number of publications occurred in 2019 and 2022, indicating a growing interest among researchers in studying creative thinking skills, which is likely to continue in the future.

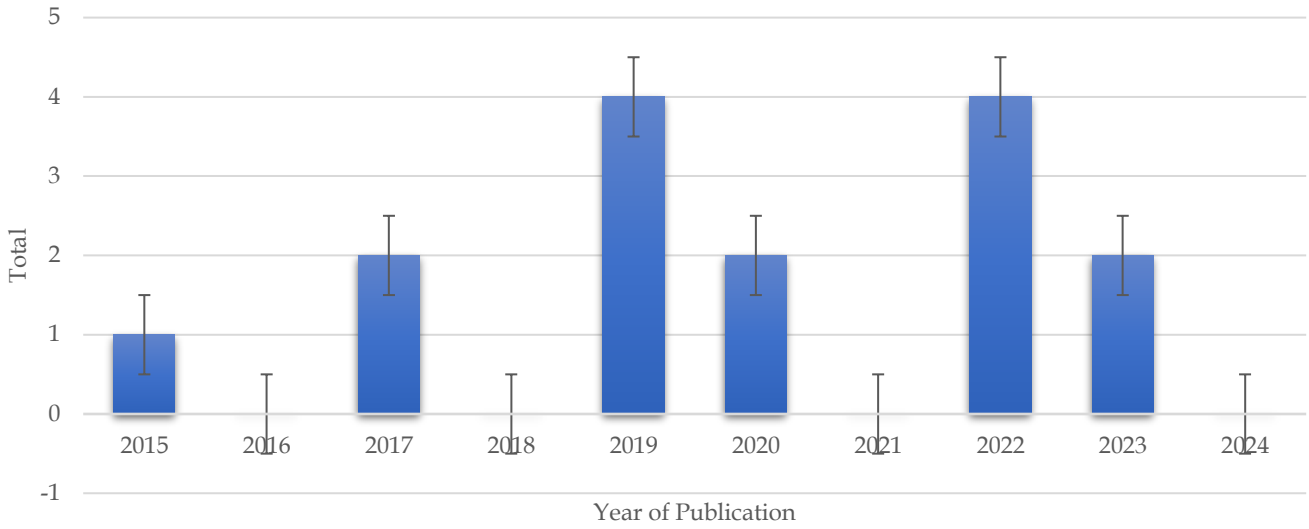

Figure 3. Number of Researches with Creative Thinking Focus in Chemistry Education in the Last 10 Years

Research arises from the sensitivity of researchers to issues that frequently occur in their environment. One of the prevalent problems today is the low level of creative thinking skills among students and college students. Research is the most effective method to address this problem, as it allows researchers to determine the appropriate and most effective learning media or designs to maximize creative thinking skills. According to Coburn & Penuel, (2016) the ultimate goal of research is to improve educational performance. The high level of research on creative thinking skills can have a significant positive influence on educational development. This research has implications for educational performance (practice) for several reasons: (1) the findings can be considered reliable information and applied by teachers; (2) the findings can change the mindset of teachers; and (3) the findings can serve as a basis for educational decision-making.

Research Subjects

The enhancement of creative thinking skills is aimed at students as a preparation for facing the challenges of the 21st century in their future lives. Based on information about the type of research, it shows that experimental design is commonly used, indicating that researchers need research subjects to test their hypotheses according to their objectives in a study. According to the graph in Figure 4, the research subjects often used are undergraduate students (prospective teachers), followed by 11th and 10th-grade students. This creative thinking research involves many undergraduate students as prospective teachers because prospective teachers must have creative thinking skills. This shows that the role of prospective teachers is very important in developing students' creative thinking skills (M. Ernawati et al., 2019; Mróz & Ocetkiewicz, 2021; Apriwanda & Hanri, 2022).

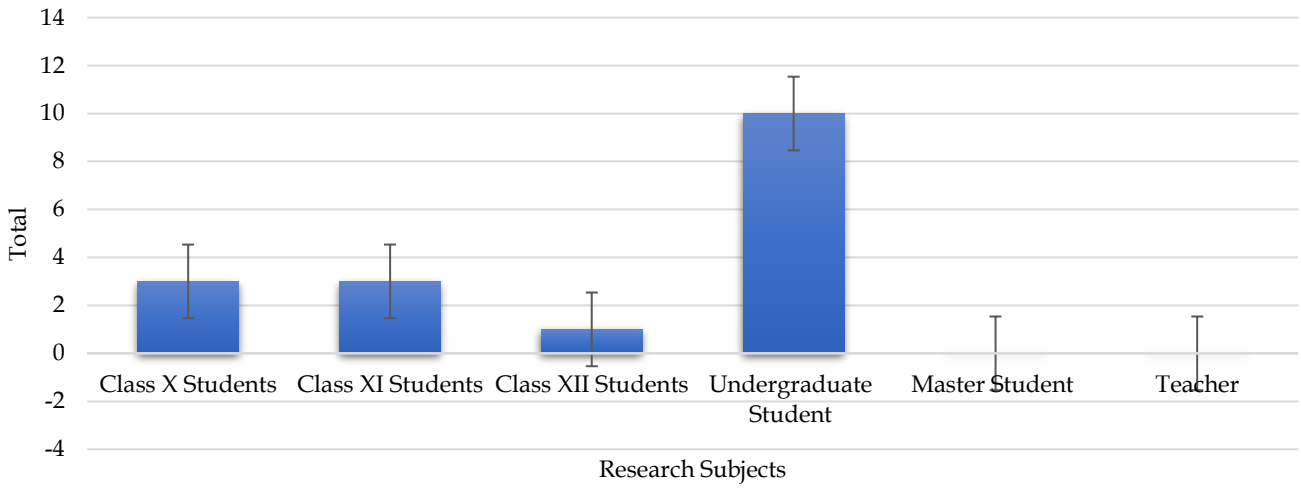

Figure 4. Distribution of Research Focusing on Creative Thinking in Chemistry Education Based on Research Subjects

The results show that, in addition to information about the comparison of junior high school and college levels, Figure 5 also indicates that the higher the educational level/class, the less frequently it is used. For instance, undergraduate students are more commonly used in research during their 4th semester, and similarly, in high school, 10th and 11th grades are used more frequently than 12th grade. This aligns with the tendency of universities and schools to be more selective in granting permission to researchers to conduct studies on final semester students who are focused on their final projects and 12th-grade students who are preparing for school and university exams. This is consistent with the findings of Susetyarini & Fauzi, (2020) that first-year students are more often chosen for research than third-year students.

Chemistry Topics Selected when Conducting Studies

Chemistry is one of the sciences that is often considered difficult for many people because it consists of abstract concepts and topics (Santos & Arroio, 2016). The abstraction of chemistry concepts can be understood through three levels: macroscopic, sub microscopic, and symbolic representations. Chemistry learning faces problems that emphasize students' difficulties in learning basic chemistry concepts, which are increasingly difficult and less meaningful (Dewi et al., 2021) and students must continue to develop their skills. From the analysis of the articles, some publications only support certain topics, while others underline several topics. The topic that many researchers choose when examining their research at the university level is biochemistry. Unfortunately, not all of the articles discuss the reasons for choosing biochemical materials in their research, except for the research by Ernawati et al., (2022) which reveals the reasons for using biochemical materials, especially amino acids and proteins, in their study. They highlight their relevance to everyday life, appropriate complexity to develop higher-order thinking skills, and potential to improve students' creative thinking skills. Biochemistry material can be related not only to one topic but to various other topics. Therefore, it is important to provide specific reasons for choosing a topic to test and develop creative thinking skills. In high school, the topics used are colloids, reaction rates, electrolyte and non-electrolyte solutions, redox reactions, and chemistry. Overall, in the following articles, there are also more that do not directly discuss the reasons for using the material. The selection of these topics, in addition to their relevance, is also because they have the potential to train creative thinking skills.

Treatment

The choice of treatment (method, approach, or model) in the learning process can affect students' creative thinking skills. Based on the analysis of these 15 articles, several treatments are used, including PBL (Problem-Based Learning), PBL with a scaffolding approach, green chemistry-based PBL, STEAM (Science, Technology, Engineering, Arts, and Mathematics), Cooperative STAD (Student Teams-Achievement Divisions), Social Complexity Inquiry (ISC), and Ethno-STEM PjBL (Project-Based Learning). The PBL model is most frequently used to enhance creative thinking skills because, during the learning process, activities are not centered on the teacher or lecturer but on students who use problems as their main focus. This aims to ensure that students can process information accurately, address and solve the given problems, and ultimately enhance their creative thinking skills. By facing problems, students are encouraged to share knowledge, associate alternative ideas, and build arguments to support the solutions they establish (Ernawati et al. 2022; Ernawati et al. 2023).

Data Collection Instruments

A research study requires an instrument for data collection. In gathering data on creative thinking skills, various instruments have been used and developed by previous researchers. The graph in Figure 4 shows that test questions are the most widely used instrument in data collection. Testing creative thinking skills objectively uses test instruments because these skills can be evaluated or measured based on students' responses to high-level questions. In measuring creative thinking skills, several indicators are used: fluency, flexibility, originality, and elaboration (Khoiri et al., 2017;M. D. W. Ernawati et al. 2023; Ariyatun, 2021). Based on the articles analyzed, the test is the main instrument in data collection. The test is developed based on creative thinking indicators and has undergone validity and reliability testing before use. This aligns with established guidelines and Bajpai & Bajpai, (2014) statement that the validity and reliability of an instrument are crucial before it is used for data collection. This emphasizes the importance of information about validity and reliability for readers.

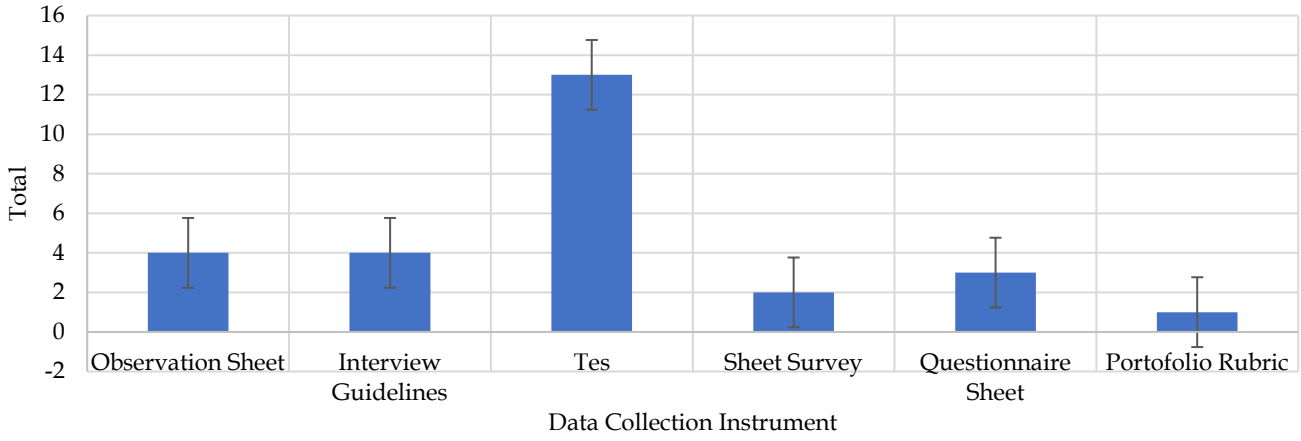

Figure 5. Distribution of Research Focusing on Creative Thinking in Chemistry Education Based on Research Instruments

Data Analysis Methods

The accuracy in choosing methods for data analysis will determine the level of validity of a study. The graph in Figure 5 shows that t-tests and ANOVA are the most widely used data analysis methods by researchers. The use of t-tests in educational research is less recommended due to several limitations. For instance, t-tests can only be used to compare the means of two groups, and assumptions such as normal distribution and equal variances are often not met in educational data, which is consistent with the findings of Grimaldi *et al*. (2019). Based on information about the type of research, many researchers use experimental designs that involve subjects to be assessed. However, there is still a tendency to overlook the use of ANCOVA in data analysis. In fact, the use of ANCOVA is recommended in such studies because it allows researchers to control for external variables that may affect the relationship between independent and dependent variables.

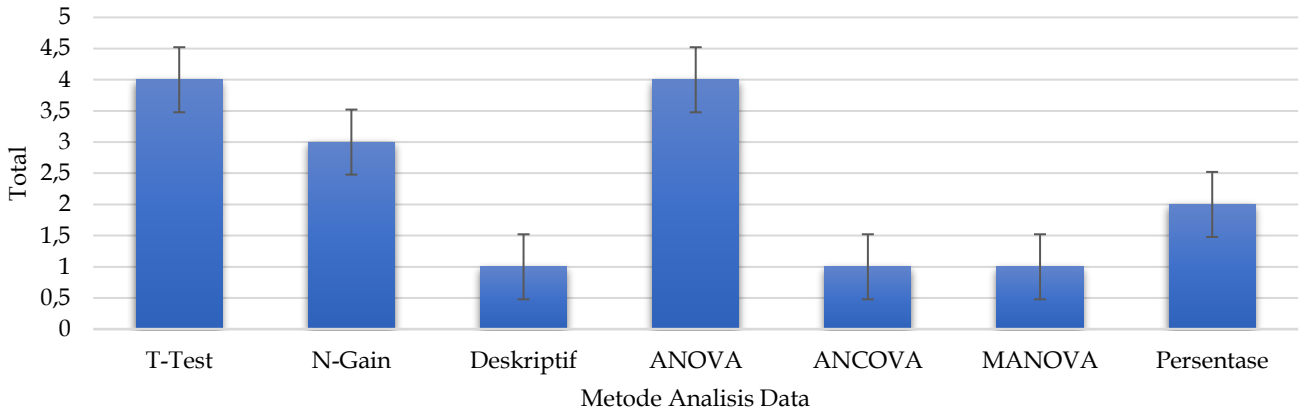

Figure 6. Distribution of Research Focusing on Creative Thinking in Chemistry Education Based on Research Data Analysis Methods

Conclusion

In this study, articles discussing creative thinking skills published in various journals on Scopus from 2015 to 2024 were reviewed. Trends indicate that over the last 10 years, there has been no consistent pattern in the number of publications focusing on creative thinking skills. Of the 15 articles analyzed, most were quantitative studies. The majority of the research subjects were undergraduate students, with the topic of biochemistry being the most frequently observed. The use of problem-based learning (PBL) methods was the most common, with tests, observation sheets, and interview sheets being the primary tools for data collection, and t-tests being the most common data analysis technique. Another significant finding of this study is the importance of developing creative and innovative learning methods to improve students' creative thinking skills in chemistry. The main focus should be on equipping prospective teachers as pioneers in transforming the educational landscape. Based on the

results of this study, several suggestions for future research are proposed: (1) Increasing the frequency of qualitative and mixed-method research to investigate the development of creative thinking skills; (2) Product development research aimed at improving students' low creative thinking skills should select the most appropriate tests and data analysis techniques in accordance with the hypothesis and research design.

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Conflicts of Interest
The authors declare no conflict of interest

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