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The Role of Technology in the Development of Critical Thinking: Systematic Literature Review

Rizka Fitriani[1*], AK Prodjosantoso[2]

[1] Chemistry Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.

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Corresponding Author:
Rizka Fitriani
rizkafitriani.2022@student.uny.ac.id

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Abstract: The role of technology in developing critical thinking skills in students. Technology helps create an interactive, collaborative learning environment and supports independent learning. This systematic study aims to investigate the influence of the use of technology, including mobile-based applications, educational games, and e-learning platforms, on the development of critical thinking skills in chemistry learning through the investigation process of articles published and indexed in Scopus. Systematic Review Method: (1) Formulate review questions, (2) Establish inclusion and exclusion criteria, (3) Develop search strategies for search strategies and find studies, (4) Select studies, (5) Extract data, (6) Assess the quality of studies, (7) Analyze and interpret the results. Articles found in the Google Scholar database, the Journal of Turkish Science Education and Scopus show that there are 15 articles that meet the inclusion criteria. The conclusion obtained is to affirm that the integration of technology in the educational process has great potential to develop critical thinking skills.

Keywords: Critical Thinking; Systematic Reviews; Technology.

Introduction

The development of critical thinking skills has become a pressing concern in chemistry education, as it enables students to analyze complex information, evaluate evidence, and make informed decisions. The integration of technology in chemistry education has been touted as a potential game-changer in fostering critical thinking skills. However, the current understanding of the role of technology in promoting critical thinking in chemistry education remains fragmented and unclear (Morales et al., 2018). In this study, we will conduct a systematic review to explore the role of technology in the development of critical thinking, focusing on the use of mobile-based applications, educational games, and e-learning platforms (Gupta et al., 2015)

The capacity to assess information critically, analytically, and thoughtfully in order to comprehend it better is known as critical thinking. (DeWaelsche, 2015). Critical thinking abilities are crucial in today's environment since it is becoming more complex and changing quickly (Changwong et al., 2018). Much research has been done to understand the factors that influence critical thinking skills, as well as how to train and improve them. In 1987, Ennis defined it as "reasoned, thoughtful thinking that focuses on deciding what to believe or what to do (Ennis, 1987). Critical thinking skills are essential in chemistry education. Critical thinking skills are essential for students to succeed in chemistry, as they need to analyze complex data, evaluate evidence, and make informed decisions. The development of these skills is crucial in preparing students for real-world challenges (Reichert & Mouza, 2018).

The use of technology can impove one's capacity for critical thought. Through the provision of interactive and immersive learning experiences, the facilitation of

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communication and cooperation, and the ability to analyze complicated data, technology has the potential to improve critical thinking abilities. Understanding how technology can be leveraged to promote critical thinking skills is essential in harnessing its full potential (Cui et al., 2019). Technology has changed the educational landscape in unprecedented ways. Mobile-based applications, educational games, and e-learning platforms have expanded accessibility, flexibility, and interactivity in learning (Sari et al., 2021). Several studies show that cognitive exercise and active and creative learning can improve a person's critical thinking skills. In addition, factors such as gender, educational background, and age also affect critical thinking skills (Drigas & Karyotaki, 2016).

The novelty of this study lies in its systematic and comprehensive approach to examining the relationship between technology and critical thinking in chemistry education. Previous reviews have focused on specific aspects of technology, such as simulations or online platforms, but this study takes a more holistic approach by examining the broader role of technology in promoting critical thinking.

Through this studies we seek to shed light on important issues and advance knowledge about how we well technology can support students growth as critical thinkers. The results of our research will make an important contribution to education practitioners, curriculum developers, and policy makers in designing learning strategies that utilize technology optimally to improve the quality of education and prepare students for future challenges. The overall focus of the study is formulated in terms of its content. Does the use of technology, such as mobile-based applications, educational games, and e-learning platforms, have a significant influence on the development of critical thinking skills in learners? How does the influence of technology compare to traditional learning methods in enhancing the critical thinking abilities of students?

Method

Research Method

This study was developed by the application of systematic review. An organized writing method that adheres to the several phases of systematic review was employed in the composition of this work. These stages or steps are described by (Zawacki-Richter et al., 2019) as follows formulate review questions, establish inclusion and exclusion criteria, develop a search strategy search strategy and find studies, choose studies, extract data, assess the quality of studies and analyze and interpret results. Which step of the research can be seen in Figure 1.

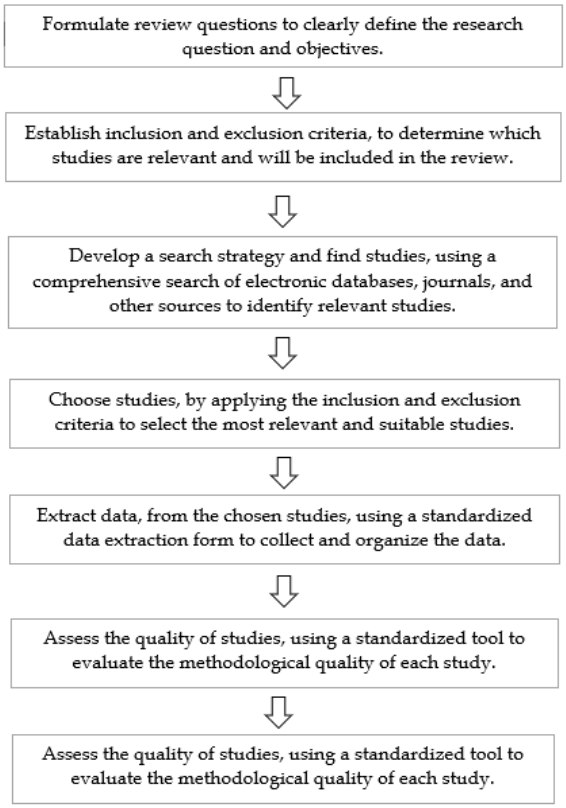

Figure 1. Systematic review research step

Establish Inclusion and Exclusion Criteria

The keywords used are "critical thinking", 'chemistry education', "critical mind", 'chemistry education', and 'critical thinking skills'. The source of data and the number of articles obtained by accessing Google Schoolar were obtained from 2012-2022 as many as 18,700 articles, while to access the Journal of Turkish Science Education 9 articles containing critical thinking chemistry education. The main inclusion criterion is that the target area of the study is not 'higher education'. After a detailed examination, 5 articles were taken out because they had nothing to do with chemistry education in schools.

Tabel 1. Article used in systematic literature review

File Codes	References	Indeks
1	(Danczak et al., 2020)	Q1
2	(Abdurrahman et al., n.d.)	Q2
3	(Kriswantoro et al., 2021)	Q3
4	(Van Brederode et al., 2020)	Q1
5	(Stephenson & Sadler-McKnight, 2016)	Q1
6	(López-Fernández et al., 2022)	Q2
7	(Lindawati, 2019)	Q2
8	(Sari et al., 2021)	Q1
9	(Schmidt-McCormack et al., 2019)	Q2
10	(Ikhsan et al., 2020)	Q3
11	(Gupta et al., 2015)	Q2
12	(Hakim et al., 2016)	Q3
13	(Gagnon & Komor, 2017)	Q2
14	(Pratiwi et al., 2016)	Q2
15	(Özgelen, 2012)	Q2

Tabel 2. Article inclusion criteria

Criteria	Description
Inclusion	• Focus on critical thinking skills
	• publicity within the last 10 years
	• In chemistry classes or science classes integrated in critical thinking topics
	• The results of empirical research contained in international journals indexed by Scopus Q1-Q3 and national journals indexed by Sinta 1-2
	• Language used is Indonesian / English

Develop a Search Strategy Search Strategy and Find Study

The search was conducted using the databases of the Journal of The Google Scholar, Scopus and Journal of Turkish Science Education. There are no limitations on the study's location.

Choosing a Study

Based on the criteria mentioned above, 18,700 articles were obtained. But only 20 articles were analyzed in detail from abstracts and 5 articles were excluded, this is due to the fact a number of studies refer to other subjects instead of chemistry subjects.

Extracting Data

If abtrack does not explicitly mention the required information (research methods, research variables, samples, chemistry topics and research objectives) in this step we read the full 20 articles to verify their relevance to the objectives, questions, and target groups of our review. A further four articles were deleted in this step lacking an explicit description of the research method and one article as having nothing to do with chemistry learning.

Assess The Quality of Studies

We compare the quality of the research that was included in our review to the following standars.

Clear research questions or hypotheses, clear description of methodology, detailed description of interventions, clear answers to research questions. The remaining 15 articles demonstrate a clear research focus, an analytic description of the research methodology, specific information about the intervention and its outcomes, as well as explanations, interpretations, and explanations, interpretations, and proposals that are research-based and accountable. All ensure the research quality of the other 15 articles analyzed in our review

Result and Discussion

The results of coding analysis from the objectives of international journal articles are found that the influence of learning models to improve critical thinking skills in chemistry learning is 6 international journal articles, while for research and development of media to measure critical thinking in chemistry learning there are 8 international journal articles, and for analytical studies of thinking skills Critical in chemistry learning is 1

international journal article. It can be concluded that the more dominant research objectives are found in the purpose of the journal article "Research and development of media" measure critical thinking in chemistry learning". However, there are several journals with the purpose of this research that are at the application stage or can be said not only limited to developing valid products (Retiyanto et al., 2023).

Various research and development have been carried out in the last decade to create learning media that are effective in measuring and facilitating the development of critical thinking in chemistry learning. Examples of media and teaching materials developed include interactive chemistry simulations, technology-based learning games, online learning platforms, and data analysis tools that can help students hone their critical thinking skills (Gürses et al., 2014). Critical thinking skills need to be developed optimally (Lazem, 2019; Lim et al., 2020). The problem during learning is that when determining what is known and asked in the problem, students do not write down the problems and questions given so that students cannot explain the results of the question analysis (Quattrucci, 2018). This is because during learning some students have a sense of insecurity and fear of being laughed at by other students when asking things that have not been understood so that when given questions students are not used to writing problems and explaining problems (Wijaya et al., 2018). The process by which critical-thinking individuals have the ability to ask questions correctly, reducing relevant information so as to formulate problems (Pursitasari et al., 2020). Students with high critical thinking skills tend to be able to review opinions given based on the knowledge they already have (Kriswantoro et al., 2021)

Tabel 3. Sample Coding Table

Sample		Paper Code	Frequency
Student	Junior High School	3.4.6	3
	Senior High School	2.7.8.10.15	5
	University	1.5.9.10.12.13.14	7
Total			15

In the sample coding table, it can be seen that there are 15 types of samples contained in 15 theme journals "Critical Thinking". Details of the samples used include: student (Junior High School, Senior High School and University). From international journal articles the most discussed samples are found in Student University A total of 7 samples and overall for samples student A total of 15 samples. Then the least sample is found in student Junior High School.

Article used in the systematic literature review came from (Changwong et al., 2018; Cui et al., 2019; Gagnon & Komor, 2017; Ikhsan et al., 2020; López-Fernández et al., 2022; Morales et al., 2018; Özgelen, 2012; Pratiwi et al., 2016; Pursitasari et al., 2020; Schmidt-McCormack et al., 2019; Stephenson & Sadler-McKnight, 2016; Susilawati et al., 2020; Van Brederode et al., 2020; Wulandari et al., 2017)

Tabel 4. Types of Research Coding Table

Paper Codes	Types of research	Frequency
2.8.12.15	Quasi experiment	4
4.5.11	Quantitative & qualitative	3
1.6.9	Qualitative	3
3.7.10	Research and development	3
13.14	Eksploratif	2
Total		15

Based on the table 4, related to the coding of the type of research from 20 international journal articles analyzed, it can be seen that the type of research that is required is contained in the "Quasi Experiment" research as many as 4 international journal articles. In quantitative and qualitative research there are as many as 3 international journal articles, for qualitative research there are as many as 3 international journal articles, for Research and Development A total of 3 international journal articles. As for exploratory research, there are only 2 international journal articles.

The quasi-experiment research in question is research related to the application of learning design to determine its impact on students' critical thinking skills. As for exploratory research to find out how students' critical thinking skills respond to a learning design.

Tabel 5. Chemistry Concepts Coding Table

Paper Code	Chemistry Concepts
1.14	Chemistry and Science
2	The Role of Energy In Life
3	Acid Bases
4	Chemical Reaction Mechanism
5.10.12	Chemistry Practicum
6	Environmental Issues
7	Chemical Equilibrium
8	Food Security & Industrial Potential and Renewable Energy
9	Analytical Chemistry

Paper Code	Chemistry Concepts
11	Stoichiometry
13	Chemical Kinetics
15	Reaction Rate

Tabel 6. Chemistry Concepts Coding Table

Paper Code	Chemistry Concept	Frequency
10.14	Chemistry and Science	2
5.1.12	Chemistry Practicum	3
3.4.7.11.13.15	Inorganic Chemistry	6
2.6.8	General Chemistry	3
9	Analytical Chemistry	1
		15

In the coding table of chemical concepts, it can be seen that there are 15 chemical concepts discussed from 15 international journal articles with the theme "Critical Thinking". The most discussed chemical concepts are found in the concept of inorganic chemistry with as many as 6 international journal articles and for analytical chemistry only 1 international journal article. Overall, there are some nonspecific chemical concepts. This is because there are several international journal articles that do not mention the concept of chemistry discussed, the research only mentions limited to learning what is done as in chemistry practicum research.

Conclusion

This systematic literature review provides a comprehensive understanding of the role of technology in promoting critical thinking skills in chemistry education. The integration of technology in the educational process has great potential to develop critical thinking skills in students. The findings suggest that technology has a positive impact on critical thinking skills, including analysis, evaluation, and problem-solving. The study highlights the importance of integrating technology in chemistry education to prepare students for real-world challenges.

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Author Contribution
Conceptualization, R.F.; methodology, R.F.; software, R.F.; validation, R.F and A.K.P.; formal analysis, R.F.; investigation, R.F and A.K.P.; resources, R.F.; data curation, R.F.; writing—original draft preparation, R.F.; writing—review and editing, R.F and A.K.P. Each author has reviewd the published version of the manuscript and given their approval."

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Conflicts of Interest
The authors declare no conflict of interest.

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