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Oriented Study of Virtual Simulation to Improve Critical Thinking Skill in Physics Learning with Inquiry Model: Bibliometric Analysis

Rahmatta Thoriq Lintangesukmanjaya[1*], Binar Kurnia Prahani[1], Dwikoranto[1], Lindsay N. Bergsma[2]
[1]State University of Surabaya, Surabaya, Indonesia
[2]Tilburg University, Tilburg, Netherland

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ABSTRACT

Objective: *To analyze the potential of virtual simulation in improving critical thinking skills in physics learning. Analysis of findings globally can be a new breakthrough in creating efforts to implement digital-based and competent learning media in the 21st century today and in the future.* ***Method:*** *This study was conducted using bibliometric analysis methods and systematic reviews using bibliometric analysis. The use of these two methods is carried out in order to obtain in-depth analysis through qualitative and quantitative data.* ***Results:*** *Based on the research that has been conducted, it is known that the trend of physics learning research with virtual simulations in educational articles over the past 10 years has continued to increase every year with a drastic increase occurring as a reminder that the use of digital technology is increasingly needed.* ***Novelty:*** *In accordance with the findings of the bibliometric analysis, it was obtained that one of the experience-based learning that can be integrated with virtual simulation is the inquiry learning model. It is recommended for future researchers to integrate inquiry learning in physics with virtual simulation media to improve critical thinking skills according to the global trend in adapting innovative learning through interactive media.*

INTRODUCTION

The era of technological development is a demand for improving 21st century skills. A person is required to have skills in 6C (Critical, Creative, Collaboration, Communication, Citizenship, and Character) (Kembara et al., 2022; Lintangesukmanjaya, Prahani, et al., 2024). By mastering these skills, a person can adapt to the era of developing technology adoption. One of the most important skills is critical thinking skills (Kennedy & Sundberg, 2020). Critical Thinking Skills are a person's skills in analyzing and finding logical opinions based on factual phenomena or realities (Neswary & Prahanı, 2022). Critical thinking is one of the high-level thinking skills that can guarantee a person in solving problems logically and analytically (Lintangesukmanjaya, et al., 2024). Indicators in critical thinking, especially in clarification, analysis, interpretation, evaluation and inference, are very important to support improving the quality of today's young generation (Black, 1988; Wahyuni et al., 2022).

Based on international research data, students' critical thinking skills are still relatively low (Indah et al., 2022). This also occurs in science learning, especially in physics learning. Many studies have found profiles of critical thinking skills that are still low by referring to general critical thinking indicators (Suhirman et al., 2021). Low critical thinking skills refer to the dynamics of learning that have not been conveyed optimally. There are several factors that are the reasons and causes for the low skills of students. The most basic reason found is the psychological understanding of students in considering physics material difficult. The difficulty of learning physics is certainly because physics is a group of sciences that prioritizes abstract concepts with complex

mathematical patterns. Physics which is associated with contextual phenomena also makes this learning require a high level of cognition. The learning that is developed should be able to minimize students' discomfort.

The problem is that the application of the learning methods used is still monotonous, especially in the era of technological development that demands the use of interesting learning media. So far, the use of learning media in several institutions has mostly used conventional media. The lack of interactive learning media also affects the comfort of learning in building students' thinking skills, one of which is students' critical thinking skills. Therefore, it is necessary to implement interesting learning media to improve students' critical thinking skills. The presence of digital media in the development of VR and AR in various fields is currently very phenomenal. One of them is virtual simulation which is the application of multimedia methods (audio, visual, video) in learning (Prahani et al., 2025; Saraswati et al., 2021). Virtual simulation also emphasizes aspects of critical thinking, especially in clarifying, analyzing and interpreting activities related to virtual simulations on learning (Darmaji et al., 2022). Therefore, the analysis of the potential of virtual simulations with critical thinking in physics learning globally is very important. This aims to evaluate the advantages and disadvantages to become findings in future research (Beisbart & Räz, 2022). Based on all of that, the purpose of this study is to analyze the potential of virtual simulation in improving critical thinking skills in physics learning. Analysis of findings globally can be a new breakthrough in creating efforts to implement digital-based and competent learning media in the 21st century today and in the future.

RESEARCH METHOD

This research was conducted using bibliometric analysis and systematic review methods. The use of these two methods is carried out in order to obtain in-depth analysis through qualitative and quantitative data (Hanif, 2020; Rossouw & Frick, 2023). The results of the bibliometric analysis can be obtained and evaluated in accordance with scientific and research developments. The Scopus database used for 10 years (2014-2024) was obtained online on May 9, 2024. Keywords 'Critical Thinking, Virtual Simulation, Education'. The stages of this research are depicted in Figure 1 (Amiruddin et al., 2023),

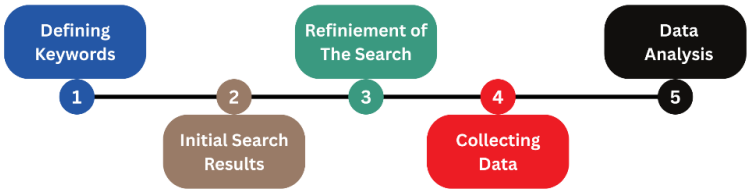

Figure 1. Bibliometric Analysis Process

Based on the results using the VOSViewer application to visualize the database that has been obtained. The keywords used in the Scopus database search are: "TITLE-ABS-KEY (Critical Thinking AND Virtual Simulation OR Education". The search resulted in 207 articles. Then, the articles were reduced to the publication years 2014-2024 (the last ten years) so that the number became 197. Furthermore, filtering was carried out using the abstract so that 159 articles were obtained. The 159 documents obtained were then

mapped using the VOSViewer application to observe the distribution map, visualization, and relationships between words. From the available data, the source of the document, the most dominant affiliation, the number of research citations, country of origin, field of study, the most prominent title source, authorship, and keywords used will be identified. Furthermore, an analysis was carried out on the ten articles with the highest number of citations based on the data that had been collected.

RESULTS AND DISCUSSION

Results

Based on the distribution of data obtained by VOSViewer analysis with a total of 159 articles. The results of data mapping obtained with the keywords "virtual simulation, critical thinking, education). The following is a picture of the research mapping found in 2014-2024.

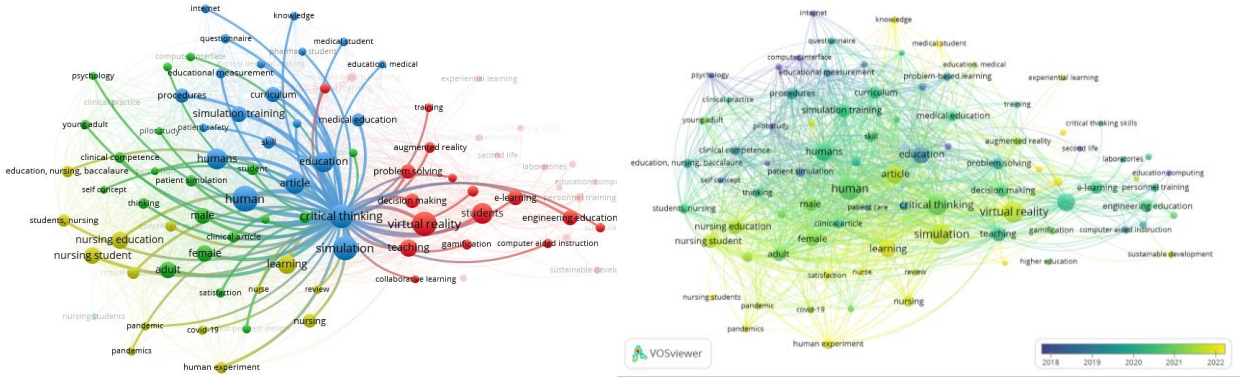

Figure 2. Result of bibliometric analysis

Based on the results of the analysis, it was found that there were differences in the sources obtained from a certain time period,

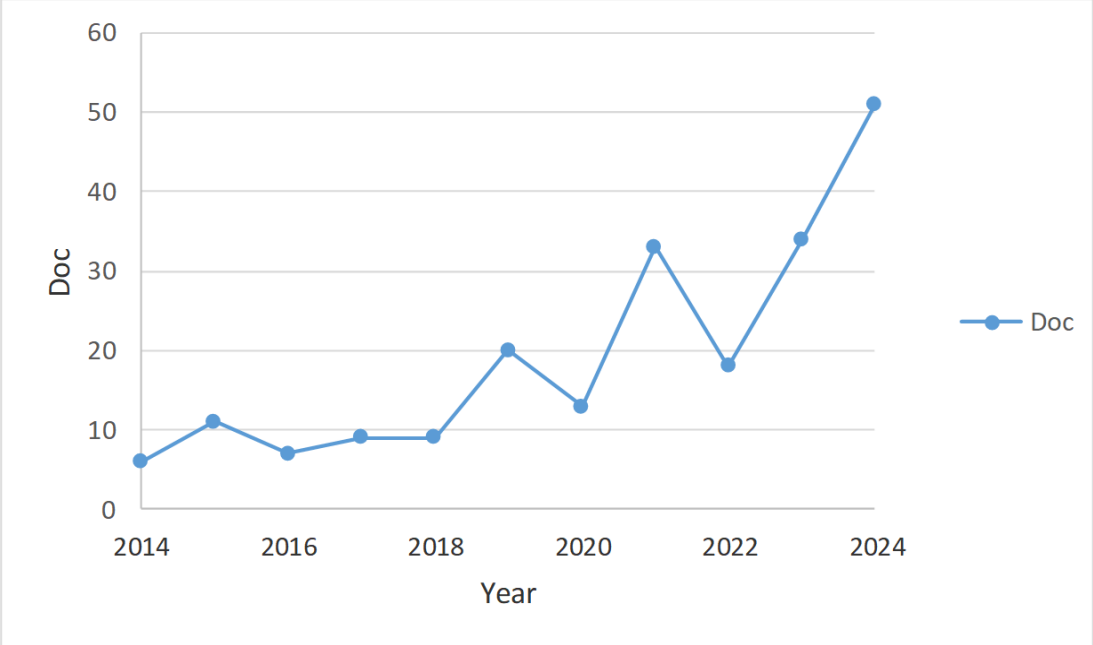

Figure 3. Difference in year of data acquisition

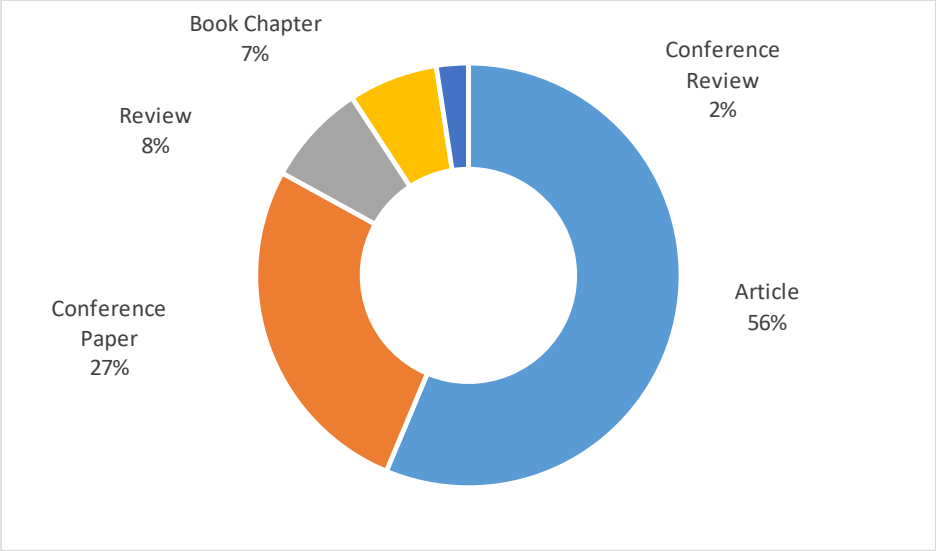

Figure 4. Comparison of source types

From the analysis results, differences were also found in each affiliation and region with their respective total documents. The top 5 affiliate sources were obtained from the results of the review analysis.

Table 1. Top 5 highest affiliate results

Affiliation	Region	Total Doc
University of Pittsburgh	United State	5
Texas A&M University	United State	4
Tecnologico de Monterrey	Mexico	3
Drexel University	United State	3
Zheijang Normal University	Tiongkok	2

The results of the data distribution and countries obtained from VOSViewer can be seen in Figure 4 below,

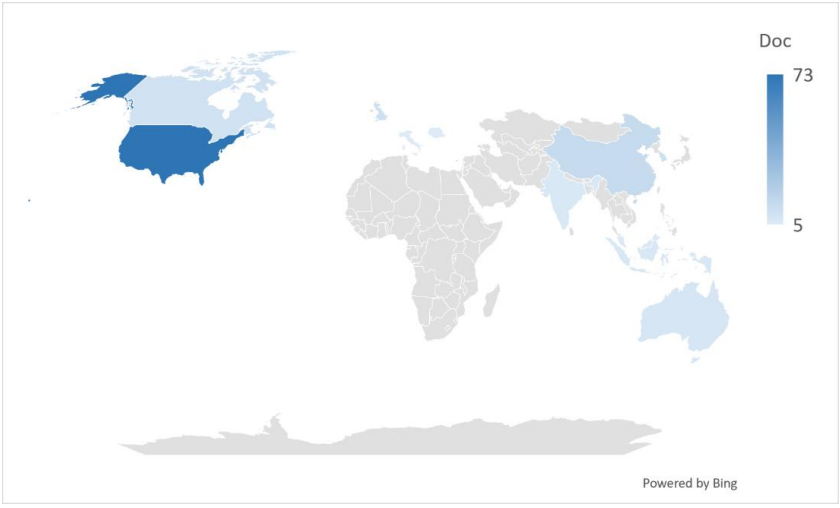

Figure 4. Distribution of data from each region

The distribution of the data obtained can be summarized in 5 top authors with a total of 418 citations. The following is the distribution data of the top citations for each author and their respective sources.

Table 2. Number of citations of top 5 authors

Author	Title	Source	Citation
Cobbett, s., & Snelgrove-clarke, e.	Virtual verses face-to-face clinical simulation in relation to student knowledge, anxiety, and self-confidence in maternal-newborn nursing: a randomized controlled trial	Nurse Education Today	138
Yang, y. t. c	Virtual ceos: a blended approach to digital gaming for enhancing higher order thinking and academic achievement among vocational high school students	Computers & Education	85
Pietroni, e., & ferdani, d.	virtual restoration and virtual reconstruction in cultural heritage: terminology, methodologies, visual representation techniques and cognitive models	Information (Switzeland)	82
Algerafi, m. a., zhou, y., oubibi, m., & wijaya, t. t.	unlocking the potential: a comprehensive evaluation of augmented reality and virtual reality in education	Electronics (Switzeland)	62
Liu, k., zhang, w., li, w., wang, t., & zheng, y.	effectiveness of virtual reality in nursing education: a systematic review and meta-analysis	Bmc Medical Education	51

Discussion

Based on the results of the bibliometric analysis with a systematic literature review, the opportunity for publication of critical thinking research through the use of virtual simulations was obtained. Many trends mention that the use of virtual simulations can be integrated into learning through a blended approach to digital gaming, cultural

heritage, augmented reality and virtual reality in education (Chircop et al., 2022; Kuo et al., 2022; Pietroni & Ferdani, 2021). The implementation of virtual simulations is not only found in educational research but also in several modern studies in the fields of technology, health, computers and information systems. In Figure 3, every year there is an up and down in publications on virtual simulations and critical thinking, but in 2022-2024 a drastic increase occurred as a reminder that the use of digital technology is increasingly needed.

Through the use of digital technology with virtual simulations becoming a very relevant tool in developing critical thinking skills because it allows users to explore complex situations in a safe and interactive environment (Darmaji et al., 2022). Through simulations, individuals are faced with realistic scenarios that require data analysis, decision making, and evaluation of the various possibilities and consequences of the actions taken. This process stimulates high-level thinking skills, such as identifying problems, formulating hypotheses, and testing solutions dynamically. Thus, virtual simulations are not only an interesting learning tool, but also an effective means of training participants in critical thinking contextually and in depth.

Several previous studies have been found in the integration of experiential learning to improve critical thinking skills (Lintangesukmanjaya, Prahani, et al., 2024; Mutohhari et al., 2021). This also has an impact on the integration of virtual simulations in experiential learning. Virtual simulations are very much in line with experiential learning models such as inquiry-based learning because both place students at the center of active and exploratory learning activities. In the inquiry approach, students are invited to ask questions, investigate, collect data, and draw their own conclusions from experiences they experience directly (Jamaludin et al., 2022; Ogegbo & Ramnarain, 2022). Virtual simulations enhance this process by providing a realistic and interactive digital environment, where students can test hypotheses, evaluate results, and reflect on their decisions without real risk. Thus, the integration of virtual simulations in inquiry-based learning not only increases student engagement but also deepens their conceptual understanding through continuous practice and reflection.

Therefore, seeing the shortcomings of previous research that have not linked simulations with inquiry learning models, further research recommends implementing inquiry with virtual simulations to improve critical thinking skills. This is in line with the development of research as an effort to improve digital technology-based learning.

CONCLUSION

Fundamental Finding: Based on the research that has been conducted, it is known that the trend of physics learning research with virtual simulations in educational articles over the past 10 years has continued to increase every year. Many studies can be studied from this topic as obtained from data mapping, including: blended approach to digital gaming, cultural heritage, augmented reality and virtual reality in education. The most types of documents in this study were articles with 56% of publications. Then, the country with the most publications was the United States. **Implication:** In accordance with the findings of the bibliometric analysis, it was obtained that one of the experiential learning that can be integrated with virtual simulation is the inquiry learning model. The inquiry learning model also has a relationship in improving critical thinking skills. This effort is in line with the use of meaningful learning models both nationally and internationally. **Limitation:** This research is limited by the findings and keywords used in analyzing bibliometrics. **Future Research:** Based on the research that

has been conducted, it is recommended for future researchers to integrate inquiry learning in physics with virtual simulation media to improve critical thinking skills according to the global trend in adapting innovative learning through interactive media.

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***Rahmatta Thoriq Lintangesukmanja (Corresponding Author)**
Afilliation: Universitas Negeri Surabaya
Address: Jl. Ketintang, Surabaya, Indonesia
Email: rahmattathoriq.20038@mhs.unesa.ac.id

Binar Kurnia Prahani
Afilliation: Universitas Negeri Surabaya
Address: Jl. Ketintang, Surabaya, Indonesia
Email: binarprahani@unesa.ac.id

Dwikoranto
Afilliation: Universitas Negeri Surabaya
Address: Jl. Ketintang, Surabaya, Indonesia
Email: dwikoranto@unesa.ac.id

Lindsay N. Bergsma
Afiliation: TSB, Tilburg University
Address: Warandelaan 2, 5037 AB, Tilburg, The Netherlands
Email: u187576@uvt.nl