ASEAN Journal of Science and Engineering

Journal homepage: http://ejournal.upi.edu/index.php/AJSE/

Artificial Intelligence (AI)-based Learning Media: Definition, Bibliometric, Classification, and Issues for Enhancing Creative Thinking in Education

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ABSTRACT

This research aims to identify effective ways of integrating Artificial Intelligence (AI) technology with innovative learning methods to improve students' creative thinking skills in various educational contexts. The bibliometric method, a quantitative and statistical approach to bibliographic data such as publications and citations, serves as the research method. Data were collected on July 2024, through the SCOPUS database using the keywords "creative thinking" OR "creative thinking skills" AND "creativity.". Data analysis was conducted in three stages: data collection, visualization, and analysis using software such as VosViewer. The results showed research trends, knowledge gaps, and potential new research areas relevant to technology integration in education. This research contributes to developing more effective and inclusive education policies and practices by ensuring all students have equal opportunities to develop essential skills in the digital age. Limitations of this study include limited access to technology in some areas and a need for teacher training in integrating AI into the learning process. Future research recommendations include focusing more on improving access to technology and teacher training to effectively use AI technology in education.

ARTICLE INFO

Article History:
Submitted/Received 21 Mar 2024
First Revised 20 Apr 2024
Accepted 19 Jul 2024
First Available online 20 Jul 2024
Publication Date 01 Dec 2024

Keyword:
Artificial intelligence (AI),
Bibliometrics,
Creative thinking,
Education,
Learning Media.

1. INTRODUCTION

Artificial intelligence (AI) technology has penetrated various aspects of life, including the education sector. In education, AI can create a more interactive and personalized learning environment (Alqahtani *et al.,* 2023). Many reports regarding AI have been well-documented (see **Table 1**). In general, AI can analyze students' learning patterns and adjust learning materials according to individual needs and abilities (Bhutoria, 2022). Each student can learn at their own pace and in the most effective way for them (Ifenthaler & Schumacher, 2023). In addition, AI can also be used to develop simulations and educational games that stimulate students' critical and creative thinking skills (Bunt & Gouws, 2020). Through this technology, students are encouraged to understand basic concepts and be trained to apply that knowledge in dynamic and challenging situations (Shieh *et al*., 2022).

Table 1. Previous studies relating to AI in education.

No	Title	Reference
1.	A review of artificial intelligence in security and privacy: Research advances, applications, opportunities, and challenges	Al-Khassawneh (2023)
2.	Chatbot artificial intelligence as educational tools in science and engineering education: A literature review and bibliometric mapping analysis with its advantages and disadvantages	Al Husaeni *et al.* (2024)
3.	How bibliometric analysis using VOSViewer based on artificial intelligence data (using ResearchRabbit Data): Explore research trends in hydrology content	Rochman *et al.* (2024)
4.	University students' awareness of, access to, and use of artificial intelligence for learning in Kwara State.	Alimi *et al.* (2021)
5.	Bibliometric analysis on artificial intelligence research in Indonesia vocational education	Rahmiyanti (2024)
6.	Primary education undergraduates' competency in the use of artificial intelligence for learning in Kwara State	Agarry *et al.* (2022)
7.	Bibliometric analysis of the legal issues relating to artificial intelligence technology in tourism	Roestamy *et al.* (2023)
8.	Artificial intelligence approach for automatic multiclass skin diseases identification	Andryani *et al.* (2023)
9.	Development of artificial intelligence techniques in Saudi Arabia: The impact on COVID-19 pandemic. Literature review	Al-Jehani *et al.* (2021)

Previous studies have shown that innovations in learning methods have significant potential to improve students' creative thinking skills. For example, digital technologies in the classroom, such as educational games and interactive simulations, can increase student engagement and facilitate creative learning (Hsu & Wu, 2023). However, while the benefits of these technologies and innovative learning methods are precise, unequal access to advanced technologies across countries and educational institutions still needs to be provided (Alam & Forhad, 2023). There is a significant digital divide, where schools in remote areas or with limited resources often need adequate access to educational technology (Yang & Hong, 2024). In addition to access issues, there are concerns regarding teachers' skills in integrating AI into the learning process (Davy *et al.*, 2023). Another study showed that many teachers feel underprepared and do not have sufficient training to effectively utilize AI technologies in the classroom (Galindo-Domínguez *et al*., 2024). Teachers often face challenges adapting traditional curriculum and teaching methods to these new technologies (Kaminskienė *et al*., 2022).

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2776-6098 e- ISSN 2776-5938

The novelty of this research lies in the holistic approach that combines technology access, teacher training, and AI-based learning media innovation to improve students' creative thinking skills. This research aims to identify effective ways of integrating AI technology with innovative learning methods. This can be used to improve students' creative thinking abilities equally across different educational contexts. Bibliometric methods were used to analyze the existing literature. Indeed, this study can identify research trends, knowledge gaps, and potential new research areas relevant to the topic of technology integration in education. Through this approach, this research can inspire the development of more effective and inclusive educational policies and practices, ensuring that all students have equal opportunities to develop essential skills in this digital age.

2. METHODS

Bibliometric research is a subset of systematic literature reviews that apply quantitative and statistical methods to bibliographic data, such as publications and citations. Detailed information on how to use bibliometric analysis is explained elsewhere (Rochman *et al.,* 2024; Al Husaeni & Nandiyanto, 2022). This research was essential to summarize the performance analysis results and science mapping generated by software and databases such as Scopus and Web of Science. Creative thinking is essential to meeting the demands of 21st-century competencies. Therefore, bibliometric research was conducted to highlight units of analysis such as authors and co-authorship, citation and co-citation, and co-occurrence related to creative thinking skills. This bibliometric analysis was conducted through three stages: data collection, visualization, and analysis (see **Figure 1**).

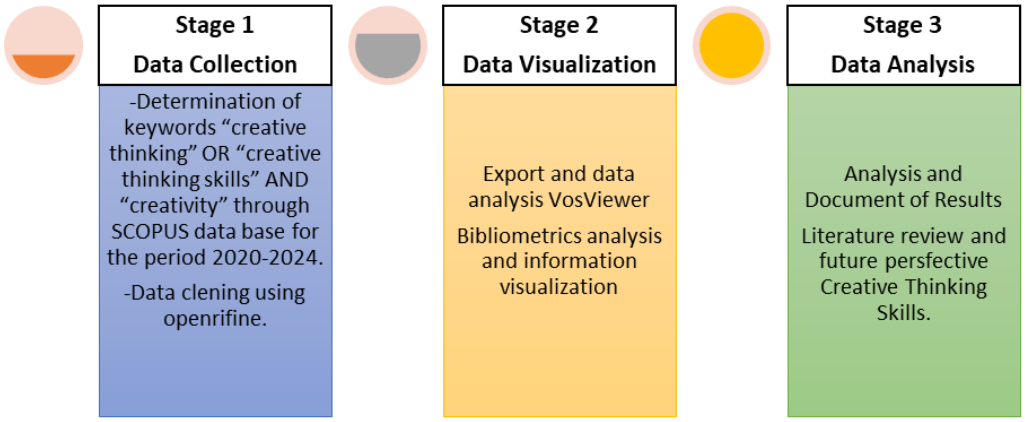

Figure 1. Stages in bibliometrics research of creative thinking study.

In general, several stages were done:

(i) Data Collection. Data was collected on July 16, 2024, at 17.00 WIB through the SCOPUS database. Access to SCOPUS is granted by the Ministry of Education, Culture, Research, and Technology (Kemdikbud Ristek) in Indonesia. SCOPUS is the most extensive database for peer-reviewed literature, such as scientific journals, books, and conference proceedings, and it provides an evaluation system to measure the impact of a scientific journal created by its authors. Documents that are indexed in SCOPUS have a high reputation. Searching documents using the keywords "creative thinking" OR "creative thinking skills" AND "creativity" resulted in a document database from 2020–2024 of 1269 documents. The data comprises 891 articles, 12 books, 91 book chapters, 207 conference papers, one letter, 12 notes, seven retracted reviews, 17 reviews, one short survey, and six unidentified documents. To overcome publication bias, before the data is

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2775-6793 e- ISSN 2775-6815

processed, a data cleaning process is carried out using the OpenRefine application in the author's keywords section by changing the separator from " (comma) to ";" (semicolon space) and combining terms or phrases that have the same meaning. The results of the data cleaning process were exported to the Excel application in *.csv format.

(ii) Data Visualization. In data visualization, *.csv data was exported to the VOSViewer application (Version 1.6.18, Universiteit Leiden, The Netherlands). Before further analysis, data cleaning is carried out through Thesaurus_term in the VOSViewer application to minimize the use of words or phrases that are still the same. Furthermore, bibliometric analysis was conducted with authors and co-authorship, citation and co-citation, and co-occurrence.

(iii) Data Analysis. The bibliometrics analysis output generated through VOSViewer is then analyzed and interpreted. At this stage, a literature review is conducted to obtain in-depth information related to the topic of creative thinking skills being researched.

3. RESULTS AND DISCUSSION

3.1. Creative Thinking

Creative thinking skills are essential for 21st-century education (Bakri *et al.*, 2023). This has attracted tremendous attention from researchers (Hafina & Fitri, 2022; Tiong & Bakar, 2022). They are interested in exploring how these technologies can improve learning effectiveness, address challenges in the current education system, and create more adaptive and personalized learning methods (Katiyar *et al.,* 2024). Researchers also see opportunities to expand their understanding of new ways of developing critical and creative skills, as well as strengthen the interaction between students and technology to achieve better educational outcomes (Valquaresma & Coimbra, 2021). Amid increasing global dynamics and complexity, individuals must be able to innovate, solve problems, and adapt quickly to change. However, developing creative thinking skills is still challenging for many educational institutions focusing on conventional learning approaches emphasizing memorization and procedural application (Duval *et al.,* 2023). Technological development, especially in artificial intelligence (AI), opens up new opportunities to overcome problems in education (Nykonenko, 2023). AI can process large amounts of data and provide real-time feedback, having enormous potential to revolutionize traditional learning methods (Fong *et al.,* 2024).

3.1.1. Productivity of creative thinking study publications

The SCOPUS database document search results provide information about the productivity of creative thinking publications. From 2020 to 2023, the productivity of creative thinking publications increased significantly. The most striking increase occurred in 2022–2023 when the number of publications increased by 294. Meanwhile, from 2023 to 2024, the increase in the number of publications was relatively lower, at 165, but is predicted to continue to increase. This increase in publications reflects the Industrial Revolution 4.0 and Society 5.0 eras, where digital transformation uses creativity to measure success (Mourtzis *et al.,* 2022). Many graduates, especially those engaged in future learning innovation, believe creativity is key to the digital revolution (Qian *et al.,* 2019). To face complex and uncertain daily life challenges, students need creativity (Beghetto and Madison, 2022). Encouraging students' creativity should be the main focus of schools in preparing them for the future (Zulkarnaen & Jatmiko, 2022). Visually, the productivity of creative thinking study publications from 2020–2024 is presented in **Figure 2**.

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2776-6098 e- ISSN 2776-5938

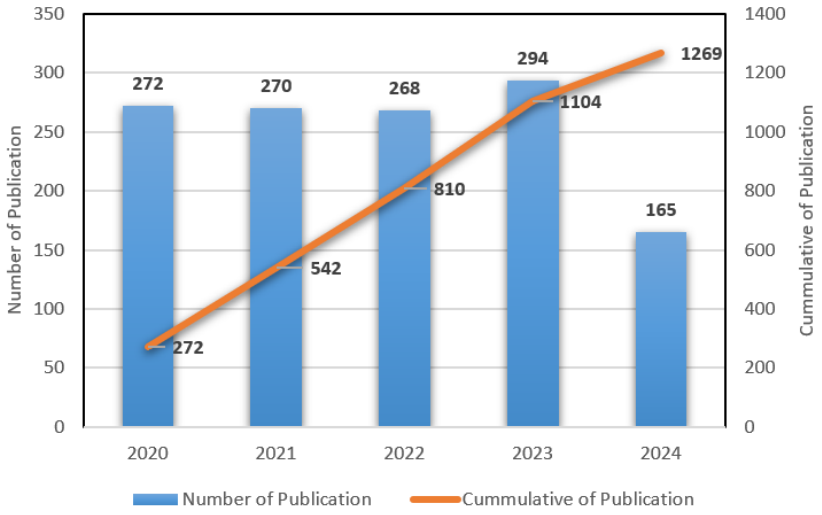

Figure 2. Productivity of creative thinking study publications, 2020-2024.

3.1.2. Co-authorship analysis by author and country

Co-authorship is the dominant author collaboration in writing articles in the SCOPUS database for studies on creative thinking. From the results of the data search, 1296 publications were found, and a co-authorship network visualization map was created based on the author unit of analysis with the minimum requirement of the number of documents equal to 5 and the minimum number of citations of an author equal to zero. From this analysis, seven authors were identified. The visualization of this result is presented in **Figure 3**.

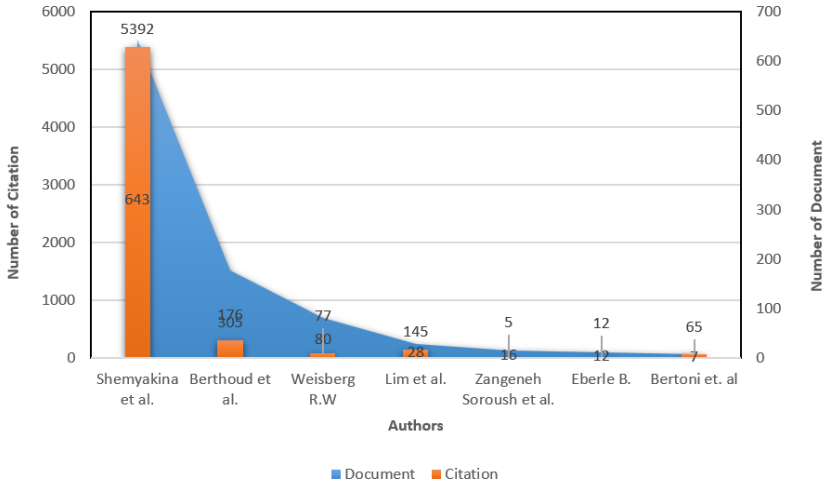

Figure 3. Visualization of co-authorship analysis with units of analysis author and number of citations.

The co-authorship network visualization map based on the country unit of analysis is shown in **Figure 4**. A co-authorship network visualization map was created from the search results of 1,296 documents. This process involved identifying countries that had a minimum of five documents and zero citations, as these were considered to have a significant research presence. This resulted in 46 documents that were suitable for analysis. **Figure 4** provides information that 10 clusters of countries have networks with other countries, indicated by circles with different colors for each cluster. There are five countries with the largest co-authorship networks, indicated by different colors and sizes of circles, namely the United

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2775-6793 e- ISSN 2775-6815

States, China, Indonesia, and the United Kingdom. The linkages between the colored clusters indicate that authors from different countries collaborate to produce articles. For example, within the same cluster, Indonesia collaborated with the Philippines, North Korea, Australia, and India. Some authors collaborate from different country clusters, such as Indonesia with Iran, the United States with Taiwan, China with South Korea, and the United Kingdom with Turkey, to produce articles collectively.

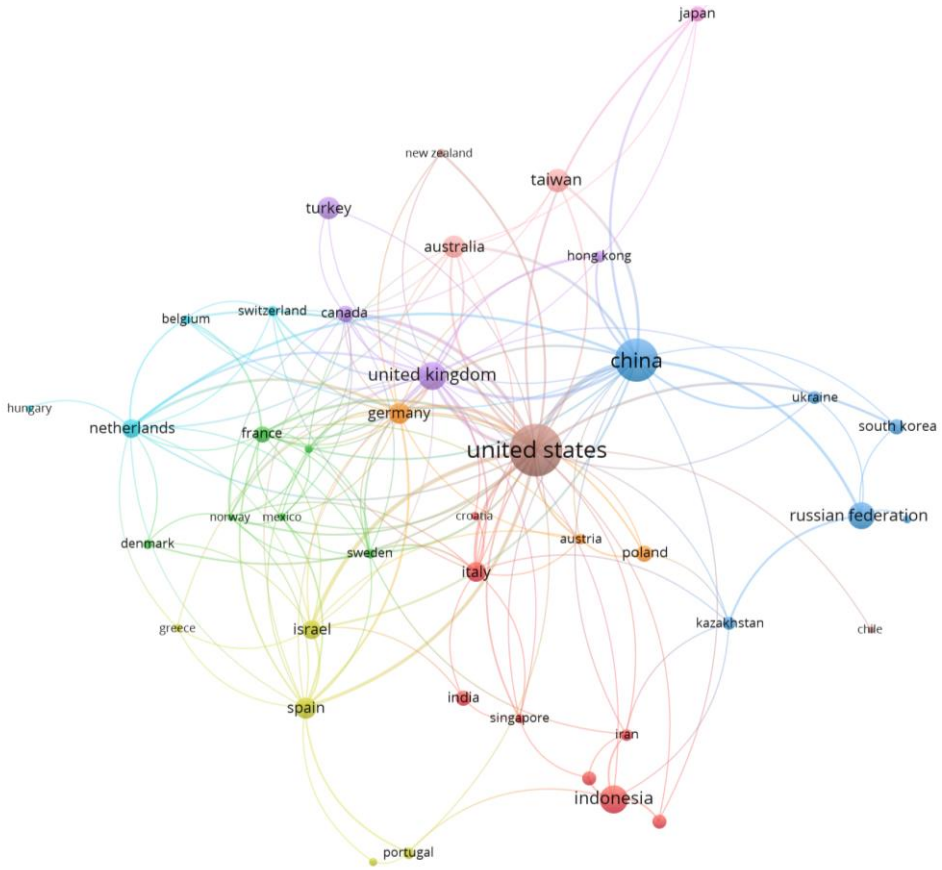

Figure 4. Visualization of co-authorship analysis with country and network units of analysis.

Indonesia, the country with the fourth-largest co-authorship network, has 78 documents. This shows that Indonesian researchers are in demand for creative thinking, which is an exciting topic. The development of higher-order thinking Skills (HOTS)-oriented learning developed by the government aims to produce learning outcomes with competencies expected in the 21st century, namely critical thinking, creativity and innovation, communication skills, collaboration, and confidence (Thornhill-Miller *et al.,* 2023). Creative thinking is one of the competencies that must be possessed in the 21st century, which is why Indonesian researchers are interested in researching the topic.

The United States, with 259 documents on creative thinking, has been a significant contributor to the field. The United States has become a reference point for global researchers in the field of creative thinking.

Unlike Indonesia and the United States, countries such as China, Taiwan, Hong Kong, and Singapore have historically had a tradition of somewhat devaluing creativity. This historical context has influenced the trajectory of creative thinking in these countries. In China, for instance, the study of creativity emerged as a by-product of research on intelligence and aptitude. Various methodologies are currently used to study creativity in these countries, reflecting the evolving nature of the field (Wong, 2022).

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2776-6098 e- ISSN 2776-5938

3.1.3. Citation analysis based on sources analysis units

Figure 5 visualizes citation analysis by source analysis unit, providing a detailed overview of the interrelationships and influence between scientific journals on the topic of creative thinking and thinking skills. Each node or point on this map represents a journal, with the node's size indicating the frequency of citations received by that journal. The lines connecting the nodes, or edges, show the citation relationships between the journals, with thicker lines indicating stronger citation relationships. **Figure 5** showcases some key journals at the center of the citation network, with the 'Thinking Skills and Creativity' journal playing a pivotal role. It is the largest node, indicating its central position and influence in the scientific literature on creative thinking and thinking skills. The journal is linked to other influential journals such as 'Frontiers in Psychology,' 'Journal of Creative Behaviour,' and 'Creativity Research Journal,' suggesting that research published in 'Thinking Skills and Creativity' is frequently cited by these journals, further reinforcing its central position in the citation network.

The color clusters in this visualization serve as a visual cue, indicating groups of journals that share close citation relationships. For instance, the blue cluster brings together journals such as 'The International Journal of Evaluation,' 'The International Journal of Technology,' and 'EDP Sciences,' suggesting that these journals frequently cite each other in the context of educational technology and evaluation research. Similarly, the red cluster, which includes 'Frontiers in Psychology' and 'Education and Information Technologies,' highlights the research focus on psychology and information technology in education. The visualization also reveals cross-disciplinary citation relationships, such as 'Thinking Skills and Creativity,' linked to journals focusing on education and psychology, as well as specialized journals like 'Journal of Intelligence' and 'Psychology of Aesthetics, Creativity, and the Arts.' This underscores the broad impact and relevance of research on the topic of creative thinking and thinking skills, demonstrating its interdisciplinary nature and its relevance across multiple disciplines. Even journals on the periphery of the map, such as 'Sustainability' and 'Nurse Education Today,' despite having weaker citation relationships, indicate that the topic of creative thinking and thinking skills is beginning to attract attention in more specialized and focused areas such as sustainability and nursing education.

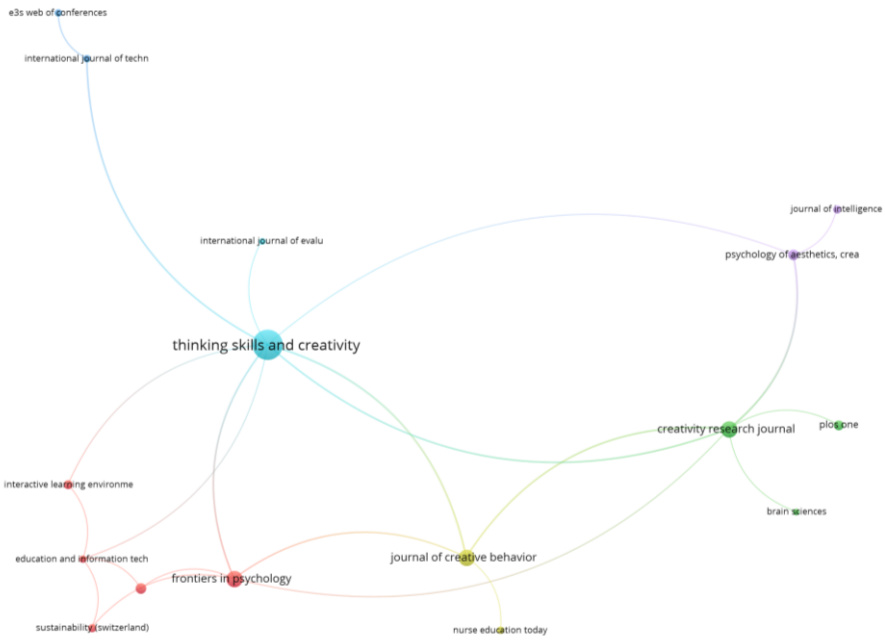

Figure 5. Visualization of citation analysis by source analysis unit.

DOI: https://doi.org/10.17509/ajse.v4i3.72611
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3.1.4. Co-occurrence analysis with keyword analysis units author

The author's keyword-based co-occurrence map visualization created using VosViewer provides a comprehensive overview of the interconnectedness of various concepts and topics in the scientific literature related to creative thinking. Each node or point in this map represents one author keyword, with the node's size reflecting its frequency of occurrence in the literature. The larger the node, the more frequently the keyword appears. The keyword' creative thinking' has the most significant node, indicating it is the most frequently discussed topic. The lines connecting the nodes, or edges, show the co-occurrence relationship between the two keywords. The thicker the line, the more often the two keywords co-occur in a single article. Nodes with the same color are grouped into clusters, indicating groups of keywords that co-occur frequently and related research themes.

There are several main clusters in this visualization. The orange cluster, for example, consists of keywords such as 'creative thinking,' 'problem-solving,' and 'innovation,' indicating a research focus on creative thinking and innovation in problem-solving. The green cluster contains keywords such as 'divergent thinking' and 'convergent thinking,' indicating a research theme on types of thinking in creativity. The red clusters, consisting of keywords such as 'education' and 'learning,' indicate a focus on educational and learning aspects of creative thinking. This visualization allows researchers to identify key themes in the literature on creative thinking, such as divergent and convergent thinking, education, and the relationship between creativity, innovation, and problem-solving. The co-occurrence map provides deep insights into how various topics in creative thinking research are interconnected, helping researchers understand the research landscape, identify under-explored gaps, and steer future research in a more interdisciplinary and comprehensive direction. The co-occurrence visualization based on the author's keywords unit of analysis is presented in **Figure 6**.

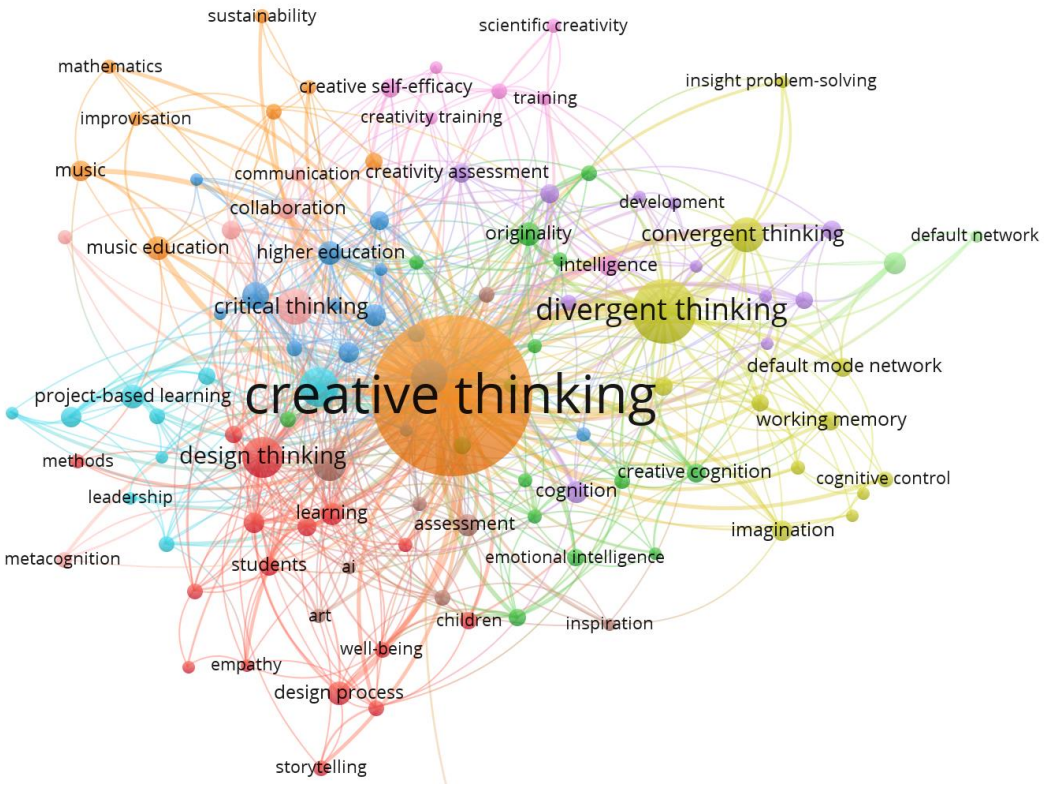

Figure 6. Co-occurrence visualization based on unit of analysis author keywords.

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2776-6098 e- ISSN 2776-5938

The visualization of co-occurrence overlays based on author keywords generated using VOSViewer provides insight into research dynamics in recent years. **Figure 7** shows the changes in the frequency and relevance of keywords used by authors in the scientific literature, spanning 2021 to 2023. In this visualization, each node or point represents one keyword, with the node's size indicating its occurrence frequency. The colors of the nodes and edges represent the period in which they appear, with blue indicating an earlier period and yellow indicating a more recent period.

The keyword' creative thinking' has the largest node and is at the center of the visualization, indicating that this topic remained a major focus in the research over the period. It is also connected to many other keywords, suggesting that creative thinking is a central theme that relates to a wide range of other research topics. The strong relationship between 'creative thinking' and keywords such as 'divergent thinking' (a thought process used to generate creative ideas by exploring many possible solutions) and 'convergent thinking' (a thought process used to evaluate and select the best solution from a range of options) suggests that research on the types of thinking in creativity continues to grow and be relevant. Some critical clusters in this visualization reflect essential themes in research, such as the green cluster covering 'critical thinking,' 'design thinking,' and 'learning,' and the yellow cluster covering 'digital technologies.'

The presence of 'digital technologies' on the periphery of the map indicates that this research area is not yet fully integrated with other major themes such as 'creative thinking', 'divergent thinking', and 'convergent thinking'. This suggests that research linking creative thinking with digital technologies is still very limited and has not been explored in much depth. However, the potential for research in this area is vast. The integration of digital technologies can provide new perspectives for developing methods and tools to enhance creative thinking. For example, the use of creative software, digital learning platforms, and interactive technologies can open up new avenues in education and learning, which in turn can encourage creative thinking among learners. In addition, further research can explore how digital technologies can be used to support divergent and convergent processes in creative problem-solving. This potential for further research is a key finding of the visualization co-occurrence overlay based on the author's keywords unit of analysis, as shown in **Figure 7**.

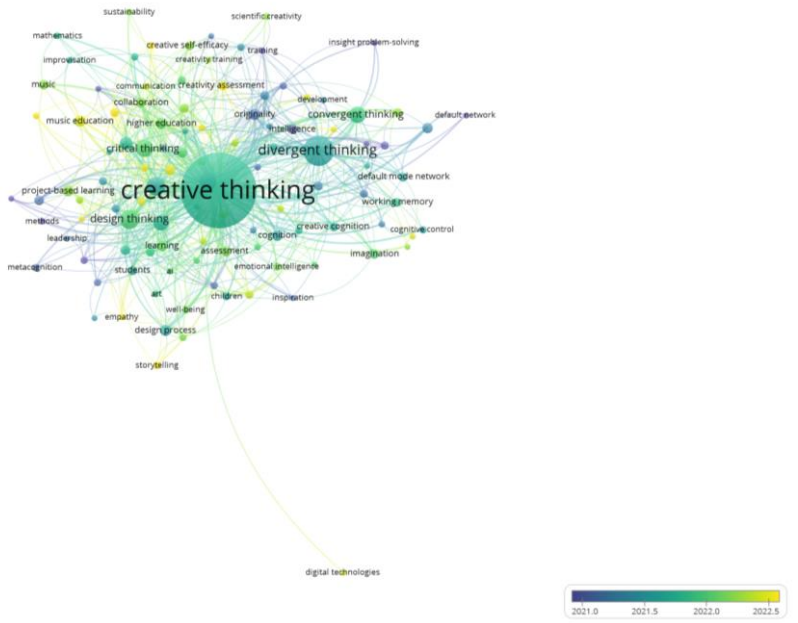

Figure 7. Co-occurrence visualization overlay based on keyword analysis unit author.

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2775-6793 e- ISSN 2775-6815

3.2. Integration of Media Technology in Education

Innovation in education is crucial to facing the challenges of ever-evolving times (Aguaded *et al.,* 2022). Through innovation, learning methods and approaches can be adapted to the needs and characteristics of the current generation, creating a more dynamic, interactive, and engaging learning environment for students (Madgafurova *et al.,* 2023). Innovation allows learning to be more effective and efficient and can answer various educational problems, such as low interest in learning and inequality in access to education (Magen-Nagar & Steinberger, 2017). Innovation improves the quality of learning and contributes to achieving more inclusive and equitable education goals (Asad & Malik, 2024).

Technological developments in recent decades have brought significant educational changes (Nicolini, 2023). Information and communication technologies enrich learning resources and change how students learn and teachers teach (Toma *et al.,* 2023). Technology's positive impact on learning includes increased education accessibility, flexibility in the teaching and learning process, and a more interactive and enjoyable learning experience (Timotheou *et al.,* 2023). However, technology integration in education faces challenges such as infrastructure limitations, as well as teachers' and students' readiness to adopt new technologies (Kaminskien *et al.,* 2022). Collaboration between technology developers, educators, and policymakers is essential to maximizing the benefits of technology in education, making the teaching and learning process more varied and adaptive to the times (Muscio *et al.,* 2022). This is different from conventional ways of using media in the teaching in learning process (Millatina *et al.,* 2022; Anggraeni & Maryanti, 2021; Ardiana *et al.,* 2022; Khamsah & Nandiyanto, 2024; Muliawati & Maryanti, 2022). Some examples of the use of digital learning media in the learning process are (i) e-learning platforms; (ii) virtual reality (VR) and augmented reality (AR); (iii) learning management systems (LMS); (iv) mobile learning; (v) gamification; (vi) simulation software; and (vii) social media.

3.2.1. E-Learning platforms

E-learning, or electronic learning, is an educational method that uses information and communication technology to provide access to learning materials online (Scott *et al.,* 2016). Many reports regarding e-learning have been well-documented (see **Table 2**). With e-learning, the teaching and learning process can be done without geographical limitations, allowing students to learn anytime and anywhere through devices connected to the internet (Schulz, 2023). Technologies used in e-learning include LMS, video conferencing, digital learning modules, and online education applications and platforms (Cazan & Maican, 2023). The main objectives of e-learning are to increase the accessibility of education for all levels of society, provide flexible learning experiences according to students' individual needs, and improve the efficiency and effectiveness of the teaching and learning process through innovative technology (Yıldız *et al*., 2022). E-learning also aims to develop self-learning skills and digital literacy needed in the modern era (Ember, 2022).

The benefits of e-learning in the learning process are significant, such as flexibility of time and place of learning, personalization of learning according to students' abilities, and provision of rich and varied learning resources (Islam *et al.,* 2023). The advantages of e-learning include high flexibility, increased student engagement through interactive media, consistent and standardized delivery of materials, ease of evaluation, and real-time monitoring of student progress (Dubey *et al*., 2023). However, e-learning also has disadvantages, such as limitations of direct face-to-face interaction between teachers and students, the need for adequate technological infrastructure, challenges of self-motivation and self-learning discipline, and issues of student data security and privacy (Sofi-Karim *et al.,*

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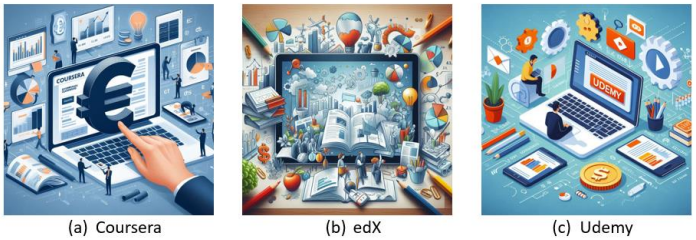
2023). With the right implementation strategy and adequate infrastructure support, e-learning can be an effective solution to improve the quality of education, with support from all parties involved, especially technology professionals who play a crucial role in its success (Teo *et al.,* 2020). **Figure 8** shows an example of how e-learning is used in the learning process such as Coursera, edX, and Udemy.

Table 2. Previous studies on e-learning.

No	Title	Reference
1.	e-book multimedia animation implementation on concept mastery and problem-solving skills of crystal structure subjects in engineering materials course	Suherman *et al.* (2023)
2.	Utilization of e-resources for learning among undergraduates	Daramola (2023)
3.	Impact of e-learning on college of education lecturers' knowledge of quantitative data analysis in SPSS	Adeniran & Onasanya (2024)
4.	A comprehensive design guide to adaptive e-learning system based on VARK learning styles	Savytri & Ratri (2023)
5.	Development of folk-dance videos for e-learning	Llupar *et al.* (2022)
6.	Feasibility analysis of the development of STEM-based physics e-book with self-regulated learning on global warming topics	Lestari *et al.* (2024)
7.	E-learning amidst the pandemic: Teachers' perspective in the Philippines	Estrellan *et al.* (2021)
8.	The challenges of remote e-assessments during covid-19 outbreaks among undergraduate engineering programs	Minghat *et al.* (2022)
9.	Analysis of teacher skills in e-learning content development during distance learning during the covid-19 pandemic	Nafsi & Maryanti (2022)
10.	A digital accessibility and inclusive design-based e-module in higher education: Does it work in a classroom with a deaf student?	Musayaroh *et al.* (2023)
11.	Survey of availability of electronic media for teaching in colleges of education in Oyo State	Daramola (2022)
12.	Students' intention to accept gamification on web-based interactive multimedia using an active knowledge-sharing learning model	Syari'Ati Fathimah *et al.* (2024)



(a) Coursera (b) edX (c) Udemy

Figure 8. Use of e-learning in the learning process.

3.2.2. Virtual Reality (VR) and Augmented Reality (AR)

VR and AR are advanced technologies that are increasingly being applied in education (Hussain *et al*., 2021). Many reports regarding VR and AR have been well-documented (see **Tables 3** and **4**). In short, VR creates interactive, three-dimensional simulated environments through devices such as VR headsets (Roussou & Slater 2017), while AR combines virtual elements with the real world through smartphones or specialized glasses (Flood, 2024). The goal of applying VR and AR in education is to enhance students' learning experiences in a more immersive and interactive way, as well as help them understand complex subject matter and increase engagement in the learning process (Geana *et al.,* 2024). With this technology,

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p- ISSN 2775-6793 e- ISSN 2775-6815

students are expected to learn more interestingly and enjoyably, develop practical skills, and gain a deeper understanding of the concepts learned (Wen *et al.,* 2023).

Table 3. Previous studies on VR.

No	Title	Reference
1.	The use of virtual reality as a substitute for the pre-school students' field trip activity during the learning from home period	Firdiarahma (2021)
2.	Colleges of education lecturers' attitude towards the use of virtual classrooms for instruction	Ekunola *et al.* (2022a)
3.	Students' learning experiences and preference in performing science experiments using hands-on and virtual laboratory	Bugarso *et al.* (2021)
4.	The effectiveness of using a virtual laboratory in distance learning on the measurement materials of the natural sciences of physics for junior high school students	Azizah *et al.* (2022)
5.	Lecturers perceived proficiency in the use of virtual classrooms for instruction in colleges of education	Ekunola *et al.* (2022b)
6.	Development and acceptability of virtual laboratory in learning systematics	Sison *et al.* (2024)
7.	Utilization of virtual reality chat as a means of learning communication in the field of education	Rivky *et al.* (2022)
8.	Virtual reality application for new shopping experience integrated with social distancing compliance	Dah *et al.* (2024)
9.	Predicting reality within the virtual: experimental validation of daylight simulation tools for architectural spaces in the tropics	Sancho-Salas *et al.* (2023)
10.	Designing virtual reality game for learning al-quran	Jumansyah & Luckyardi (2023)

Table 4. Previous studies on AR.

No	Title	Reference
1.	Augmented reality for cultivating computational thinking skills in mathematics completed with literature review, bibliometrics, and experiments for students	Angraini *et al.* (2024)
2.	Development of augmented reality application for exercise to promote health among elderly	Bangkerd & Sangsawang (2021)
3.	Application of augmented reality technology with the fuzzy logic method as an online physical education lecture method in the new normal era	Albar *et al.* (2021)
4.	Trends on augmented reality in education: bibliometric analysis and visualization using r studio	Supriyadi *et al.* (2023)
5.	Augmented reality in education review: bibliometric computational mapping analysis using vosviewer	Nugraha *et al.* (2023)
6.	A bibliometric analysis of augmented reality in higher education	Utami *et al.* (2023)
7.	Mobile augmented reality application through metaverse approach as social studies learning media in junior high school	Ruhimat *et al.* (2023)
8.	Designing collaborative augmented reality geographic information system for land suitability visualization	Maulana & Kanai (2023)
9.	Implementation of augmented reality on earthquake and tsunami socialization in BMKG goes to school	Ruhimat & Soegoto (2022)
10	Potential agricultural land suitability visualization using augmented reality geographic information system (AR-GIS)	Maulana & Kanai (2022)

The benefits of using VR and AR in learning are significant (Aguayo & Eames, 2023). These technologies allow students to experience realistic learning environments that are difficult to replicate in traditional classrooms, increase motivation and engagement through interactive

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2776-6098 e- ISSN 2776-5938

learning methods, and enable contextualized and applied learning (Lin & Yu, 2023). The advantages of VR and AR include immersive learning experiences, safe simulation of risky situations, personalization of learning, and bridging the gap between theory and practice (Jin *et al.,* 2024). However, these technologies also have drawbacks such as high cost, the need for adequate infrastructure, teacher and student readiness, and potential health issues such as eyestrain and addiction (Yoo & Son, 2024). Therefore, the right implementation strategy, infrastructure support, and readiness of all parties are needed to maximize the benefits of VR and AR in education (Abeywardena, 2023). An example of using VR and AR in learning can be shown in **Figure 9**.

(a) Virtual Reality (b) Augmented Reality

Figure 9. The use of VR and AR in the learning process.

3.2.3. Learning management system (LMS)

The LMS is a digital platform designed to design, manage, and measure online learning activities (Kim *et al.,* 2023). Many reports regarding LMS have been well-documented (see **Table 5**). In general, its main purpose is to provide an integrated solution in the educational process, from administration, documentation, tracking, reporting, and subject matter delivery and testing (Barut Tuğtekin, 2023). LMS improves the efficiency and effectiveness of learning in schools and universities, as well as training and professional development in various organizations (Fanshawe & Barton, 2023). The benefits of LMS include flexible access to learning materials, interactive features such as discussion forums and online quizzes, and simple tracking and evaluation of learning progress through reporting and analysis features (Krumova, 2023).

Table 5. Previous studies on LMS.

No	Title	Reference
1.	Determinants of learning management system (LMS) adoption by university students for distance learning	Soko *et al.* (2024)
2.	The influence of Spada learning management system (LMS) on algorithm learning and programming of first grade students at Universitas Pendidikan Indonesia	Al Husaeni & Hadianto (2022)
3.	The effectiveness of distance learning using learning management system media and WhatsApp groups at senior high school	Agustina & Nandiyanto (2021)
4.	Development of a learning management system (LMS) to facilitate online learning of biodiversity materials	Hizqiyah *et al.* (2022)

The use of LMS has both advantages and disadvantages. The main advantages are time and operational cost savings, reduced physical space requirements, and support for dynamic and innovative learning methods (Krishnan *et al*., 2022). The LMS is also scalable, allowing access for many learners simultaneously (Gamede *et al.,* 2022). However, LMSs require a stable internet connection, which can be a constraint in areas with inadequate digital infrastructure (Oguguo *et al.,* 2021). Adapting new technologies requires additional time and training, as

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2775-6793 e- ISSN 2775-6815

well as large initial investments in software and hardware (Costley, 2022). With a thorough understanding of the advantages and disadvantages of LMS, educational institutions and organizations can optimize their use to achieve more effective and efficient learning (Al-Nuaimi & Al-Emran, 2021). **Figure 10** shows an example of using the LMS in learning such as Google Class Room, Canvas, and Blackboard.

(a) Google Class Room (b) Canvas (c) Blackboard

Figure 10. The use of learning management system (LMS) in the learning process.

3.2.4. Mobile learning

Mobile learning, or learning through mobile devices, is an educational method that uses mobile device technology, such as smartphones and tablets, to access learning materials flexibly and at any time (Coelho *et al.,* 2023). Many reports regarding mobile learning have been well-documented (see **Table 6**). The main objective of mobile learning is to increase the accessibility of education for students by providing a learning platform that can be accessed from anywhere without being limited by physical location (Capella *et al.,* 2023). Mobile learning also aims to facilitate more interactive and dynamic learning, allowing students to develop digital skills that are essential in the modern technological era (Wang *et al.,* 2023). Through mobile learning, students are expected to learn more independently and at their own pace and learning style (Mohtar *et al.,* 2023).

Table 6. Previous studies on mobile learning.

No	Title	Reference
1.	The use of mobile learning in schools as a learning media: Bibliometric analysis	Zafrullah & Ramadhani (2024)
2.	Design, development, and evaluation of a mobile learning application for tourism education	Arrasyid *et al.* (2020)

Mobile learning has significant benefits for the learning process. First, mobile learning provides flexibility in terms of learning time and place, allowing students to access learning materials anytime and anywhere (Hinze *et al.,* 2023). Second, mobile learning supports personalization of learning, where materials can be tailored to students' individual needs (Levene & Seabury, 2015). Third, mobile learning enables the use of various interactive media, such as video, audio, and educational applications, which can increase student motivation and engagement in the learning process (Gasca-Hurtado *et al.,* 2024). Limited access to mobile devices and stable internet connections is still a major challenge, especially in areas with inadequate digital infrastructure (Al-Said, 2023). In addition, mobile learning can lead to over-reliance on technology and reduce face-to-face interaction between teachers and students (Kyrylova *et al.,* 2023). Maximizing the benefits of mobile learning requires adequate infrastructure support as well as readiness from all parties involved in the education process (Devourou *et al.,* 2022). **Figure 11** shows an example of using mobile learning such as Duolinggo, Khan Academy, and Kahoot!.

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2776-6098 e- ISSN 2776-5938

(a) Duolinggo (b) Khan Academy (c) Kahoot!

Figure 11. The use of mobile learning in the learning process.

3.2.5. Gamification

Gamification is the application of game elements in a non-game context to increase user engagement and motivation (Ho *et al.,* 2023). Many reports regarding gamification have been well-documented (see **Table 7**). In education, gamification is applied to make the learning process more interesting and interactive by using mechanisms such as points, levels, challenges, and rewards (Sáez-López *et al.,* 2024). The main goal of gamification in learning is to increase student participation, strengthen their engagement with the subject matter, and encourage positive behavior and academic achievement (Fuentes-Riffo *et al.,* 2023). Through gamification, it is expected that students can be more motivated to learn and achieve educational goals in a more fun and challenging way (Kabilan *et al*., 2023).

Table 7. Previous studies on gamification.

No	Title	Reference
1.	Influence of gamification elements on students' academic performance	Adeoye (2023)
2.	Students' attitude towards gamification-based teaching in mathematics in basic schools	Attah *et al.* (2024)
3.	Undergraduate students' awareness to adopt gamification for learning in University of Ilorin, Nigeria	Ekunola *et al.* (2022)
4.	Students' intention to accept gamification on web-based interactive multimedia using an active knowledge-sharing learning model	Syari'Ati Fathimah *et al.* (2024)
5.	Teaching self-development skills using gamification via blackboard e-learning	Xue *et al.* (2023)
6.	Students' attention and confidence in learning experience via gamification	Zin *et al.* (2023)
7.	Development of gamification apps to enhance critical thinking and creative thinking	Shavab *et al.* (2023)
8.	Autonomous monitoring with facial expression recognition and gamification to support blended learning model	Kurniawan & Putra (2023)
9.	Computational bibliometric analysis on adaptive gamification using vosviewer	Hayati *et al.* (2023)

The benefits of gamification in the learning process are multifaceted (Fuentes-Riffo *et al.,* 2023). First, gamification increases student motivation and engagement by providing stimulating challenges and motivating rewards (Kaya & Ercag, 2023). Second, gamification helps improve information retention and concept understanding through a more interactive and iterative learning experience (Takbiri *et al.,* 2023). Thirdly, gamification can facilitate collaborative and competitive learning, encouraging students to work together and compete healthily (Kirsch & Spreckelsen, 2023). However, there are some drawbacks to using gamification for learning. Over-reliance on game elements can take the focus away from the actual educational objectives, and not all students may respond well to this approach (Alarcon Fortepiani, 2023). In addition, poorly thought-out gamification design can lead to boredom or frustration. To maximize the benefits of gamification, it is important to design game elements that are balanced and relevant to the learning objectives, as well as ensure adequate support

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2775-6793 e- ISSN 2775-6815

from educators in its implementation. **Figure 12** shows an example of using gamification such as Salesforce Trailhead, Class Craft, and Zombies, Run!.

(a) Salesforce Trailhead (b) Class Craft (c) Zombies, Run!

Figure 12. The use of gamification in the learning process.

3.2.6. Simulation software

Simulation software is software used to mimic or simulate real-world processes or systems in a virtual environment (Brunzini *et al.,* 2020). In an educational context, simulation software allows students to experience and interact with dynamic models that represent certain phenomena or concepts, such as scientific experiments, medical procedures, or economic simulations (Connolly *et al.,* 2022; Shabudin *et al.,* 2022; Soetan *et al.,* 2023). The main purpose of using simulation software in learning is to provide a more immersive and contextual learning experience, which is difficult or risky to realize in the physical environment (Jefferies *et al.,* 2023). With simulation software, students can test hypotheses, conduct experiments, and observe the results directly in a safe and controlled environment (McBane *et al.,* 2023).

The benefits of simulation software in the learning process are significant (Rudolph *et al.,* 2021). First, it allows students to learn through hands-on and practical experiences, which can deepen their understanding of the subject matter (Jovanović *et al.,* 2022). Second, simulation software can increase student engagement and motivation by providing an interactive and challenging learning environment (Connolly *et al.,* 2022). Third, the software allows the simulation of complex and dangerous situations, so students can learn without physical risk (Jefferies *et al.,* 2023). However, there are also some drawbacks to using simulation software, one of which is the high cost of developing and procuring software and supporting hardware (Ligot & Birattari, 2022). In addition, the use of simulation software requires adequate technical skills from teachers and students, which may require additional training (Pit-Claudel *et al.,* 2021). Finally, over-reliance on virtual simulations may reduce students' opportunities to gain hands-on experience in the real world (Jamalpuri *et al.,* 2022). To maximize the benefits of simulation software, a balanced integration with traditional learning methods and adequate support from educational institutions are required (Healy & Drayton, 2022). **Figure 13** shows an example of using simulation software such as PHET Interactive Simulation, Minecraft, and Microsoft Flight Simulator.

(a) PHET Interactive Simulations (b) Minecraft (c) Microsoft Flight Simulator

Figure 13. Use of simulation software in the learning process.

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2776-6098 e- ISSN 2776-5938

3.2.7. Social media

Social media is a digital platform that allows users to create, share, and interact with content and communicate with others online (Jafar *et al.,* 2023). Many reports regarding social media in education have been well-documented (see **Table 8**). In the context of education, social media is used to support the learning process by providing a means to share information, discuss, and collaborate among students and teachers (Vicari & Kirby, 2023). The main purpose of using social media in education is to increase student engagement, facilitate more effective communication, and create a more interactive and collaborative learning environment (Tang & Hew, 2017). With social media, students can access various learning resources, participate in discussions, and get real-time feedback (Sutherland *et al.,* 2020).

Table 8. Previous studies on social media in education.

No	Title	Social media	Reference
1.	Students' intention to share information via social media: A case study of covid-19 pandemic	-	Hashim *et.al.* (2020)
2.	Combining chatbot and social media: Enhancing personal learning environment (PLE) in language learning	Chatbot	Haristiani & Rifa'I (2020)
3.	Social media on the students' academic performance	-	Bedua *et al*. (2021)
4.	Social media efficacy on prevention and control of covid-19 pandemic in Ilorin south local government area, Kwara state	Facebook, Twitter	Abubakar *et al.* (2022)
5.	Perception of Japanese students in using online video as a learning media	Online video	Winarni & Rasiban (2021)
6.	The effectiveness of Youtube media to improve knowledge and literacy of elementary school students	YouTube	Mulya *et al.* (2023)
7.	The effectiveness of using whatsapp social media as learning media at elementary school	WhatsApp	Suroto & Nandiyanto (2021)
8.	The use of whatsapp social media as reinforcement online learning during the Covid-19 pandemic	WhatsApp	Ramdhani & Nandiyanto (2021)
9.	Effect of webinar multimedia platform on students' academic performance in selected educational technology concepts in University of Ilorin.	-	Nuhu & Onojah (2022)
10.	Strengthening the value of pancasila in elementary schools in online learning through whatsapp group media	-	Maulidayani et al. (2022)
11.	The influence use of social media on the learning motivation of junior high school students	-	Sopian *et al.* (2022)
12.	Indonesian public response to online learnings during the covid-19 pandemic: An analysis of social media	-	Prabowo & Suroso (2022)
13.	Perception of undergraduate students on the utilization of social media to enhance learning in University of Ilorin	WhatApp	Aladesusi *et al.* (2021)
14.	Webtoon comic media to improve reading comprehensions for students with hearing impairment in special primary schools	Webtoon	Hartati *et al.* (2023)
15.	The effect of electronic word of mouth (E-WOM) on social media tiktok to brand trust and its impact on buying interest in mixue brand ice cream products (Survey on state university students in West Java)	E- WOM, TikTok	Rosmayanti & Ratnasari (2024)
16.	Social media da'wah strategy in implementing Islamic da'wah	Chatbot	Hidayat *et al.* (2024)
17.	Sustaining students' mental health through the use of tiktok application	TikTok	Gajo et al. (2023)
18.	TikTok platform to train middle school students' computational thinking skills in distance learning	TikTok	Reskianissa *et al.* (2022)

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2775-6793 e- ISSN 2775-6815

Table 8 (Continue). Previous studies on social media in education.

No	Title	Social media	Reference
19.	Utilization of YouTube videos during online learning to increase literacy in English for middle school students	YouTube	Sutanto *et al.* (2022)
20.	The effectiveness of using YouTube applications as learning media to increase reading and writing interest of elementary school students	YouTube	Nafilah & Sakti (2022)
21.	Optimizing instagram in sociology materials to improve digital literacy for junior high school students	Instagram	Risnandar & Sakti (2022)
22.	Effect of facebook-based learning on students' performance in educational technology concept	Facebook	Issa *et al.* (2021)

Social media has a variety of benefits for the learning process. First, social media allows easy and quick access to information and learning resources, which can support students' self-learning (Dong *et al.,* 2023). Second, social media facilitates collaboration and discussion among students, both in small and large groups, which can enrich their learning experience (Bruguera *et al.,* 2022). Third, social media allows teachers to provide learning materials, assignments, and feedback more efficiently and flexibly (Jiang *et al.,* 2023). However, the use of social media in education also has some drawbacks. One of them is the potential for distraction, where students can be distracted by non-educational content on social media platforms (Shannon *et al.,* 2024). In addition, privacy and data security issues are important concerns, as students' personal information can be exposed (Al Fraidan, 2023). Finally, not all students have equal access to devices and adequate internet connections, which can create a digital divide (García Zare *et al.,* 2023). To maximize benefits and minimize risks, the use of social media in learning should be well-regulated and accompanied by clear guidelines to maximize the benefits and minimize the risks (Lai & Widmar, 2021). **Figure 14** shows an example of using social media such as Facebook, YouTube, and Edmodo.

(a) Facebook (b) YouTube (c) Edmodo

Figure 14. Use of Social Media in the learning process.

3.3. Creative Thinking in Education

Creative thinking encompasses all cognitive activities that individuals engage in in response to specific objects, problems, or conditions, as well as efforts directed at specific events and problems that depend on students' abilities (Pinkow, 2023). Many reports regarding creative thinking have been well-documented (see **Table 9**). When faced with such situations, students seek to utilize their imagination, intelligence, insight, and ideas (Ayasrah, 2023). In addition, students also seek to propose authentic and novel designs, generate diverse hypotheses, and solve problems by finding and applying new implementations (Duval *et al*., 2023). This entails recognizing their knowledge deficits and bridging these gaps by adopting new perspectives, making unconventional connections, and taking risks based on students' insights to achieve creative thinking (Wang & Burdina, 2023).

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2776-6098 e- ISSN 2776-5938

Table 9. Previous studies on creative thinking.

No	Title	Reference
1.	Development of gamification apps to enhance critical thinking and creative thinking	Shavab *et al.* (2023)
2.	Local material based (LMBE) research experience on DNA extraction to develop student's critical and creative thinking skills during COVID-19 shutdown.	Supriyanti *et al.* (2021)
3.	Analysis of adolescent creative thinking skills scale based on creative personality perspective	Hafina & Fitri (2022)
4.	The engagement of critical and creative thinking activities in the teaching and learning process	Tiong & Bakar (2022)
5.	Introduction of Indonesian poem (pantun) as a creative effort of elementary school students in improving language skills in the Covid-19 pandemic era	Medani & Sakti (2022)
6.	Eco-creative hub model as the key to integrating creativity and sustainability	Khusaini *et al.* (2023)

One form of digital technology implementation that can support this creative thinking process is the use of AI in learning media (Yang & Hong, 2024). The use of AI media in the learning process is very important because AI can provide a more personalized, adaptive, and interactive learning experience. Through AI, learning materials can be customized to each student's needs, abilities, and learning styles so that each student can learn at the pace and in the way that is most effective for them (Nykonenko, 2023). In addition, AI can also provide real-time feedback, helping students correct mistakes and understand concepts better. The implementation of AI in this learning medium not only improves learning effectiveness but also encourages students to develop creative thinking skills.

The importance of using AI-based learning media lies in its ability to overcome some challenges in traditional education, such as limited time and teacher attention in providing individualized guidance to each student (Nykonenko, 2023). AI can analyze student learning data and provide timely recommendations or interventions, enabling more efficient and effective learning (Fong *et al.,* 2024). In addition, AI can assist in automating administrative tasks so that teachers can focus more on teaching and interacting with students (Ahmad *et al.,* 2022). AI-based learning media has an important role in improving students' creative thinking skills (Hu *et al.,* 2022). AI can provide a rich learning environment with challenges and stimulation that encourage students to think divergently and convergently (Kalyani, 2023). For example, AI can generate problems or projects that require creative problem-solving, encouraging students to explore different solutions and new ideas (Kirkpatrick, 2023). In addition, AI can facilitate collaboration and discussion among students through digital platforms, broadening their horizons and perspectives in the learning process (Alwazzan, 2024). Thus, the use of AI-based learning media not only improves learning effectiveness but also helps develop creative thinking skills that are essential in this digital era (Hsu & Chen, 2022).

4. CONCLUSION

The issue raised in this research is how to integrate AI into learning media to overcome the challenges of traditional education, which tends to focus on memorization and procedural application. This research aims to identify effective ways of combining AI with innovative learning methods to improve students' creative thinking abilities equally across different educational contexts. The research method used is bibliometrics, which is a subset of

DOI: https://doi.org/10.17509/ajse.v4i3.72611
p- ISSN 2775-6793 e- ISSN 2775-6815

systematic literature review with the application of quantitative and statistical methods to bibliographic data. The research was conducted through three stages: data collection from the SCOPUS database, data visualization using the VOSViewer application, and data analysis to highlight various units of analysis such as authors and co-authorship, citation and co-citation, and co-occurrence. The data was collected on July 16, 2024, and consists of documents indexed in SCOPUS from 2020 to 2024.

The results show that the integration of AI technology in learning can provide a more personalized, adaptive, and interactive learning experience, as well as being able to provide real-time feedback. The use of AI is proven to be able to customize learning materials to the needs, abilities, and learning styles of each student. Thus, each student can learn at the pace and in the way that is most effective for the student. This study also identifies research trends and knowledge gaps in the topic of technology integration in education and provides recommendations for further research that can explore more deeply the use of digital technology to support divergent and convergent processes in creative problem-solving.

This study's limitations include the inequality of access to advanced technology in different countries and educational institutions, as well as a lack of teacher skills in integrating AI into the learning process. This research contributes to the development of more effective and inclusive education policies and practices, ensuring that all students have equal opportunities to develop essential skills in the digital age. Recommendations for future research are to further explore how digital technologies can be used to support divergent and convergent processes in creative problem solving and how best to train teachers to effectively utilize AI technologies in the classroom.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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