25 (2), 2024, 659-670

Jurnal Pendidikan MIPA

e-ISSN: 2685-5488 | p-ISSN: 1411-2531

http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Integration of Digital Technologies in Physics Experiments: A Bibliometric Analysis

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Abstract: Digital technology plays an important role in physics experiments by increasing the accuracy of data collection, enabling complex simulations and conducting real-time analysis, which accelerates scientific discovery, and improve test accuracy. The purpose of this study is to provide an overview of the conduct of research on the integration of digital technologies into physics experiments. This study conduct a bibliometric analysis of the integration of digital technology into physics experiments from January 2014 to May 2024. Based on the keywords, only articles selected by SCOPUS in English were included, and using the PRISMA guidelines we obtained 344 articles for analysis. In this studies, sample articles from SCOPUS in *RIS formats are processed using the VOSviewer to facilitate visualization and trend detection. Our analysis revealed seven prominent trends, included e-learning, digital twin, numerical model, high energy physics, application specific integrate, analog electronic circuit, and tracking detectors. The inspection results show that there was no significant development, research on the integration of digital technology into physics experiments has not been seriously conducted from the point of view of future teachers and teacher education, and only a few countries have investigated it. Therefore, based on the results of this bibliometric analysis, it provides an overview and opportunities for further research.

Keywords: bibliometric, digital technology, physics experiments, VOSviewer.

▪ INTRODUCTION

Approaches to teaching physics through digital technology, their main concept is that physics is very interesting, although it is a complex science, and the teacher should improve the methodology of teaching physics according to modern requirements, introduce technology in the learning of the timely process (Angell et al., 2004). Digital technology is increasingly used in educational practice worldwide (Abdullah & Ward, 2016). Mobile phones, Wiki platforms, social media, and video games are gradually becoming popular among colleges. This trend is changing the way higher education is taught and learned (Abdullah et al., 2016), prompting a growing interest among researchers to explore the topic of digital literacy in today's higher education environments.

With the exponential speed of technology that is probably at the forefront of many, if not all, regions of the world, the education system has seen its own unprecedented pace of change that would otherwise be passive and irrelevant. Technology has expanded access to education, allowing learning to cross borders and occur in real-time (Matthews & Thakkar, 2018; Abu Talib et al., 2021). Technology is a powerful tool to transform education, making it meet the demands of the times, especially when the Industrial Revolution 4.0 found its way (Yang & Gu, 2021; K. Zervoudi, 2020). The growing need for this involvement in many areas has consistently been highlighted as extensive

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DOI: http://dx.doi.org/10.23960/jpmipa/v25i2.pp659-670
Received: 29 August 2024
Accepted: 25 September 2024
Published: 27 September 2024

(Staddon, 2023). Technological development has great potential to dramatically accelerate economic growth and social development (Snowie Y. Balansag, Lexter R. Natividad, 2018). But as the world embraces these changes in technology, resources, and workforce, academics may risk a rapid transition of skills and equipment. Digitalization and technological development have paved the way for the transformation of people's lifestyles, including changes in business activities and models, government choices and policies, and educational reforms and changes (Jardinez & Natividad, 2024; Djankov et al., 2018). What may be a noble goal may be lacking. This also applies to higher education and the production of quality graduates who will soon become the world's workforce. In general, knowledge takes on a new form when a new technology is introduced, and thus the way of integration becomes dependent on this thoroughness. It can be argued that many existing studies create an overload in the core of information technology. Looking at them linearly and keeping them as a research corpus can be a systematic way of analyzing them.

The future can have both positive and negative consequences. Philosophically, everything is uncertain, because changes happen at the snap of a finger. Although the goal of every educational institution, especially higher education, is to prepare students for work, technological developments, and related concerns show that one must be prepared to accept possible successes and their disadvantages (Verde & Valero, 2021). This infiltration of technological progress into higher education can have many aspects. This requires removing barriers to training both researchers and students to integrate technology into the learning process (e.g., access restrictions, inadequate training, and support limitations) (Johnson et al., 2016). Preparation is essential to harnessing technological change and realizing its potential to drive innovation. In academia, it will revolutionize the connections between and among researchers and students, leading to a significant paradigm shift even in teaching-learning. It transforms learning approaches and strategies into collaborative and complementary pathways, fills long-standing equity and accessibility gaps, and tailors learning experiences to learner needs and appropriate academic requirements (Carlsen et al., 2022).

Understanding these aspects can be promising to embrace Industrial Revolution 4.0. In the context of progress, it is appropriate to contribute to economic revitalization by facilitating social development and technological development in a manner linear to the progressive demands of the time. "Industrial Revolution 4.0, with its rapid development and profound effects on all aspects of social life in every country, if this revolution is left behind, reverse development is also inevitable" (Trí et al., 2021). If all the advantages are considered and taken advantage of, new and great opportunities await. The direction and paradigm of higher education are fundamentally changing, and according to the educational environment, the role of the teacher and students, as well as teaching methods and methods. More than all these things can be taken holistically and segmented simultaneously. In this case, a bibliometric study is required, since this rigorous approach is popular for a comprehensive assessment and evaluation of relevant literature. Existing research identifies the technical tools that enable integration; Some fix and contextualize terms and determine the adequacy or appropriateness of existing technology integration practices, but more bibliometrically needs to be done to communicate topics and gather knowledge in a more aggregated way. Therefore, the purpose of this study is to provide an overview of the conduct of research on the integration of digital technologies into physics experiments. This article offers perspectives on integrating digital technologies into experiments in physics.

▪ METHOD

Research Design

This study is based on systematic quantitative research. We evaluated the literature on digital technology in the field of education by bibliometric analysis, Bibliometrics studies used a quantitative approach to measure, track, and analyze the social and structural relationships between various components of the literature (Donthu et al., 2021; Rojas-Sánchez et al., 2023).

Study Search Procedure

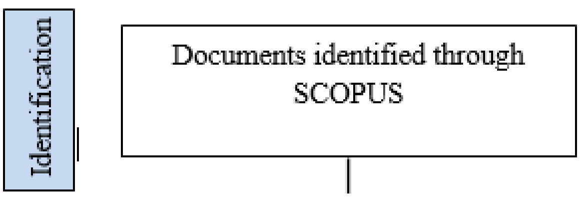
We evaluated the search results of Scopus on 11 May 2024, we did a web search with the keywords {digital technology} and {physical experiments} and in the subject. The publication period was 2014 - 2024. Using keyword analysis and article titles, research groups and topics using Scopus sources were analyzed in 7 categories. The database contains 344 articles related to digital technology in physics experiments, including 191 conference papers, 135 articles, 10 conference reviews, 6 reviews, 1 erratum, and 1 note. The screened data was organized using a flow diagram utilizing Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009; Angelito & Angeline, 2023; Sarı & Aypay, 2024), (see Fig. 1).

Inclusion and Exclusion Creteria

The inclusion and exclusion criteria give the researcher reason for making the right decision (Melin, 2006). Studies selected for inclusion met the following criteria: (a) articles published between January 2014 and May 2024; (b) They come from all countries and must be identified by SCOPUS; (c) must be written in English, and (d) must include studies of the integration of digital technology into physics experiments. The defined inclusion criteria were used to filter the selected articles.

Data Analysis

In this study, sample articles from Scopus in *RIS formats are processed using the VOSviewer to facilitate visualization and trend detection (Novia et al., 2021; Salmi et al., 2017; van Eck & Waltman, 2010). The Center for Science and Technology Research has created VOSviewer, software for creating and viewing bibliometric networks. The distribution of publications by year and genre, trends in publication time and type, producing countries and universities, as well as research areas studied at Leiden University can be seen (Kousha & Thelwall, 2018). The VOSviewer can also be used to evaluate any form of online bibliometric data, including citation relationships between publications or journals, collaboration between researchers, and co-publishing of scientific publications (Strozzi et al., 2017).



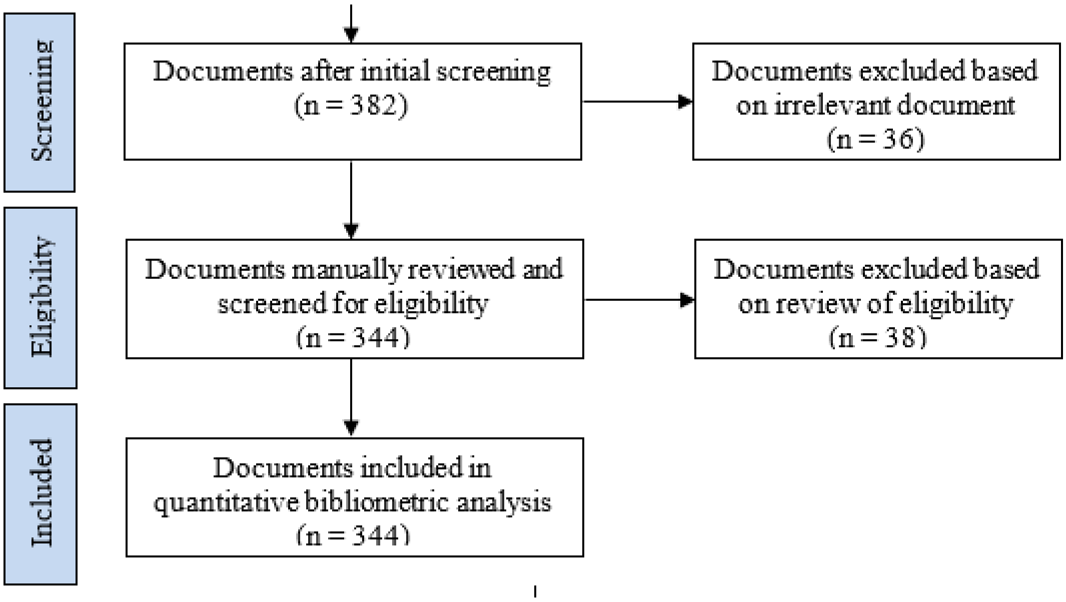


Figure 1. PRISMA guidelines describing the collection of documents from SCOPUS

▪ RESULT AND DISSCUSSION

The following findings discuss the literature on issues related to the integration of digital technology in physics experiments, which have been achieved within the parameters of the research project. Research findings are presented in tables and figures.

The Thematic Trend

The trend of publication of scientific articles with the title word digital technology in physics experiments published in one decade according to Scopus 344 documents (see Fig. 2).

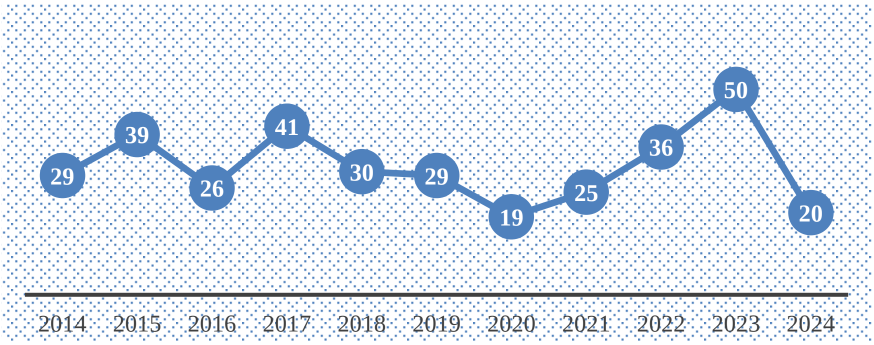


Figure 2. Papers regarding digital technology on physics experiments published in one decade

If you read articles by country with the keyword "digital technology in physical tests", 51 countries have publications about digital technology in physical experiments. The countries are US, China, Switzerland, Italy, Germany, Russian Federation, United Kingdom, Poland, France, Spain, India, Japan, Australia, Belgium, Canada, Chile, Indonesia, Netherlands, Austria, Brazil, Czech Republic, Norway, Mexico, Romania, Ukraine, United Arab Emirates, Croatia, Greece, Israel, Kazakhstan, Taiwan, Finland, Malaysia, Slovakia, Argentina, Armenia, Bulgaria, Colombia, Denmark, Estonia, Hungary, Iran, Ireland, Lebanon, Maroco, Peru, Portugal, Qatar, Saudi Araba, Slovenia, and Sweden. The US is the countries that publish the most articles on this topic digital technology in physical experiments (79 articles), China has 59 articles and then Switzerland has 51 articles, but in this case, Indonesia has only 6 papers). This opportunity is related to the study of digital technology in physical experiments. This statement contained the results of the VOS viewer's analysis of the RIS file. There are five clusters, each cluster is divided as follows: the first cluster has 33 items, the second cluster has 28 items, the third cluster has 27 items, the fourth cluster has 23 items, and the fifth cluster has 15 items. are red, green and blue. The United States has the highest number of publications on digital technology in physics experiments, tied with other countries. Table 1 shows the top 10 Countries/Territories for digital technology in physics experiments research.

Table 1. Top 10 Countries/ Territories for digital technology in physics experiments research

Country/Region	Documents	Percentage (%)
United States	79	15.40
China	59	11.50
Switzerland	51	9.94
Italy	49	9.55
Germany	38	7.41
Russian Federation	35	6.82
United Kingdom	21	4.09
Poland	17	3.31
France	15	2.92
Spain	9	1.75

Additionally, since scientific publications fall into several different categories, the top 10 subject categories are illustrated in Figure 3. The main contributors are publications in Physics and Astronomy, Engineering, and Computer Science. Specifically, the most common majors were Physics and Astronomy (164; 25.5%), Engineering (121; 18.8%), Computer Science (90; 14.0%), Mathematics (53; 8.2%), and Energy (34; 5.3%) followed. Among them, biochemistry, Genetics, and Molecular (11; 1.7%) are found to be the least published field (Caliskan et al., 2021).

Keywords are considered "descriptors of macroscopic-level content" (C. Chen et al., 2008) and can help clarify key research topics and research directions in "integrating digital technology into physics experiments." The subjects of the field can be narrowed down by the keywords of the corresponding publications (C. M. Chen & Tsai, 2012). Figure 4 shows the number of publications by document type. Conference papers are the most (55.5%) and then articles (39.2%). There is huge potential for this research to be researched and published, but also how exciting it is to publish in credible conference papers. After analysis using the VOSviewer, the visualization and mapping can be seen in Figures 5 and 6, respectively. The results were compiled by keywords in short and abstract presentation groups of various "digital technologies physics experiments" studies that form basic education. A total of 126 terms are collected, but if you want to highlight

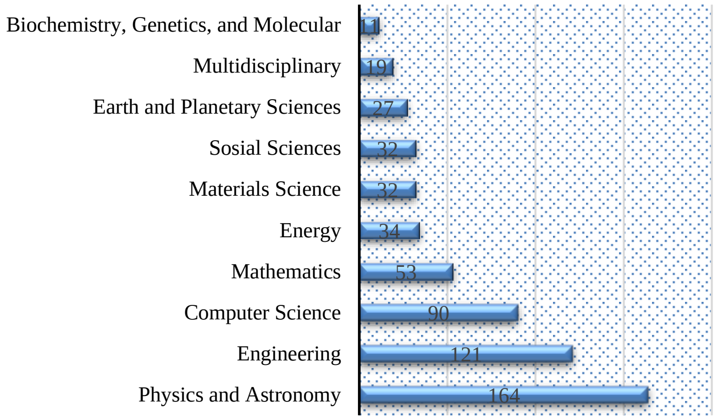


Figure 3. Visualization of subject area from Scopus analysis

the most common topics in "high energy physics" in digital technology physics experiments. Using bibliometric analysis, research can be made more efficient by combining many parameters. We can support future research by using the Integrating Digital Technology in Physics Experiments data.

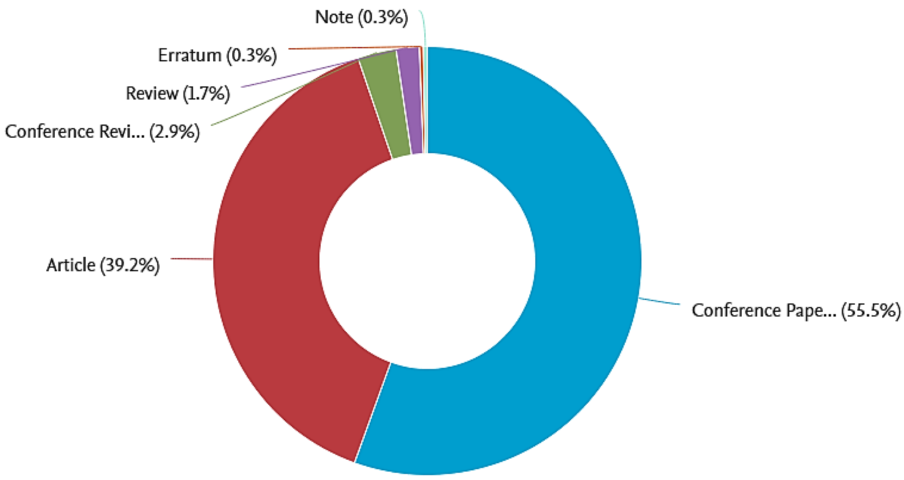
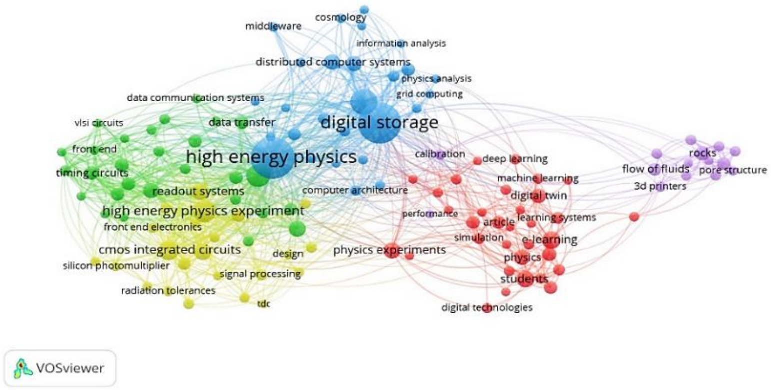


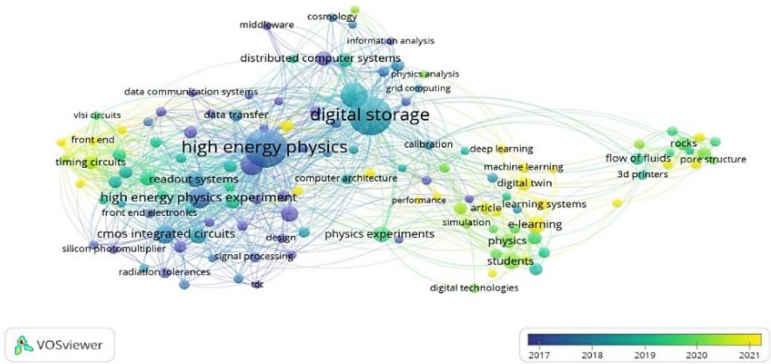
Figure 4. Publications based on documents by type issued

The Main Trend of the Integration of Digital Technology Into Physics Experiments

Previous studies have proposed mapping metadata keywords to find novelty (Gamage et al., 2022; Goerlandt et al., 2021; X. Chen et al., 2021; Pournader et al., 2021). Therefore, it was important to look at the correlations between less important or minor keywords. Figures 5 and 6 show mapping visualization of keywords co-occurrence on all digital technology in physics experiments (2014–2024). Figure 5 shows a visualization of keyword co-terms across all digital technology in physics experiments studies in the past ten years to find research news and relationships. The map visualization revealed five main clusters as the focus of digital technology in physics experiments study. The first cluster was represented by red nodes (n = 33) consisting of physics experiments,



(5.a)



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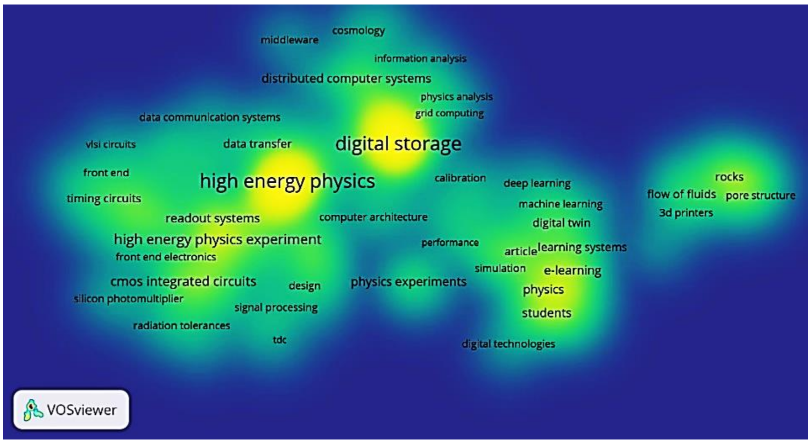

(5.c)

Figure 5. Mapping visualization of topic area using VOS viewer about digital technologyin physics experiments; (5.a) network visualization; (5.b) overlay visualization; (5.c) density visualization

virtual reality, e-learning, digital twin, students, education, digital technologies, etc. The second cluster was represented by green nodes (n = 28), consisting of data acquisition, application spesific integrate, timing circuits, digital electronics circuits, integrated circuits, etc. The third cluster was represented by blue nodes (n = 27), which included high energy physics, digital storage, data handling, distributed computer systems, information management, big data, physics analysis, etc. The fourth cluster was represented by the yellow node (n = 23), which consisted of high-energy physics experiments, CMOS integrated circuits, pixels, readout systems, integrated circuits design, signal processing, tracking detectors, etc. The fifth cluster was represented by the purple node (n = 15), which consists of rocks, the flow of fluids, computerized tomography, numerical models, etc.

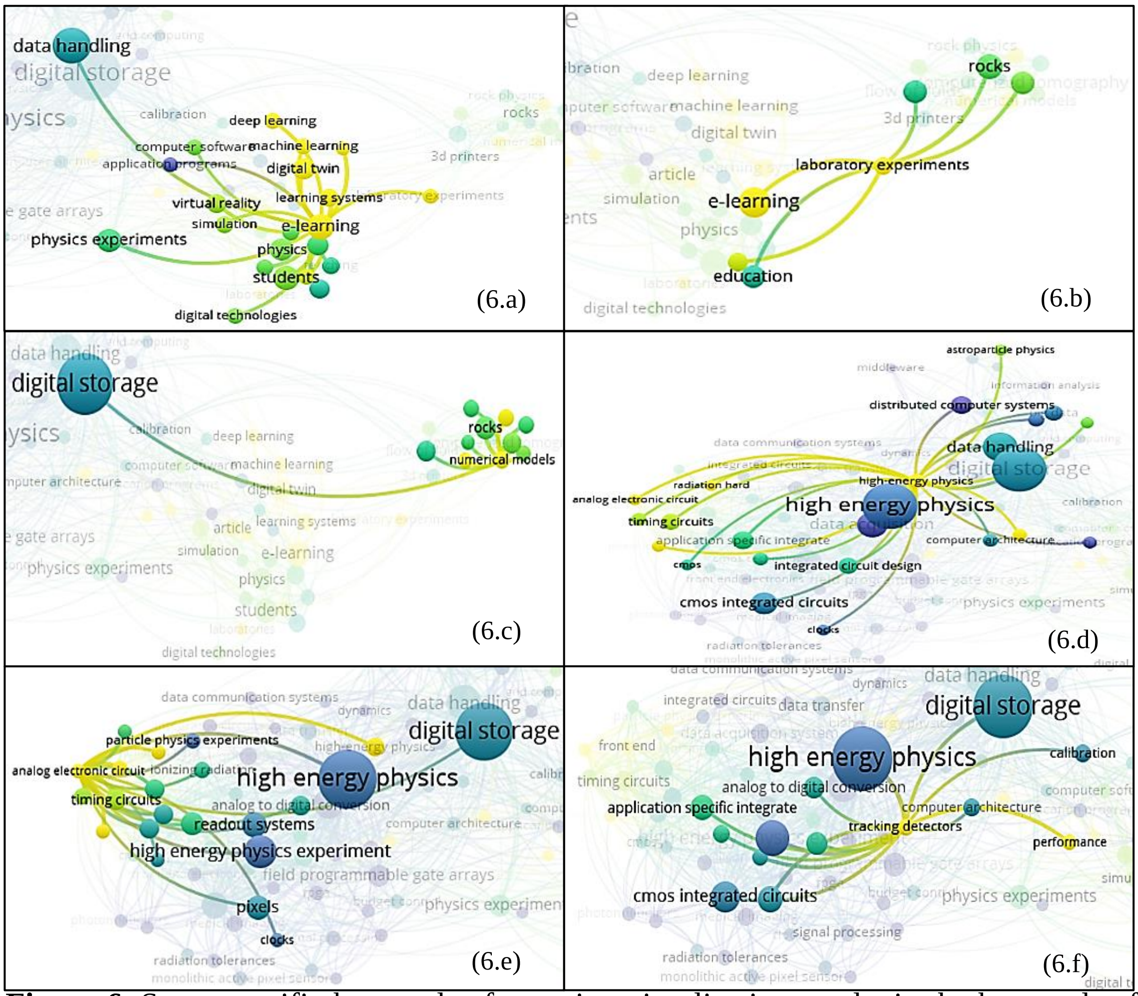

Figure 6. Some specific keywords of mapping visualization results in the keywords of (6.a) e-learning, digital twin; (6.b) laboratory experiments, (6.c) numerical model; (6.d) high energy physics, application specific integrate; (6.e) analog electronic circuit; and (6.f) tracking detectors

Figure 6 shows the main trends of digital technology in physics experiments research from 2014 to 2024. If future researchers wanted to study digital technology in cutting-edge experimental physics, there was still an opportunity to learn about these studies, because the cutting-edge trends still had a broad spectrum and different terms. This is because digital technology can enhance and assist education in many ways. Some examples of specific keyword mapping visualization results of the integration of digital technology in experiments physics included e-learning, digital twin (Fig. 6.a), laboratory experiments (Fig. 6.b), numerical model (Fig. 6.c), high energy physics, application specific integrate (Fig. 6.d), analog electronic circuit (Fig. 6.e), and tracking detectors (Fig. 6.f). Therefore, there was still room for further research to develop digital technology in physics experiments research with keyword mapping visualization. As mentioned, it was still possible to research the less used keywords in digital technology in physics experiments or improve the more used keywords.

The Need for Digital Technology into Physics Experiments

A survey based on Scopus and VOSviewer data on the development of the publication of scientific articles "integrating digital technology into physics experiments" during the last ten years shows that no research has been done on the integration of digital technology in physics experiments, for teachers and teacher education. The integration of new technologies, including digital sensors, into education and the rapidly evolving way in which we produce process, and review information must impact our teaching and learning (Kanna et al., 2018). In addition, experiments integrated with digital sensors enable real-time data collection in educational environments. Technology-enhanced learning has transformed traditional educational practices by using innovative tools and applications to improve teaching and learning (Cowling et al., 2022; Rehman, 2023). With the help of technology and sensors, teachers can create dynamic learning spaces that adapt to the needs of each student and encourage active participation. As education advances, the combination of technology and sensors opens the door to a future where learning becomes more interactive and customizable. Conducting real experiments using digital technology allows students hands-on learning experiences to ask questions, explore concepts, and conduct research to solve problems (Wahyudi et al., 2019).

▪ CONCLUSION

It can be concluded that from 2014 to 2024 there will be fluctuations in research on the "integration of digital technology in physics experiments". Only 19 articles were published on this topic in 2020, and 50 articles have been published in 2023. 344 article documents, by document type, have been released. Conference papers and articles are the types of documents that are most often researched in terms of the type or type of document. Based on Scopus and VOSviewer data, the results of a study on the development of publication of research articles "integration of digital technology in physics experiments" over the last ten years prove that research on the integration of digital technology in physics experiments has not been carried out significantly on learning for prospective teachers and teachers. Lecturers at higher education institutions need to reduce future skills with past skills to formulate and develop various transformative experiences for prospective teachers so that they continue to be updated and able to accelerate by sharing learning quality problems that change periodically according to the demands of the times.

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