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Exploring Trends in Physics Practicum: A Literature Review and Bibliometric Analysis

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Abstract

This study aims to conduct a literature review on physics practicum using the Systematic Literature Review (SLR) method and bibliometric analysis through visual mapping with the VOSviewer software. The focus of this research is on articles published between 2020 and 2025, with the keyword "Physics Practicum." A total of 122 articles were identified, with 14 selected for the literature review. The results indicate that the number of publications on physics practicum decreased from 2020 to 2023, increased in 2024, and then declined again in 2025. The study also reveals that both conventional and digital technologies, such as Arduino-based sensors, smartphone applications, wireless sensor networks, as well as advanced technologies like Augmented Reality (AR), Virtual Reality (VR), and e-learning platforms, have enhanced the effectiveness of physics practicum. However, significant research gaps remain, particularly in the development of worksheets and assessment tools that provide a holistic evaluation of psychomotor skills and overall practicum performance. The bibliometric analysis using VOSviewer highlights keyword mapping that clusters aspects of methodology, evaluation, technology, and external factors such as the pandemic, offering valuable insights for future development of physics practicum.

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INTRODUCTION

Physics practicum is a hands-on learning activity where students test physics theories through direct investigation in the laboratory. This approach allows students not only to grasp theoretical concepts but also to interact with physical phenomena, making their understanding more concrete. Practicum plays a vital role in deepening students' grasp of fundamental physics principles and their real-life applications. By engaging in direct inquiry, students are actively involved in the scientific process, reinforcing their understanding of the physical world.

Numerous studies emphasize the importance of practicum: One study found that practicum modules can develop 21st-century skills, with a feasibility of 94-96.8%

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across content, learning processes, and media, [1]. Another study demonstrated an online practicum model using wireless sensor networks, achieving excellent user acceptance with a SUS score of 91.63, [2]. Additionally, the effectiveness of practicum was evaluated, with an average score of 76.2, highlighting the significant contributions of technology and collaboration, [3]. However, challenges remain, such as laboratory limitations (63% of teachers) and time management issues. Despite these challenges, evidence strongly supports the role of physics practicum in developing scientific and technical skills.

In Indonesia, physics practicum supports the development of science process skills, as outlined in the Ministry of Education and Culture Regulation. Science process skills focus on students' ability to observe, process data, and draw scientific conclusions, aligning with the goal of physics practicum to develop scientific skills through hands-on investigation [4]. With the implementation of the 2013 Curriculum, which emphasizes the importance of science process skills, physics practicum becomes an essential tool for fostering students' scientific thinking abilities. As such, research based on literature reviews is crucial for building a strong theoretical foundation to improve practicum quality.

Several studies on physics practicum provide insights into evolving concepts and methodologies in physics education. Research on technology use, such as computer simulations, shows that these tools enhance students' understanding of complex concepts (Olson & Lou, 2015). Recent studies have also led to the development of innovative practicum tools that improve both accuracy and conceptual understanding. These include: a light refraction index measurement device with an automatic laser system [5], a digital calorimeter based on Arduino for measuring the specific heat capacity of liquids [6], a video tracker tool for analyzing uniform linear motion [7], and an Arduino-based gravity acceleration measurement device with angle sensors and stepper motors [8]. Additionally, augmented reality (AR)-based applications have been developed to visualize physics concepts interactively [9]. These tools not only improve measurement precision but also enhance the learning experience. Despite these advancements, no research has specifically reviewed literature on physics practicum from 2020 to 2025.

This study aims to conduct a literature review on physics practicum using the Systematic Literature Review (SLR) method. The focus is on analyzing existing studies related to physics practicum. The novelty of this research lies in its use of the SLR technique to systematically organize the review, its specific focus on physics practicum, and the application of bibliometric analysis through VOSviewer software. This research will provide valuable insights for further studies and serve as a reference to deepen the understanding of physics practicum implementation.

METHOD

Literature Review Method

This study uses the Systematic Literature Review (SLR) method in conducting a literature review. The SLR procedure used consisted of six stages, namely (i) Designing

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research questions; (ii) Determination of research criteria; (iii) searching for research data; (iv) Selection of research data; (v) Research quality assessment; and (vi) Analysis of the results of the synthesis of research questions. Figure 1 shows the stages of the research carried out by observing the SLR research procedure.

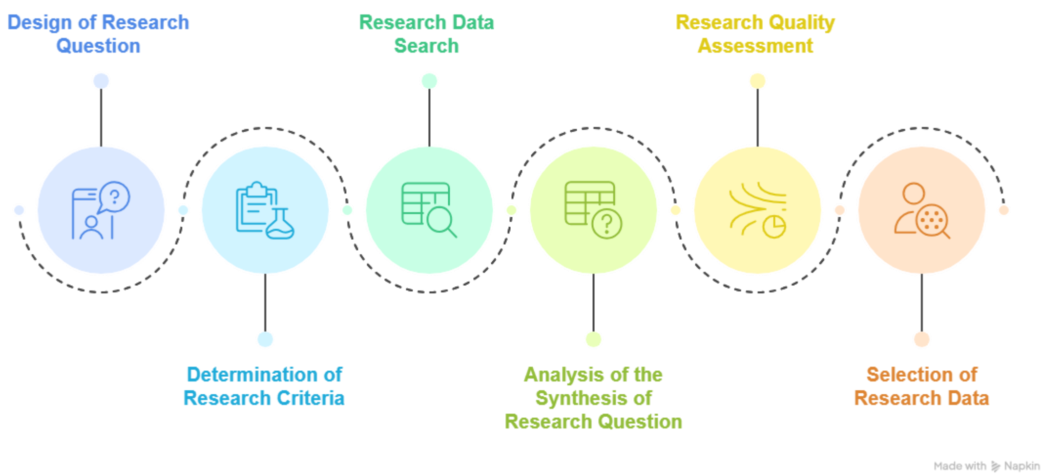

Figure 1. Research stages

The search for publication data in this study used the publish or perish application 7. The data search was carried out on December 27, 2025. The data search was carried out on published data in the 2020 – 2022 range in publication databases, namely Scopus. The keywords used in searching data on the publish or perish 7 applications are "Physics Practicum". Keyword searches are carried out by matching the titles and abstracts of related articles. The number of articles obtained from the search results is 122 articles originating from the Scopus database for data processing for bibliometric analysis using the VOSviewer mapping visualization. The number of articles found for literature study after experiencing article selection based on the suitability of the title of the article with the research objective, namely 14 articles used for literature review.

Bibliometric Analysis Mapping Method

Bibliometric analysis mapping has 4 stages, namely data search using the publish or perish 8 application, data processing using the Microsoft Excel application, data mapping using the VOSviewer 1.6.18 application, and data analysis from the VOSviewer mapping visualization results. The published or perish 8 search result data is stored in .csv and .csv formats. ris. Data in .csv format is processed using Ms. Excel to get data on the number of articles per year and see the research that has been done by researchers regarding the keywords used. Data stored in *.ris format is used in data mapping using VOSviewer. The data that has been mapped is then analyzed to see the development of research on the "Physics Practicum". The data from this mapping is

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analysed to obtain existing research trends and the results of terms that are often used as study material to find novelty for further research.

RESULTS AND DISCUSSION

Search Results Matrix

Based on the search results for articles of Physics Practicum, 122 articles were found in the Scopus database. **Table 1** shows the research matrix from the results of the search conducted. Based on the data in **Table 1** shows that the total number of citations of all articles regarding the physics is 271.

Tabel 1. Research matrix

Paper	122
Citations	271
Year first	2020
Year last	2025
Cites/year	54,20
Cites/Paper	2,22
h-index	5
g-index	4

Table 1 shows the number of citations in 2 types, namely 54.20 citations per year and 2.22 citations per article. Articles on the physics have an h-index of 5. The h-index shows the author's level of metrics in measuring the productivity and impact of citations from publications (Dinis-Oliveira, 2019). The higher the h-index value, the better the research in that field (Mingers *et al.*, 2012). Research of physics practicum has an h-index of 5 can be said to be not very good and not widely cited by many people. The publication of physics practicum has a g-index value of 4. **Table 2** shows the ten articles with the highest number of citations. Based on **Table 2**, the article entitled " Student worksheet with AR videos: Physics learning media in laboratory for senior high school students " published in 2020 has the most citations with a total of 31 citations.

Table 2. 10 articles with the highest number of citations

No	Title	Year	Number of Citations	Ref
1	Student worksheet with ar videos: Physics learning media in laboratory for senior high school students	2020	31	[10]
2	Implementing e-learning-based virtual laboratory media to students' metacognitive skills	2020	25	[11]
3	The development of multi representation practicum modules with PhET in Hooke's law concept	2020	10	[12]
4	Development of augmented reality in the basic physics practicum module	2020	9	[13]
5	The usefulness of Lab X Change virtual lab and PhyPhox real lab on pendulum student practicum during pandemic	2022	8	[14]
6	Evaluation of virtual workspace laboratory: cloud communication and collaborative work on project based laboratory	2022	5	[15]

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No	Title	Year	Number of Citations	Ref
7	TPACK and augmented reality in kinematics practicum module: Forming HOTS physics education students	2021	4	[16]
8	Hots and the 21st century learning skills: Formed with practicum-based physics learning worksheets	2021	4	[17]
9	Improving motivation and science process skills through a mobile laboratory-based learning model	2021	4	[18]
10	The modern physics practicum: Students creatively and critically thinking in the 21st-century competencies	2023	3	[19]

Research Development

Figure 2 shows the development of publications regarding of physics practicum in the range of 2020 to 2025. Figure 2 shows that the development of research has decreased from 2020 to 2023, namely 36 articles in 2020, 33 articles in 2021, 16 articles in 2022, and 2023 in year 13. Whereas in 2023 the development of research has increased, namely 20 articles in 2024 and 41 articles in 2024. The most research took place in 2020, namely 36 articles, and the lowest research occurred in 2025, namely 4 articles.

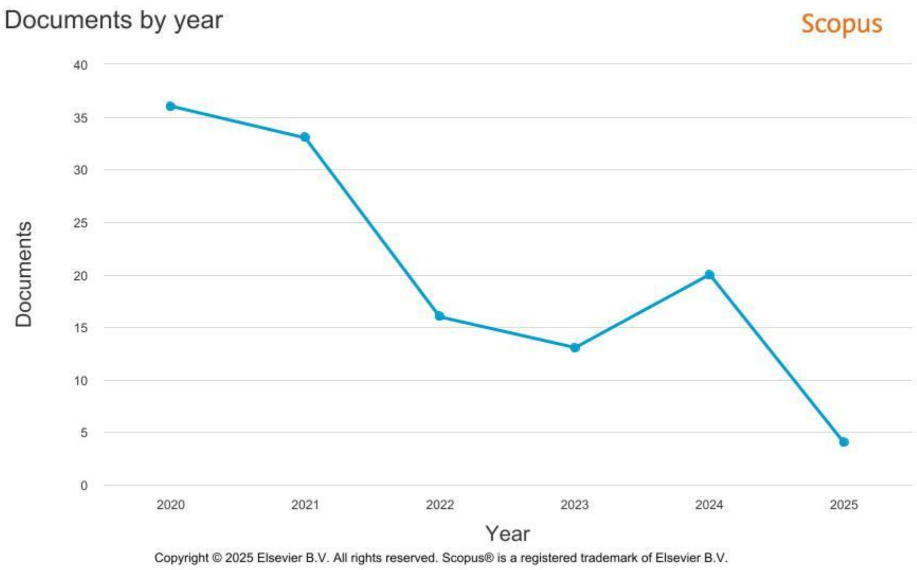

Figure 2. The development of research on physics practicum

Figure 2 shows the number of articles published on physics practicum each year from 2020 to 2025, based on Scopus data. In 2020, there were 36 articles published. The number gradually decreased over the following years, with 33 articles in 2021, 16 articles in 2022, and 13 articles in 2023. There was a slight recovery in 2024, with 20 articles published, but a significant drop occurred in 2025, with only 4 articles published. This trend highlights a general decline in publications, with a peak in 2020 and a sharp decline towards 2025.

Current Studies of Physics Practicum

Table 3 presents the results of a review of 14 Scopus-indexed articles that directly address the topic of physics practicum. Each entry in the table includes information on the study title, objectives or problems addressed, topics discussed, tools used in the experiments, research findings, and references. This table provides a comprehensive

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overview of the various approaches and technologies applied in physics practicum to enhance students' understanding of physics concepts.

In general, the table highlights that physics practicum has involved a range of advanced technologies and innovative learning tools, such as Arduino, Augmented Reality (AR), Virtual Reality (VR), MATLAB, wireless sensors, and e-learning platforms. These technologies are used to deepen students' understanding of various physics concepts, from gravitational acceleration to waves and mechanical motion.

The majority of studies listed in this table focus on the application of AR and VR to visualize complex physics concepts, which have been shown to enhance students' understanding and provide a more interactive practicum experience. Additionally, there are studies utilizing Arduino-based sensors for more accurate measurements and e-learning platforms to facilitate online practicum experiments, especially during the COVID-19 pandemic. These findings emphasize the importance of technology in physics practicum to increase student engagement, effectiveness, and conceptual understanding.

Table 3. Studies of physics practicum

No	Title	Objectives/Problems	Topics	Tools	Research Findings	Ref.
1	A Novel Arduino-Based Instrument for Measuring the Gravitational Acceleration	Designed and built an Arduino-based gravity acceleration measuring device with the tilt method.	Gravitational acceleration	Arduino Uno, angle sensor, stepper motor, LCD, computer	The research showed an improvement in students' understanding of physics concepts (g = 0.52) after using AR. Both students and teachers gave positive feedback, with students showing high enthusiasm and finding the AR-based practicum easy, fun, and practical	[20]
2	Application of Augmented Reality to Physics Practicum to Enhance Students' Understanding of Concepts	Improve students' understanding of physics concepts through augmented reality (AR)-based practicums.	Heat	AR application "MeCalor"	Improved understanding of physics concepts with positive responses from students and teachers to the use of AR	[9]
3	Determining the Speed of Sound in a Home Experiment	Develop a simple experimental method to determine the speed of sound in the air with everyday tools.	Sound Speed	Smartphone, Spectroid, Audacity, foil	The measured sound speed ranges from 328 m/s to 360 m/s, with errors below 13%	[21]
4	Practical Media to Optimize	Develop MATLAB-based practicum media	Waves	MATLAB, the supportin	MATLAB-based media enhances student understanding with	[22]

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No	Title	Objectives/Problems	Topics	Tools	Research Findings	Ref.
	Online Learning for Students on Sine Wave Material	for online learning of sine wave concepts.		g hardware	positive responses to media and improved science process skills	
5	An Effort to Enhance Student's Computational Thinking Skill	Improve students' computational thinking skills by using expression-based e-worksheets in physics learning.	Direct Current Electrical Circuit	Expression-based e-worksheet (EBEW)	The use of EBEW significantly improves students' computational thinking skills compared to conventional worksheets	[23]
6	Improving Motivation and Science Process Skills Through a Mobile Laboratory-Based Learning Model	Assess the influence of the mobile laboratory-based learning model (MLBL) on students' motivation and science process skills during the COVID-19 pandemic.	Kinetics and Motion	Video analysis of physical phenomena, AR media	MLBL improves students' motivation and science process skills, despite internet access constraints in some areas	[18]
7	Online Physics Practicum Supported by Wireless Sensor Network	Develop an online physics practicum model supported by a wireless sensor network (WSN) to improve students' inquiry skills after the COVID-19 pandemic.	Physics Measurements	Wireless sensors, computer/laptop devices	The WSN-based practicum system improves students' inquiry skills, with high accuracy in data measurement and excellent user acceptance rates	[24]
8	PJB-Lab: Practicing 4C Skills in Physics Practicum	This study aims to test the effectiveness of PJB-Lab in improving 4C skills (critical thinking, creativity, communication, and collaboration) in physics teacher candidates. It also aims to create practical applications of Archimedes'	Application of Archimedes' principle in the submarine project & Application of hydrostatic pressure in the	Tube, small pump, simple construction materials, and pressure and depth measurement tools	JB-Lab has been proven effective in significantly improving students' 4C skills. The scores for critical thinking, creativity, communication, and collaboration were in the high category after participating in PJB-Lab activities. The practicum products, namely the submarine and Hydram, show that students are able to apply physics concepts in real-world	[25]

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No	Title	Objectives/Problems	Topics	Tools	Research Findings	Ref.
		principle and hydrostatic pressure in submarine and hydraulic pump projects.	hydraulic pump (Hydram)		products that function as intended	
9	Application of Augmented Reality to Physics Practicum	Improve students' understanding of physics concepts with augmented reality (AR)-based practicum.	Transfer Panas	AR Applications MeCalor	Increased students' understanding of physics concepts with a positive response to AR	[9]
10	Utilization of Augmented Reality Media in Science Lab Activities	Using AR media in laboratory activities to improve competence in explaining scientific phenomena.	Scientific Phenomena	AR Applications	Improve students' ability to visually explain scientific phenomena through AR	[26]
11	The Development of Virtual Laboratory Assisted by Flash and PhET to Support Distance Learning	Develop a virtual lab using Adobe Flash and PhET for physics practicum during distance learning.	Fluid	Adobe Flash, PhET simulation	Development of effective virtual labs for distance learning in fluid materials	[27]
12	Design and Prototype Testing of the Video Tracker Analysis-Based Uniformly Varied Rectilinear Motion Tool for Uniformly Accelerated Rectilinear Motion and Uniformly Decelerated Rectilinear Motion Experiments	This study aims to design and test a practicum prototype based on video tracker analysis for experiments on uniformly accelerated and decelerated motion. This tool is expected to facilitate students' understanding of the concept of uniformly accelerated motion in physics experiments	Mechanics	Video tracker	The experiment results show that this tool can measure time, speed, and acceleration accurately, in accordance with the theory of uniformly accelerated motion. In the accelerated motion experiment, objects moving down a steeper incline exhibited higher acceleration, consistent with the existing theory.	[7]

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No	Title	Objectives/Problems	Topics	Tools	Research Findings	Ref.
13	Development and Application of a Linear Optics Model for Dielectric Wall Accelerators	This study aims to develop a linear beam dynamics model for the dielectric wall accelerator (DWA) and implement this model in the open-source code TRANSOPTR. This model is used to study beam injection phenomena and beam transport in DWA, with the main goal of assessing longitudinal stability and limiting the transverse beam size.	Optics	The simulation model uses input data in the form of DWA cell configuration	The linear model developed using the TRANSOPTR code successfully predicted the beam dynamics in the DWA, including the transverse and longitudinal beam stability. One of the key findings is the importance of selecting the correct injection energy and acceleration gradient to maintain beam stability	[28]
14	Acceptance of Augmented Reality via Mobile Devices by Higher Education Students in Physics Practical Work	This study aims to analyze the factors that influence students' acceptance of using Augmented Reality (AR) through mobile devices in physics practicum work in higher education, using the Technology Acceptance Model (TAM)	Motion & Force	Online simulation software	Online simulations are effective in facilitating the understanding of waves and optics, with better results than traditional learning methods	[29]

Problems Current Issues of Physics Practicum

In further studies, we examined the underlying issues from several previous research studies. Current issues regarding physics practicum, based on literature reviews from various studies, can be summarized as follows:

Several studies have identified limitations in practical tools that are accurate and affordable, such as in the measurement of gravitational acceleration[20], as well as difficulties in understanding abstract physics concepts through conventional methods,

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which has prompted the use of technologies like Augmented Reality (AR) for better visualization [9]. Additionally, during the pandemic, limited access to formal laboratory equipment led to the need for experiments that can be conducted at home with simple tools [21].

Students' critical thinking and analytical skills in physics practicum have not developed optimally, requiring technology-based approaches and more active project-based learning models [18], [25], [30]. Online learning has also created challenges related to accessibility to learning media, driving the development of media based on MATLAB and interactive technologies to address these limitations [22]. Moreover, the limited development of metacognitive skills in students to control their learning process can be addressed by e-worksheet-based or AR-based learning [11], [23]. The use of virtual reality (VR) is also proposed to provide a more immersive practicum experience, which is crucial during remote learning [27].

Overall, the main challenges in the development of physics practicum include limited access to laboratories, difficulty in understanding abstract concepts, and the development of students' critical and metacognitive thinking skills, which require technology-based solutions to improve learning effectiveness.

Topics and Tools in Physics Practicum

Based on the review of articles related to physics practicums, it was found that the topics explored encompass a wide range of both fundamental and modern concepts in physics. Several articles discuss the measurement of gravitational acceleration using an Arduino-based device [20], while others focus on the topic of heat transfer in physics using Augmented Reality (AR) applications [9]. The speed of sound is also measured in a home experiment setup [21], as well as sinusoidal waves, which are simulated using MATLAB to facilitate interactive understanding of the concept [22].

Other topics include basic physics experiments applied within the context of project-based physics practicums utilizing cloud-based digital communication technologies [15], as well as the use of wireless sensors in physics experiments for measuring distance or other variables [24]. Various experiments also explore abstract concepts in modern physics, such as the measurement of the e/m ratio in electron beams, supported by e-learning-based virtual laboratories [11].

Equally important, several articles discuss direct current circuits and geometric optics experiments through AR-based guides for visualizing complex concepts [31], as well as the use of AR videos and Student Worksheets (LKS) to teach various measurement concepts in physics [10]. In the context of basic physics, some articles also emphasize the importance of mobile learning media in supporting practicum learning [32].

Overall, these articles showcase various practicum methods and tools used to enrich students' understanding of physics concepts, both through hardware and modern software-based technologies.

Looking ahead, there remain significant opportunities to further explore additional topics in physics, particularly those related to quantum physics, particle physics, and astrophysics. Furthermore, the development of practicum tools based on the Internet of Things (IoT) and Artificial Intelligence (AI) for physics experiments could open new

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horizons in physics teaching and research. Further utilization of Virtual Reality (VR) and computer-based simulations for experiments involving more complex physics concepts also represents a promising area for exploration. With the ongoing advancements in technology, the potential to enhance both teaching and research in the field of physics is vast.

Based on the review of 25 articles related to physics practicum, it can be concluded that the tools and devices used are diverse, ranging from conventional to digital technologies, to support the understanding of physics concepts. Some physics practicum, such as the measurement of gravitational acceleration, are conducted using Arduino Uno, a potentiometer-based angle sensor, stepper motor, and LCD, which enable accurate measurement of tilt [20]. Augmented Reality (AR) technology is also used to visualize physics phenomena, such as in the teaching of heat transfer through the "MeCalor" app on Android devices [9]. The measurement of the speed of sound in air involves a smartphone with Spectroid and Audacity apps, along with simple tools such as a pen tube, foil, paper, and cups as resonators [21]. Meanwhile, other basic physics practicum use questionnaires to measure thinking habits [30], as well as MATLAB-based media for interactive sine wave simulations that support online learning [22].

Additionally, technology-based practices are increasingly developing with the use of cloud-based virtual platforms such as Slack, Google Drive, Trello, and Zoom, which enable collaboration in project-based physics laboratories [15]. The use of e-Worksheets for DC circuit practicum also supports understanding through expression-based simulation [23]. Other practicum, such as modern physics experiments (e/m ratio of electron beams), are conducted using e-learning-based virtual laboratories with Google Classroom [11], while video analysis and tracking software, together with AR media, are used to analyze motion and kinetics in observed physics phenomen [18], [33]. For sensor-based physics measurements, several practicum use Wireless Sensor Networks (WSN) connected to computer devices for real-time measurements [24].

Various simple tools, such as submarine and Hydram models, are used to understand Archimedes' principle and hydrostatic pressure in hydraulic pumps [25], while teaching physics concepts like electrical circuits and geometric optics is facilitated with AR-based practicum guides that allow clearer visualization of these concepts [31]. In the context of temperature and heat, Android-based AR media are used to interactively depict these phenomena [26], and general measurements are conducted with AR video-based Student Worksheets (LKS) that support learning [10]. Other basic physics practicum are supported through mobile learning-based guides accessible via Android devices [32], while inquiry-based models are used to improve science process skills in both physics and chemistry practicum [34]. QR-Code technology and 3D videos are also applied in LKS to support discovery learning models in physics practicum [35], while Flash-based virtual laboratories and PhET simulations are used for fluid mechanics in high school physics [27].

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Based on the findings, there are opportunities for future research focused on further developing tools and media for practicum that integrate advanced technologies such as AR, VR, or AI-based simulations to enhance a more interactive and in-depth learning experience. Research into the impact of virtual technology and wireless sensors in improving practical skills and data analysis in physics also holds significant potential. Furthermore, further studies are needed on how cloud-based platforms and mobile applications can be better integrated into the physics curriculum to support more effective and comprehensive online learning

Mapping Bibliometric Analysis of Physics Practicum

Bibliometric analysis mapping was carried out using the VOSviewer application. Several provisions are made, namely, the minimum value of the appearance of the term is 5 times so that 70 terms are found. Figure 3 shows the network visualization between terms. Network visualization shows the connectedness between terms (Al Husaeni & Nandiyanto, 2023). The circle in the figure is a node. The node describes a term found of physics practicum (Al Husaeni & Al Husaeni, 2022). Based on the cases in Figure 3, it is known that the size of the color nodes indicates the number of occurrences of a term (ie the number of times the keyword appears) (Nandiyanto et al., 2021). The greater the circle of a term, the higher the number of occurrences, and the thicker the links between nodes, the greater the total link strength between these terms (Al Husaeni & Nandiyanto, 2022).

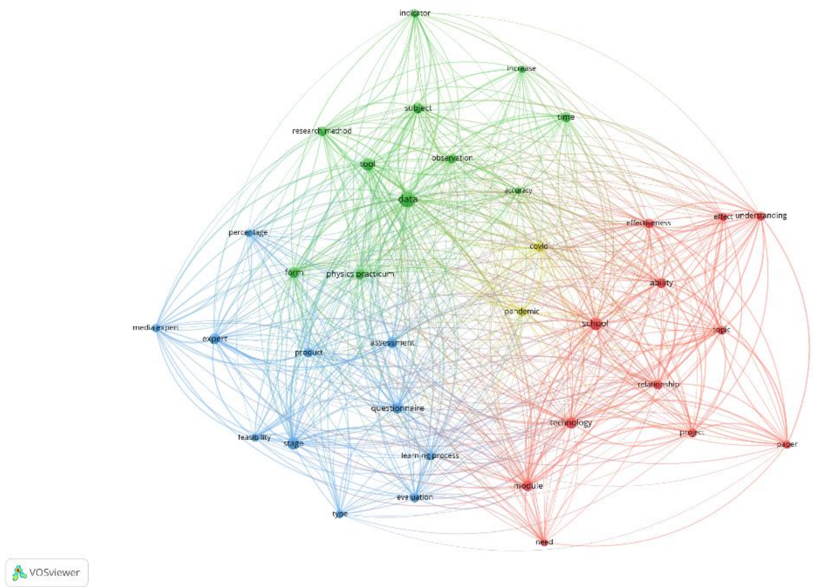

Figure 3. Network visualization of physics practicum

Figure 4 presents a network visualization of the key terms associated with physics practicum, generated using VOSviewer. The central node, "physics practicum", is surrounded by various related keywords that form distinct clusters, each representing a different thematic aspect of the practicum process.

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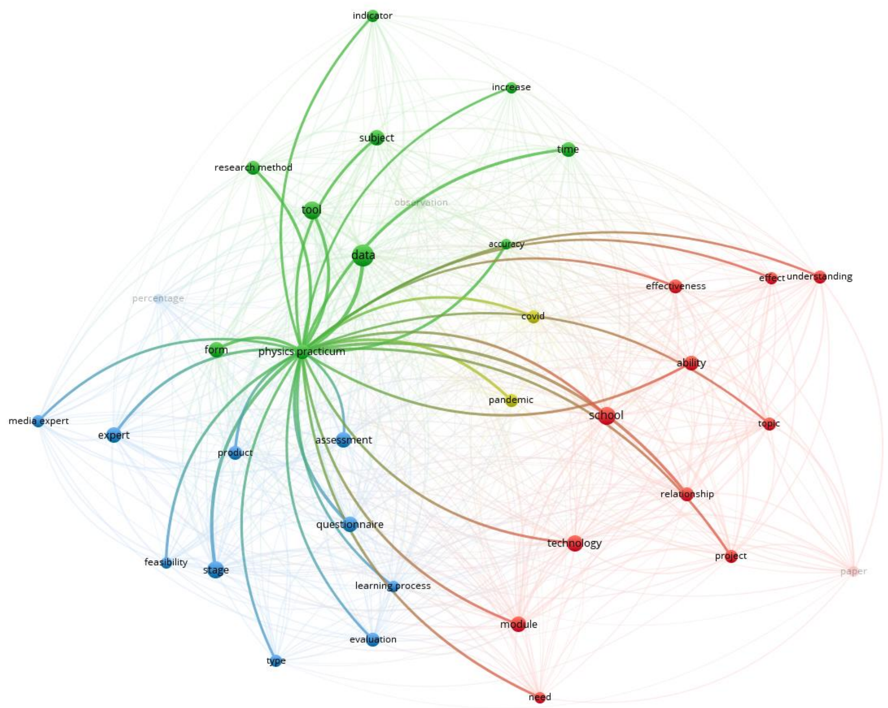

Figure 4. Network visualization of term physics practicum

The first cluster (green) includes terms such as data, tools, research methods, and indicators, which highlight the core components of physics practicum research, emphasizing the importance of data collection, experimental tools, and research methodologies. The second cluster (blue) focuses on assessment, questionnaire, and evaluation, reflecting the critical role of evaluation in assessing students' understanding and skills during the practicum. The third cluster (red) contains terms like technology, project, school, and effectiveness, showing the significance of technological integration in practicum activities and its impact on enhancing student learning outcomes. Finally, the fourth cluster (yellow) includes keywords related to pandemic and covid, indicating the external influences that have shaped the execution of physics practicum, such as the shift to online learning and modifications in the delivery of practicum activities during the pandemic. This network visualization provides a comprehensive overview of the multifaceted nature of physics practicum, highlighting its methodological, evaluative, technological, and external dimensions, and offers valuable insights for improving the design and implementation of physics education practices in the future.

CONCLUSION

Based on the results of the literature review on physics practicum, it can be concluded that research in this area continues to offer substantial opportunities across a variety of fields and practicum topics. A total of 122 publications were identified, with the following distribution: 36 in 2020, 33 in 2021, 16 in 2022, 13 in 2023, 20 in 2024, and 4 in 2025. The analysis of topics and devices used in physics practicum reveals that both conventional and digital technologies—such as Arduino-based sensors, smartphone applications, wireless sensor networks, and advanced technologies like Augmented

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Reality (AR), Virtual Reality (VR), and e-learning platforms—have contributed to more interactive and effective learning experiences. However, significant research gaps remain, particularly in the development of worksheets and assessment tools to evaluate the psychomotor aspects and overall practicum performance of students, areas that have not been comprehensively explored to date. Future research should focus on creating evaluation instruments that provide a holistic measurement of practicum skills. Additionally, the bibliometric analysis using VOSviewer highlights a network visualization of terms related to physics practicum, with "physics practicum" as the central node surrounded by clusters representing methodological, evaluative, technological aspects, and external factors such as the pandemic. This network provides valuable insights for the ongoing development and refinement of physics practicum, offering directions for future research and improvement in the field.

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