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Bibliometric Analysis: The Use of PhET Simulation in Physics Learning

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ABSTRACT

Since the birth of industry 4.0, almost all aspects of life have been projected onto the virtual world or the internet. Then followed again by society 5.0, initiated by the Japanese government. One of the SDGs goals that must be realized is quality education. Not a few teachers have difficulty providing simple experimental tools. PhET simulation is a virtual lab application that provides free trials. PhET simulation is important in helping teachers and students carry out the physics learning process. Given this role, it is necessary to research previous studies regarding the relationship between PhET simulation and other terms and indicate opportunities for further research on PhET simulation. This research uses the text analysis method, presenting the data as bibliometric analysis. Using the Publish or Perish (PoP) application, 930 articles were published in the last ten years. Opportunities for further research based on the results of bibliometric analysis (title and abstract) with the keywords PhET simulation can be linked to critical thinking skills, data, inquiry models, process skills, and perception.

INTRODUCTION

Changes in the pattern of people's lives in the 21st century are very clear. Since the birth of industry 4.0, almost all aspects of life have been projected onto the virtual world or the internet. Then followed again by society 5.0, initiated by the Japanese government. The characteristic of society 5.0 is that it contains three core elements of human-centricity, sustainability, and resilience (Carayannis & Morawska-Jancelewicz, 2022). In the era of society 5.0, the concept of life is centered on humans but integrates the latest technology (Wibawa & Agustina, 2019). The era of society 5.0 is also expected to be able to change and find solutions to social problems by uniting real life and virtual life (Skobelev & Borovik, 2017). Society 5.0, or fashionable society, provides a big opportunity and a challenge for the Indonesian government to realize the 2030 SDGs. One of the goals of the SDGs that must be realized is quality education. It means equal education will be realized, ensuring inclusive education and the opportunity to obtain lifelong education for everyone (Ishatono & Raharjo, 2016).

Education is a conscious and planned effort through learning and teaching. In learning, various branches of knowledge influence life, one of which is physics. Physics is what discusses natural phenomena, energy, celestial bodies, motion, and others. Physics learning is inseparable from observation and experimentation (Suprapto et al., 2020; Dasilva, 2019). If students do not do experiments in learning, student misconceptions will easily occur (Dhanil & Mufit, 2021). One of the efforts made through inquiry-based learning activities is through experimental activities.

Experiments are investigative activities to obtain data and test hypotheses from the physics problems found. Experimental activities aim to provide experience for students to gain direct learning so that students' thinking skills increase (Yunzal & Casinillo, 2020). In addition, experimental activities in physics aim to compare the material concepts studied against the results obtained (Dhanil & Mufit, 2021). However, the problem is the limited experimental equipment at school, which causes student-oriented learning conduct investigations not to occur (Yunzal & Casinillo, 2020). One alternative form of carrying out experimental activities in schools is through a virtual laboratory.

A virtual laboratory is an experimental device accessed through software such as smartphones and computers. In the virtual laboratory, real experimental equipment is available in virtual form. One form of virtual laboratory that is often used in learning is PhET. PhET is a simulation medium used to demonstrate or conduct virtual physics experiments (Rizaldi et al., 2020)(Novebrini et al., 2021). PhET provides various forms of physics experiment simulations with data presentation and user input (Ayu & Festiyed, 2019).

The presence of PhET as simulation results in various investigative studies related to learning using PhET. In studying physics, PhET can improve students' learning abilities (Bektiarso et al., 2022). PhET is a simulation suggestion that helps inquiry-based learning occur (Susilawati et al., 2022). Using PhET encourages student-centered learning. PhET can improve students' learning abilities (Susilawati et al., 2022) (Yanti et al., 2020). In addition, PhET can be used as a medium in online learning (Blacer-bacolod, 2022). Various forms of PhET-related research provide new challenges for future researchers.

Bibliometric studies are necessary to analyze a broad set of information related to published data (Comarú et al., 2021). Data was obtained using mathematical and statistical methods to analyze publications (Thompson & Walker, 2015) scientifically. The results of bibliometric research show the growth of the research field (Dehdarirad et al., 2015). The information presented in the bibliometric is in the form of data from related studies in the form of authors, countries, and evolution of publications from time to time in countries and journals intended for the publication of similar research results (Mathankar, 2018). Bibliometric techniques can generate similar broad sets of information (Comarú et al., 2021). Thus, bibliometrics is used to assist in understanding the theoretical roots of a particular scientific field.

This study aimed to conduct a bibliometric analysis of the effect of using PhET simulation in learning physics and to find out the trend of publications with PhET simulation. In order to produce bibliometric data and network analysis, various related articles were obtained through Google Scholar, with a population of 930 articles used to analyze the study findings.

METHODS

This research is a bibliometric analysis research and literature study about simulated PhET. This study uses the Publish or Perish (POP) and VOS Viewer applications. VOS viewer is a software capable of displaying bibliometric maps and publication trends in the

past few years. The steps in the research include (1) collecting data from the Publish or Perish (POP) application, (2) recording data from search results in the POP application, (3) analyzing article data using the VOS viewer application, (4) storing data in image form (5)analyze the relationship between the terms obtained. The results of the VOS Viewer analysis consist of three categories: networking visualization, overlay visualization, and density visualization. Networking visualization will display the analysis results of terms interrelated with research results related to PhET simulation. Overlay visualization will display research results for the last ten years. Density visualization shows the density of key terms with other terms.

RESULTS AND DISCUSSION

Search results using POP obtained as many as 930 international journal articles and proceedings. The data is taken from the commonly used database, namely Google Scholar. It aims to obtain many research data. The total number of citations, yearly, per paper, and author were 7838, 783.80, 8.43, and 2.45, respectively. The citation metric also shows an h-index and g-index of 42 and 59. The authors are not only from Indonesia but come from various countries in the world. While the keywords written to obtain data are PhET simulations.

In the next stage, the article will be stored in RIS format to read in the VOS Viewer application. The analysis results obtained 11 clusters and 181 terms related to PhET simulation. Data analysis on the VOS viewer consists of three: networking visualization, overlay visualization, and density visualization. The VOS viewer also displays clusters of terms in research with the keyword PhET simulation, as shown in Table 1.

Tabel 1. Cluster Division

Cluster	Term
1	Collision, Critical Thinking Skill, Direction, Dynamic Electrical Material, A Handout, Equivalent Fraction, Guided Discovery, Independence, Light Refraction, Parabolic Motion, PBL, PhET Application, PhET Media Simulation, PhET Simulation Application, Scaffolding Approach, Scaffolding Approach Assists, Science Learning, Significant Effect, Simulation Model, Simulation PhET, Student Conceptual Understanding, Student, Problem Solving, Usability, Utilization, Vibration, Wave, Wave Material.
2	Active Learning, Auditory Display, Description, Design Principle, Educator, Educator Perception, Energy, Evaluation, Focus, Goal, Information, Interaction, Interactive Science Simulation, Interactive Simulations, Internet, Lesson, Opportunity, Perspective, PhET Project, PhET Website, Physics Teaching, Science Teaching, Set, Sound, Value.
3	Alternative, Conservation, Didactic Strategy, Discovery, Exploration, Force, ICT, Interactive Computer Simulation, Matter, Pandemic, PhET Platform, PhET Simulation Media, Physics Concept, Physics Concepts, Physics Learning, Platform, Play, Simulator, Teaching Physics, Way, Work.
4	Cognitive, Demonstration Method, Dynamic Electricity, Dynamic Fluid, InquiriBerbantuanPhET, Inquiry Training, LKPD, LKS, PBL Model, Pembelajaran, PhET Simulation, Program, Student Achievement, Student Experiment, Students Worksheet, Virtual Experiment, Virtual Lab PhET Simulation, Virtual PhET Simulation.
5	Accessibility, Biology, Challenges, Feedback, Inclusive Design, Inquiry Activity,

	Interactive Visualization, Math, PhET Interactive Simulation, PhET Interactive Simulation, PhET Team, Practice, Present Study, Science Education, Science Simulation, Simulation Design.
6	Collection, Combination, Data, Increase, Kinetic Theory, Lab, Laboratory Experiment, Mechanical Wave, Models, Perception, Physics Educational Teaching, Physics Teacher, Students Misconception, Subject, Video, Virtual Simulation, Virtual Simulation Medium.
7	*Belajar*, Charge, Elasticity, Impulse, Inkuiri, Inquiry Model, *Laboratorium*, PhET Simulation, *Momentum, Pembelajaran Inkuiri*, *Penerapan Model*, *Pengaruh Model*, *Pengembangan*, PhET Virtual Laboratory, Real Laboratory, *Simulasi PhET*, Virtual Laboratory Medium.
8	Collaborative Creativity Learning, Contribution, Inquiry Learning, PhET Simulation, Software, Physics Subject, Practicality, Projectile Motion, Student Science Process, Student Worksheet, Teaching Material, Temperature, Validity
9	Comprehension, Content, Critical Thinking, Electrical Circuit, Learning Model, Learning Outcome, Media PhET Simulation, Physics Lesson, Scientific Simulation, Treatment.
10	Distance Learning, Field, Interactivity, Modern Physics, Online Learning, PhET Computer, Simulation, Physics Class, Quantum Physics, Role.
11	Control Group, Electromagnetism, Experimental Group, PhET Simulation Laboratory, PhET Simulator, Simulations, Solar System, Student Engagement.

Networking Visualization (NV)

Visualization of the relationship between terms can be seen in Figure 1. A different color distinguishes each cluster.

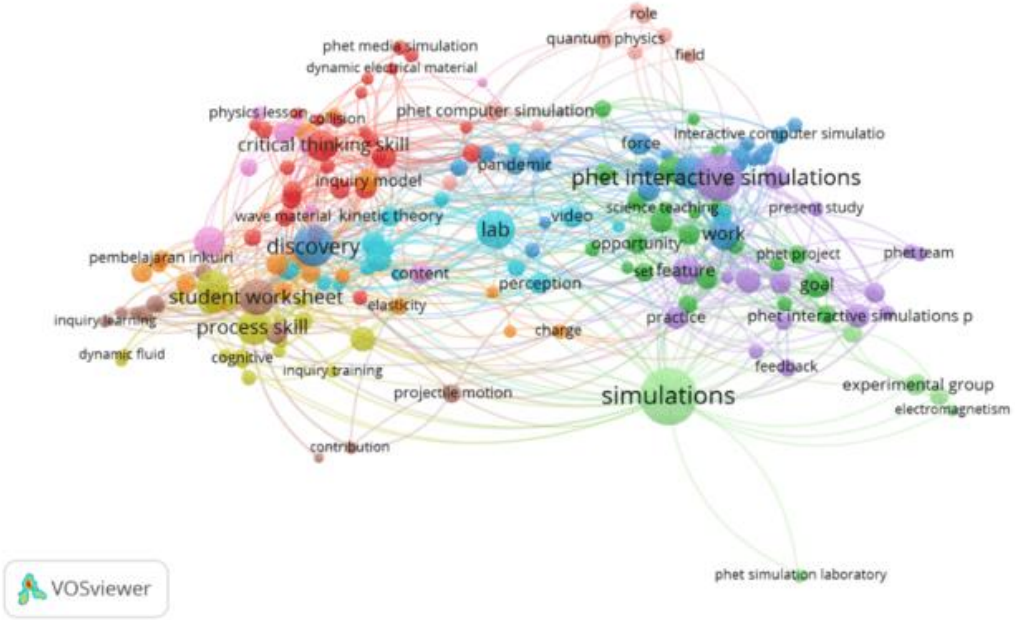

Fig. 1. Networking Visualization

Based on the picture, seven terms have large circles, namely simulations (green), PhET interactive simulations (purple), critical thinking skills (red), discovery (dark blue), student worksheets (brown), process skills (light green), and lab (blue). The simulation terms are interconnected with 55 other terms, and 44 relationships were formed. Each cluster also

forms relationships with other clusters. Among the terms significantly related to simulations are discovery, critical thinking skills, process skills, lab, pandemic, and cognitive. Another term often used by researchers is PhET interactive simulations. This term has a relationship with 40 other terms, and 31 relationships are formed. Among the terms often used in PhET interactive simulations are physics class, lab, student worksheet, process skill, virtual simulation, practice, and accessibility. Then, the red cluster shows a relationship between critical thinking skills and 17 other terms, and 21 relationships are formed. Among the terms often researched using critical thinking skill variables are utilization, information, model simulations, process skills, and physics concept. Several terms with the keywords PhET simulations have not been used by researchers, such as perception, data, inquiry, and others. Thus, there are still opportunities to find novelty research displayed by the visualization network.

Overlay Visualization **(OV)**

The second analysis is an overlay visualization that displays research updates related to PhET simulation. The articles were obtained from 2012 to 2022, or the last ten years. The result of the analysis can be seen in Figure 2.

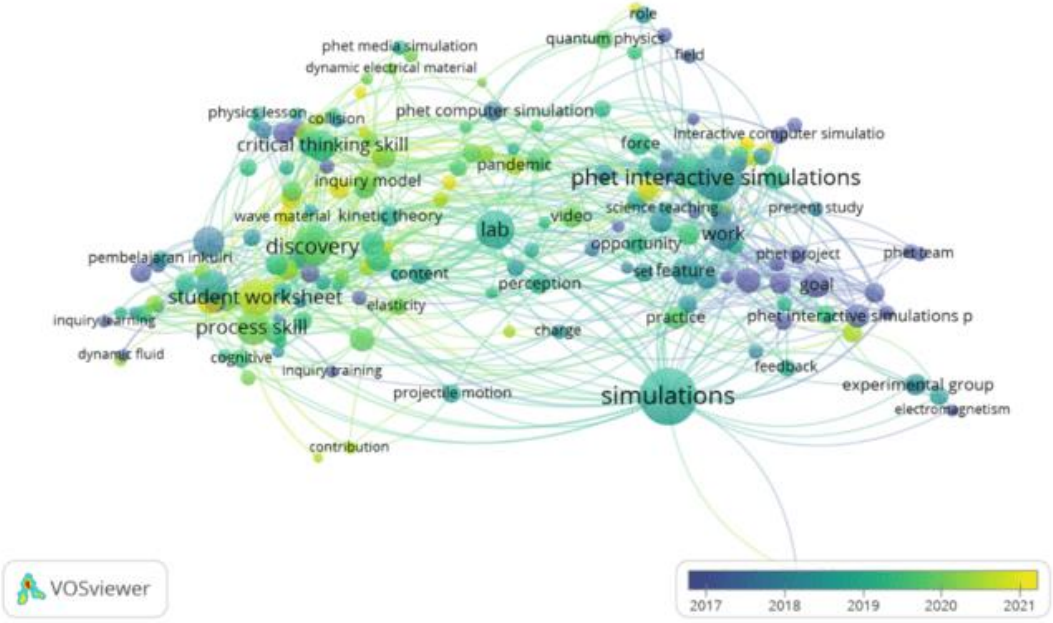

Fig. 2. Overlay Visualization

Based on Figure 2, it can be seen that there is a spectrum of dark and light colour. The meaning of this colour is the darker the colour displayed by the VOS viewer, indicating that research with this term has been carried out for a long time and vice versa (Yu et al., 2020). Furthermore, the brighter colour displayed by the VOS viewer shows that research with this term is still new (Durieux & Gevenois, 2010) (Gómez-Domínguez et al., 2022). The analysis results explain that the latest research with research terms using the keywords PhET simulation includes those related to pandemics, inquiry models, and worksheets. Inquiry learning, the PhET team, and the PhET project are terms that have long been researched by research using the keyword PhET simulation.

Density Visualization (DV)

Figure 3 shows the results of the VOS viewer density visualization with the PhET simulation keyword.

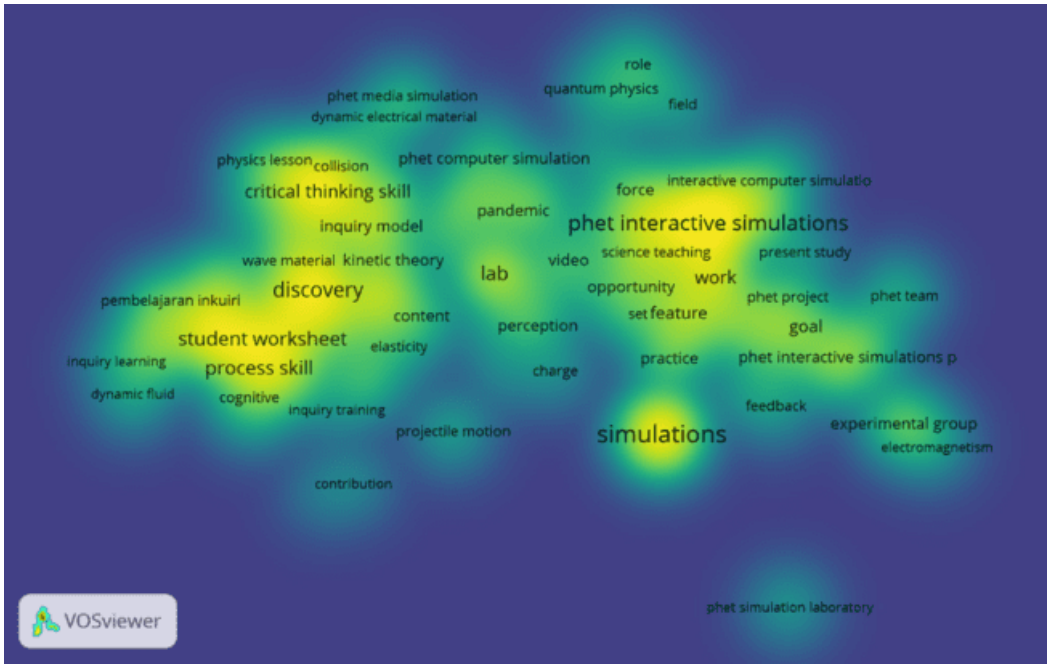

Fig. 3. Density Visualization

Based on Figure 3, terms that have a bright, bright background color, like yellow, indicate that research with these terms has been frequently researched and vice versa (Blacer-bacolod, 2022) (Donthu et al., 2021) (N. J. Van Eck & Waltman, 2014). The display of density visualization can show that the background color is increasingly blurry, as shown by the VOS viewer on this term. It means there still needs to be more research done by researchers, especially with the keyword PhET simulation. Often used terms include simulations, student worksheets, discovery, process kill, critical thinking, PhET interactive simulations, and inquiry models. Previous researchers have extensively researched this term related to learning using PhET simulations. Terms that have yet to be widely researched include contribution, feedback, charge, role, field, inquiry learning, opportunity, and inquiry training. This term is important for future researchers because it can become a gap, for example, investigating the correlation between variables.

CONCLUSION

PhET simulation research needs to be improved to determine the level of success of students in mastering physics experiments. The existence of a PhET simulation can assist teachers in training students' scientific skills, especially conducting physics experiments. In addition, PhET simulation is a virtual lab that provides many abstract simulations such as heat, gas kinetic energy, static electricity, dynamics, electron movement, and others. The researcher recommends that future researchers review the literature reviews about variables that have been widely researched before, as shown in networking visualization, overlay visualization, and density visualization.

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