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A Systematic Literature Review of Physics Education Teaching Regarding Oscillations

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ABSTRACT This article provides a detailed analysis of the various methods used in physics classrooms to teach oscillation and its related concepts. We thoroughly searched reputable databases, including Scopus and Web of Science. We analyzed 50 articles published between 2018 and 2023 using content analysis techniques such as elimination, classification, and grouping into themes. Our unit of analysis was the articles' methods, results, and conclusions. The results of this study are: (1) The trends in the development of research on the topic of oscillation and its derivatives from 2018 to 2023 indicate a declining interest. (2) During the period from 2018 to 2023, Indonesia emerged as the primary contributor to research on the topic of oscillation; (3) From 2018 to 2023, researchers predominantly focused on the topic of pendulum in the field of oscillation research (4) The most prevalent method for imparting oscillation content and its derivatives employed by researchers between 2018 and 2023 was experimentation, and (5) The most prevalent type of empirical research conducted on the topic of oscillation between 2018 and 2023 was pure research involving laboratory experiments. This systematic literature review is a foundation for developing various learning tools such as teaching materials, technology-based instructional media development, and primarily instruments related to oscillation and its derivatives. Overall, this systematic review highlights the need for more research on effective teaching methods for oscillation and provides practical insights for educators and researchers alike.

Keywords Oscillation, Science, Physics, Teaching, Systematic literature review

1. INTRODUCTION

A systematic literature review (SLR) identifies, evaluates, and interprets all available research on a specific research issue, subject area, or phenomenon of interest (e.g., Powell & Koelemay, 2022; Zhong & Xia, 2020). In the context of oscillation, an SLR would involve a comprehensive search of databases such as Scopus and Web of Science to identify all relevant articles published. The articles would then be screened and assessed for quality and relevance using pre-determined inclusion and exclusion criteria (Chong, Lin & Chen, 2022; Krnic Martinic, Pieper, Glatt & Puljak, 2019). Data would then be extracted and analyzed using rigorous statistical and content analysis techniques to synthesize the findings from the included studies. An SLR aims to provide an unbiased, comprehensive, and reproducible overview of the current state of knowledge on the topic of interest (Farrokhnia, 2020; Nyirahabimana, Minani, Nduwingoma & Kemeza, 2022). SLRs are particularly useful in fields such as physics education, where a large and complex body of literature exists and where there is a need to identify the most effective teaching methods for complex concepts such as oscillation. By following a standardized and rigorous process, an SLR can provide valuable insights into the best practices for teaching oscillation and related concepts, as well as identify gaps in the current knowledge that require further research.

To conduct a thorough review of the teaching of oscillation and related concepts, it is crucial to first identify how the topics related to oscillation are being taught in the classroom. Teachers must continually modify their professional abilities in order to be able to teach in the

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various educational positions they may hold if we are to continue to increase the quality of teaching and learning (Borrachero et al., 2019; Mallidis-Malessas, Iatraki & Mikropoulos, 2022). Following the theoretical lessons, students are instructed to show the rules and theories that are then presented as "unquestionable" by the teacher or the textbook in an authoritarian manner. The second one is based on a learning model that encourages students to independently "build" scientific knowledge while interacting with their surroundings. This learning model produces cognitive outcomes that result from an inductive process and are derived from common sense. The third, experimentation, is defined as introducing the apprentice to scientific procedures while simultaneously promoting the abstraction of conceptual information that enhances the subject's aptitude for "doing science" (da Silva, Laburú, Camargo & Chistófalo, 2019; Purba & Hwang, 2018). It is necessary to expose the present status of previous research to develop a solid foundation for teaching oscillations. This will allow for the establishment of a robust foundation. It is beneficial to add to the body of literature, and one way to do so is by meticulously evaluating the publications. Considering the difficulties described earlier, doing such an analysis on a country-by-country basis to ensure the reliability of the results is an effective way to make a valuable contribution to the existing body of research.

Even though primary, middle, and high school curricula, as well as teacher training programs worldwide, include subjects related to the concept of oscillation, academic research on how to teach these subjects has only recently begun (in the 2000s) (Aygün & Hacıoğlu, 2022; Farrokhnia, 2020; Karamustafaoğlu, 2012), research has discovered that when elastic waves propagate in periodic elastic composite media, they would have elastic wave band gaps like the photonic band gaps of electromagnetic metamaterials (Ingram & Motta, 2020). It may be a sign of these challenges why a scientific understanding of the oscillation concept has developed more slowly than other ideas. (Chiriacescu, Chiriacescu, Miron, Berlic & Barna, 2020; Lisboa, Peña, Negrete & Dib, 2021). As an illustration, it was discovered that the oscillation concept is perceived as a wave-converting substance. This impression among students may make it challenging to teach the topic. Several publications have found that diverse student groups and teacher candidates have similar knowledge gaps and misunderstandings (Hauko, Andreevski, Paul, Šterk & Repnik, 2018; Volfson, Eshach & Ben-Abu, 2021). It may continue to be difficult to perceive globally, limiting its literary contribution.

Meanwhile, in many nations' science and physics curricula, oscillation topics are covered directly or indirectly at various grade levels (Hauko et al., 2018; Kurniawan, Kusairi, Puspita & Kusumaningrum, 2021). The concept of oscillation is significant because it applies to numerous scientific disciplines, including physics, mathematics, engineering, and biology. A solid grasp of the concept of oscillation can aid in modeling natural phenomena like vibrations, sound waves, and electronics, as well as technological applications like ocean wave power generation and digital signal processing. In addition, a fundamental comprehension of music and art requires understanding oscillation (Rinaldi & Fauzi, 2020; Sumardi, Amalia & Prabowo, 2022; Volfson et al., 2021).

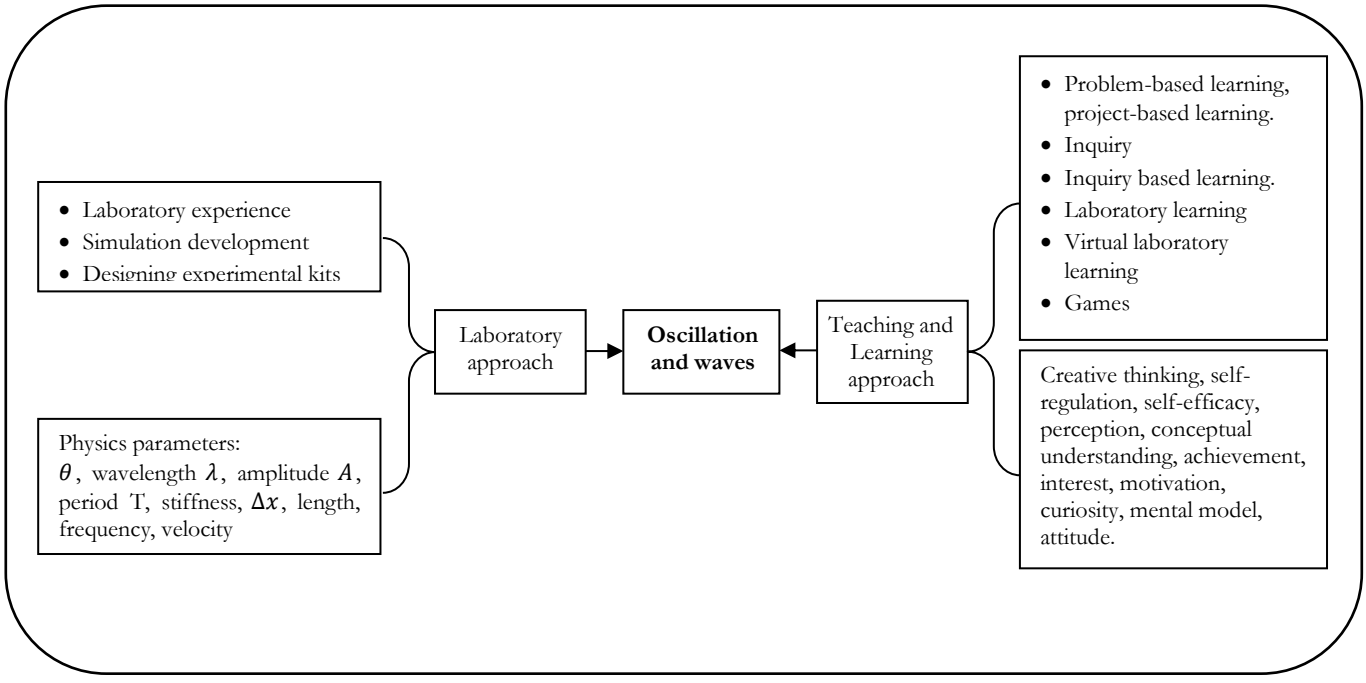

Figure 1 Conceptual framework of oscillation and waves

Researchers who intend to conduct further research in this field may find it helpful to refer to this review to update their knowledge and interpret their findings. The study's examination of the articles revealed that science and physics instruction addressed the topic of oscillation with some aspects of any domain of cognitive, any methods, and any skill aspects independently or jointly. Numerous studies have investigated the delivery of oscillation material within the classroom setting. These examinations have employed diverse instructional models, assessed a range of cognitive skills, and extensively explored the characteristics of spring materials without instructional interventions. Nevertheless, there remains a lack of studies that integrate the problem-solving approaches employed in earlier research with contemporary investigations. This juxtaposition aims to compare the methodologies adopted in historical studies with the contemporary emphasis on both pure content and pedagogical considerations within the overarching framework of research. An in-depth introduction to oscillation is presented for those working in education, research, and software development in science and physics. Importantly, this study does not attempt to criticize the methodology or the substance of the papers it examines. For clarity, please refer to the following Figure 1

1.1. Rationale

Several fundamental reasons necessitate a reevaluation of the topic, including the increase in relevant published literature on oscillation and the limited scope of previous assessments that covered oscillation content in learning and oscillation as a subject matter. The last five years of research on oscillation in learning have produced 33 articles that will be discussed in this systematic review. In contrast, the remaining 17 articles are devoted to oscillation and its derivatives in laboratory and mathematical evaluations. The exploration of articles within the last five (5) years was chosen due to the rapid evolution of research themes, ensuring that the discussions are contemporary and up-to-date, and considering the resource capabilities for data processing. Therefore, this article contributes to providing sufficient information for researchers interested in studying the topic of oscillation and its derivative concepts specifically. In this research, the researchers formulated several questions to guide the readers in understanding this article more easily.

1. What are the trends in the development of research on the topic of oscillation and its derivatives from 2018-2023?
2. Which country mostly conducts research on the topic of oscillation within the range of 2018-2023?
3. What are most topics addressed by researchers in oscillation research from 2018-2023?
4. What are the most prevalent methods for imparting oscillation content and its derivatives employed by researchers between 2018 and 2023?
5. What was the most prevalent type of empirical research conducted on oscillation between 2018-2023?

2. METHOD

This research, a systematic review, looked at worldwide articles on the teaching of oscillations. The ability to map and summarize the current body of knowledge regarding primary research on a particular subject is one of the possible contributions of systematic reviews to the research field (Nyirahabimana, Minani, Nduwingoma & Kemeza, 2022; Powell & Koelemay, 2022). A systematic search technique may or may not be used in systematic reviews. It is better to use the systematic review method in this study. Creating a conceptual framework and creating research questions are the first two steps of a systematic review (Tinmaz, Lee, Ivanovici & Baber, 2022).

2.1. The searching strategy

The author used keywords or keyword combinations. There are six combinations of keywords to look for in the article. The combinations are (1) elasticity, Hooke Law, (2) vibration oscillation, (3) spring, stress, and strain; combination (4) simple harmonic pendulum; (5) sound and wave, (6) plastic and nonplastic. Those related to the concept of oscillation and its derivatives search for relevant literature in the two most popular databases, Scopus and Web of Science. The document search had been limited to journal articles published between 2018 and 2023 and only in the form of journal articles.

2.2. The Selection Criteria

This article's sources were based on Scopus and Web of Science. The 50 documents among the findings appeared to be duplicated (The selection process is like Figure 2). There were five inclusion criteria were then used to screen the abstracts and compile relevant studies:

1. The articles processed were limited to those published in journals.

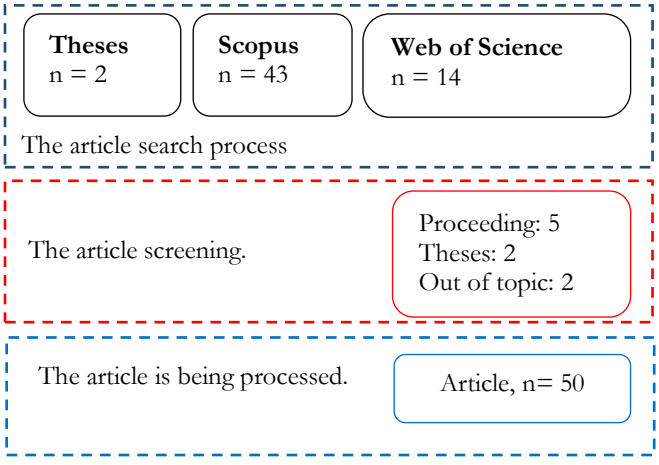

Figure 2 The process of determining articles to be reviewed

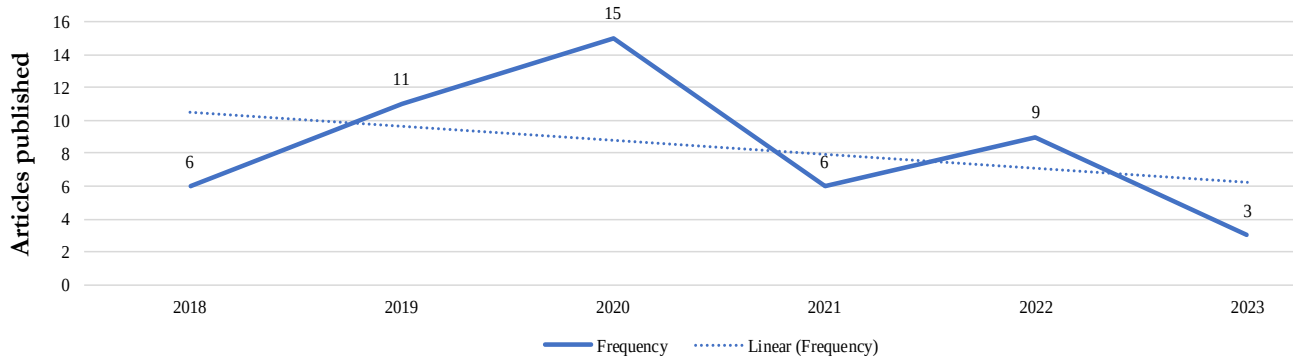

Figure 3 Trends in oscillation research

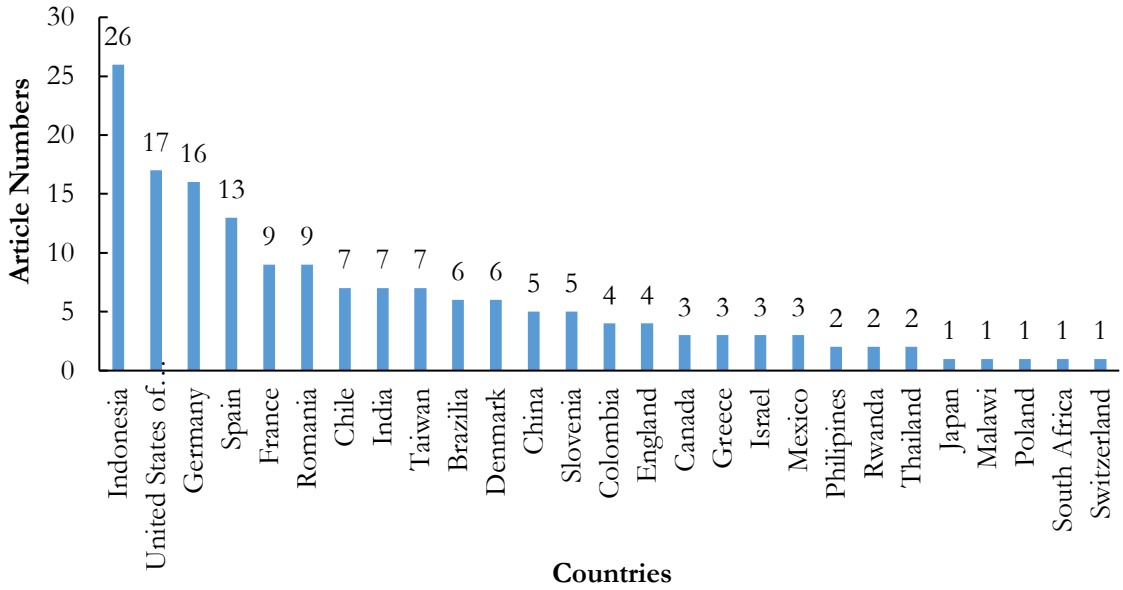

Figure 4 The distribution of articles' authors by country

2. The study investigated the topic of oscillation and its derivatives.
3. The study utilized quantitative, qualitative, and mixed methods data.
4. The study involved the analysis of oscillation in any given subject.

The research was conducted in science education and applied science classes.

2.3. Data Analysis

The author summarized common concerns and themes then coded and extracted them into a categorization matrix using Microsoft Excel software. To fulfill the study subjects, articles were coded and categorized in the following:

1. The identification details of the article, including the author's name, country of origin, publication year, and topic addressed, are considered during the analysis.
2. The approach employed in the learning process is considered in synthesizing the article.
3. The synthesis of the article takes into account the research methodology utilized.

3. RESULT AND DISCUSSION

3.1. Trends of research

The analysis revealed a declining trend in publications about oscillation. In 2020, 15 research articles were published, whereas in 2023, only three were published. As the year is still just beginning (until June 2023), this is to be expected, and the number of articles will probably increase by the end of 2023. In 2020, this oscillation topic was covered in publications from eight countries, including Indonesia and the United States, which each published four articles.

3.2. The country that mostly conducts research.

In addition, a bibliometric analysis is conducted to assess each country's contribution. Figure 4 displays the distribution of articles' authors by country. Indonesia and the United States of America (USA) dominate the list of publications on oscillation topics in physics, with 26 and 17, respectively. Germany in the 3rd with 16 authors,

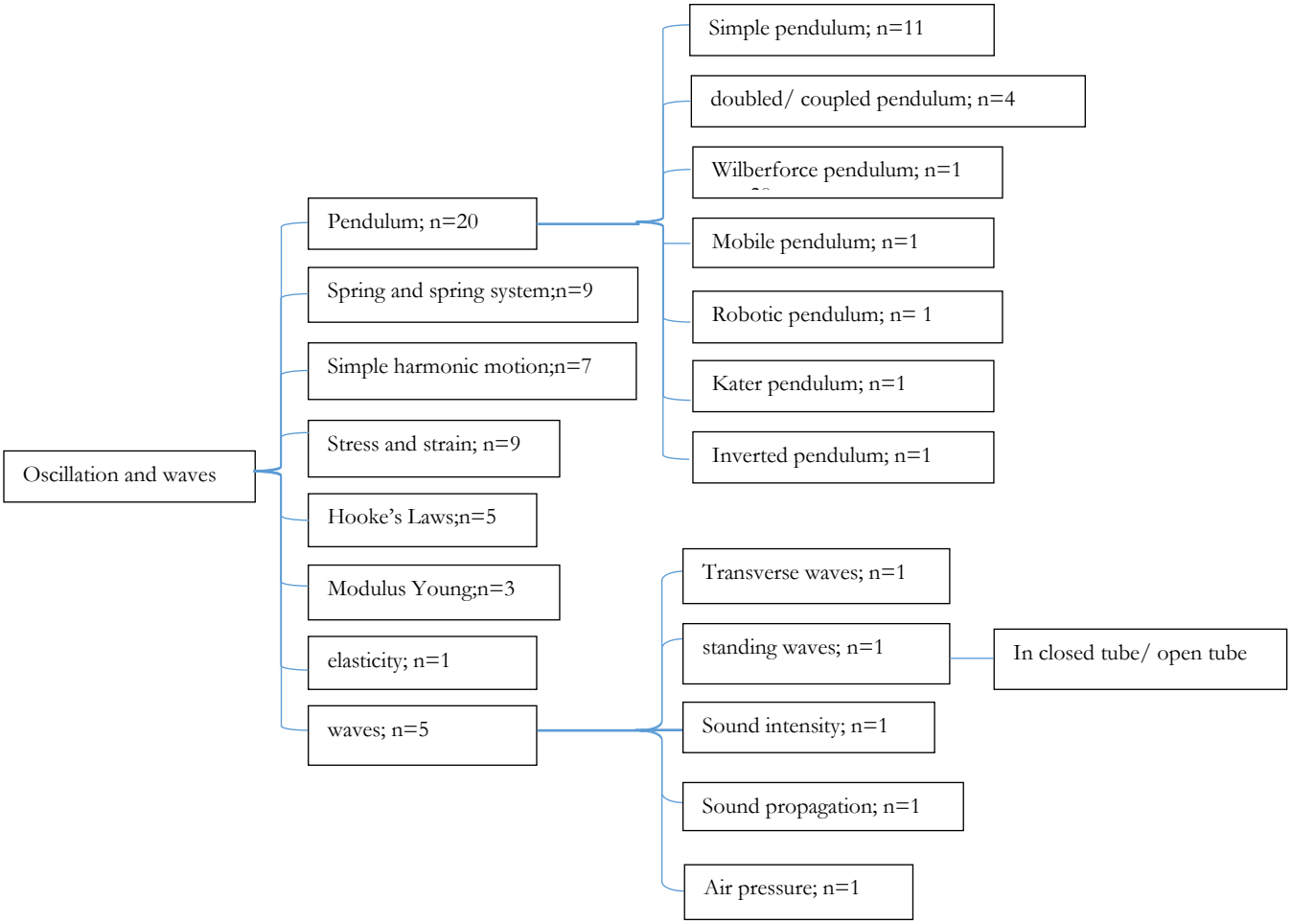

Figure 5 Distribution of sub-concepts of oscillation from systematic literature review

followed by Spain with 13 authors. Additionally, France and Romania are each represented by nine authors. The calculation of the number of authors is done on a per-country basis. For example, if an article consists of 3 authors from Indonesia, Malaysia, and Australia, the researcher records the data as one author from Indonesia, one from Malaysia, and one from Australia. Conversely, if an article is written by five individuals from the same country, the researcher records it as one country, but the number of authors is still counted as 5.

3.3. The topics that researchers most addressed.

Following the process of document analysis, the researchers prepared an overview of the themes presented in each of the 50 articles. The pendulum, spring and spring system, simple harmonic motion, stress-strain, Hooke's law, Young's modulus, waves, and elasticity are the eight sub-concepts of oscillation that researchers worldwide most frequently investigate. All of these sub-concepts, the pendulum and wave sub-concepts have been studied extensively. It is noted that the sub-concept of the pendulum is further subdivided into seven sub-sub concepts and wave into five sub-sub concepts. In other words, numerous research opportunities exist for the remaining six oscillation sub-concepts, including Hooke's law and others. Figure 5 depicts the distribution of sub-concepts of oscillation from systematic literature review.

3.4. The most prevalent methods for presenting oscillation content by researchers.

When presented appropriately, the oscillation content will benefit both the instructors and the students. In this section, we will examine how to present oscillatory content and its derivatives in the context of learning. When it comes to the actual learning process, utilizing a specific method typically entails not just one but multiple different combinations of approaches and instructional strategies. Only eight articles did not describe how the learning process was carried out directly, which caused the researchers to have difficulties determining how the learning process was carried out. In conclusion, the recapitulation of the oscillation content learning can be observed in Table 1. This table demonstrates that learning procedures that rely on minds-on, such as analogy and context-based idea maps, are seldom used in science, whereas learning, primarily dependent on hands-on activities, dominates the field.

Tabel 1 The list of learning approaches

Learning Approach	f
Problem Based Learning	4
Project Based Learning	1
Inquiry/ Based Learning	5
Simulation	8
Smartphone-based learning	6
Laboratory	6
Experiment	13
Computer-based Learning	2
Concept-Context Map	1
Analogy	1
Augmented Reality	1
Not available	8

3.5. The most prevalent type of empirical research methodology used by researchers.

There are a total of fifty empirical studies, eleven of which are purely research-based (laboratory experiments), three of which use mixed methods, eleventh of which use quasi-experiments, three of which are qualitative, one of which uses task-based interviews, one of which is a survey, and two of which use Research and Development. Regrettably, there are still 22 papers that do not make it clear if the research is qualitative, quantitative, or a mixture of the two. Nevertheless, the researcher assumes that these studies indicate a trend towards pure research or the calculation of variables, solving variables mathematically (10 articles), utilizing survey methods to distribute instruments (3 articles), qualitative methods: elucidating how students utilize a specific media or tools (5 articles) in the process of comprehending the concepts of oscillation and its derivatives, describing software, features, and elements relevant to the concepts of oscillation and its derivatives (3 articles), and analyzing the usage of various types and forms of springs (2 articles). These assumptions are not listed in Table 2 as they represent the researcher's subjective analysis rather than being based on written statements in the analyzed documents.

Table 2 Summarizes research methods

Methodology	**f**
Mixed Methods	3
Quasi-experimental	8
Qualitative	3
Task-based Interview	1
Research and Development	2
Laboratory experiment	11
No explicit of research methods	22

3.6. Implications for Research and Practice

The review provides a helpful summary of research on oscillation topics in physics and engineering education, which enhances our understanding of their distribution among authors, affiliations, publication years, and target participants, as well as learning approaches and methods. Moreover, this synthesis can be a reference for future researchers who aim to build upon the existing knowledge in physics learning.

RQ 1: What are the trends in developing research on oscillation and its derivatives from 2018-2023?

The prevalence of research advancement in oscillation and its derivatives is declining. This can be understood as the importance of learning the fundamental concept of oscillation, whose applications and derivatives have a broad range of applications, such as in the discussion of waves (Garcés-Gómez, López, Cárdenas, Henao-Cespedes & Toro-García, 2020; Lisboa, Peña, Negrete & Dib, 2021) and in the creation of sounds (Lisboa, Peña, Negrete & Dib, 2021; Volfson, Eshach & Ben-Abu, 2021). In addition, the current development in research is interdisciplinary, so that a topic is not being addressed merely within a single discipline but across multiple fields of study (Bathgate et al., 2019; McComas & Burgin, 2020). However, despite a decreasing pattern, this research will continue because physics and physics education program students must take a course on this subject (Batlolona, Diantoro, Wartono & Latifah, 2019; Batlolona, Diantoro, Wartono & Leasa, 2020).

RQ2. Which country mostly conducts research on oscillation within the range of 2018-2023?

Indonesia is the country where oscillation and its derivatives research are most prevalent. This indicates that 1) The topic of oscillation and its derivatives is still a primary concern for researchers, including those in Indonesia, and 2) There is a possibility that numerous problems, such as content-related, misconception-related, and learning-process-related problems, plague this topic. Consistent with previous research, which found that misconceptions about oscillation persist (Ballesta-Claver et al., 2021; Volfson, Eshach & Ben-Abu, 2021), these findings indicate that misconceptions about oscillation persist. In addition, the concept of oscillation is taught in Indonesia's elementary, secondary, and higher education curricula, and it is one of the most important ideas that must be conveyed to students. It is not remarkable that numerous publications, particularly on the subject of oscillation, originate from authors affiliated with Indonesian universities.

RQ3. What are most topics addressed by researchers in oscillation research from 2018-2023?

Researchers frequently discuss pendulums (20 articles), springs and spring systems (9 articles), simple harmonic motion (7 articles), Hooke's law, strain and stress, and waves, each with five articles, as the primary topics of oscillation. Pendulums, for instance, have been investigated from various angles, including double pendulum systems, inverted pendulums, Kater's pendulum, and even robotics. Moreover, the applicability of oscillation in wave concepts is addressed extensively in this research, with five articles devoted to the topic. This further indicates that the

application/derivatives of the oscillation concept are expansive and must be investigated in additional contexts. This is consistent with Dandare's (2018) and (Ionascu, 2022) assertion that students must have a solid grasp of fundamental physics concepts as a prerequisite for further study. It is widely accepted that oscillation is included in fundamental physics concepts.

RQ4. What are the most prevalent methods for imparting oscillation content and its derivatives employed by researchers between 2018 and 2023?

Following the use of virtual laboratories or simulations, inquiry learning, and problem-based learning, actual laboratory experiments were found to be the most prevalent method for teaching the concept of oscillation among the 13 articles analyzed in the study. While analyzing the data, it was discovered that eight articles did not mention the teaching method employed in the classroom. The results of these studies (n = 8) provide insufficient explicit information regarding the teaching processes applied in the context of oscillation learning. These articles are generally associated with distributing instruments and processing their results, utilizing specific software/hardware explaining their outcomes, and employing particular media. It can be concluded that 42 (out of 50) of the analyzed articles used innovative learning designs to teach oscillation and its derivatives. Innovative learning in these articles can refer to the freedom of students to investigate activities independently, the development of their knowledge through the performance of teacher-designed activities, and the use of engaging computer applications or non-computer teaching media. This is consistent with previous research indicating that implementing technology in education is essential for students to visualize and comprehend abstract concepts (Banda & Nzabahimana, 2023; Price & Mohr, 2019).

RQ5. What was the most prevalent type of empirical research conducted on oscillation between 2018-2023?

Based on the analysis of 50 articles presented in this study, 28 studies explicitly state the research approach used, and some even clearly state the research method and design used. Of these 28 articles, 11 studies were conducted in the laboratory and focused on the substantive content through testing or mathematical calculations. The results of studies using this method generally answer mathematical/theoretical problems that cannot yet be directly applied in the classroom (Israilov et al., 2023). On the other hand, 22 other articles (out of the total of 50) did not explicitly state the method or design of the study. Still, most of the articles in this group could present the learning stages carried out in the classroom along with the treatments applied.

According to analysis, the primary focus of this research was on two distinct topics: first, the process of teaching physics, and second, the subject matter of physics itself. Although many studies have examined physics learning on the issue of oscillation and its derivatives, there are still very few articles that particularly discuss oscillation themes comprehensively. Following are some conclusions that can be made based on study and field findings:

- Better comprehension of the subject under study on an oscillation in study) researchers can gather wide-ranging and in-depth data on the subject by conducting a systematic literature review. The conclusion is that academics can learn more about the subject and spot informational gaps that need to be filled.
- Empirical data can be strengthened by systematic literature review findings, which can offer solid data to back up research conclusions. The upshot is that researchers might use these data to support their conclusions and boost their confidence in their work.
- Finding directions for additional research: The outcomes of a thorough study of the available literature can point out areas that still require investigation. The conclusion is that scientists can build on these findings to conduct additional studies and close knowledge gaps.

In conclusion, systematic literature reviews can have many beneficial ramifications for future study and practice. Researchers, practitioners, and decision-makers can use these implications to create studies and policies that are better and more efficient.

4. CONCLUSION

Current studies on oscillations and waves show a downward tendency in this field's study over the previous five years. Additionally, Indonesia has the most prolific authors when it comes to producing essays about the ideas of oscillations and waves. This is understandable given that these ideas are emphasized heavily in Indonesia's secondary and higher school curricula. The subjects researchers explore most frequently include the pendulum, springs and spring systems, simple harmonic motion, stress-strain, Hooke's law, Young's modulus, waves, and elasticity. While some of these topics are also tested in the classroom to give students educational experiences through various ways and learning models, like hands-on activities, all of these topics are frequently examined in the lab (through laboratory experiments). Laboratory experiments, quasi-experiments, mixed techniques, and qualitative research are the sorts of study that are widely used to investigate the notions of elasticity, oscillations, and waves

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