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Student's Conceptual Understanding in Physics Learning: A Systematic Literature Review

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ABSTRACT
This article presents a systematic literature review (SLR) on concept understanding in physics learning. The method used in reviewing the literature is the SLR and PRISMA protocol with the stages of identification, screening, eligibility, inclusion, abstraction, and data analysis assisted using the Mendeley and VOSviewer applications. The findings of this study explain that there are still many difficulties, such as calculating in unsymmetrical field source distributions, such as two opposing point charges or currents, and misconceptions such as electricity and magnetism experienced by students and college students that affect students' understanding of concepts in physics learning. The challenges and misconceptions can be overcome by using various treatments, such as providing test instruments that can measure student understanding, developing conceptual models, and using virtual practicum activities. Future research needs to explore students' conceptual understanding of physics learning by using other topics that previous research has not studied.

INTRODUCTION

Learners' knowledge and academic development is a challenge in 21st-century learning [1]. The ability of learners to advance in the field of education depends on the understanding and application of concepts obtained during the learning process. Concept understanding is the learners' mastery of physics concepts that underlie the phenomena being investigated so that they can apply them in a new context [2] [3]. Conceptual understanding reflects students' ability to reason and understand mathematical concepts, operations, and relationships, which will help solve problems [4]. Concept understanding is an essential key in learning to reduce misconceptions in students [2]. Misconceptions in physics are characterised by the inaccuracy of students' ideas related to physics based on experiences or observations of physics in everyday life [5] [6]. Misconceptions are caused by the understanding that concepts that a person acquires from his past life may not be in accordance with some scientific facts, thus affecting the quality and quantity of student learning [7].

Based on a literature study of previous research in the 2018-2023 period shows that misconceptions about understanding physics concepts in vector material [8], kinematics [9] [10], motion dynamics

[11] [12], fluids [13], waves and light [14] [15], temperature and heat [16], electricity and magnetism [17] [18], quantum [19], astronomy [20], and integral and differential [21]. These misconceptions have been addressed in various ways, including using test instruments [8] [12] [14], practicum activities [22] [23], and learning in small groups [24]. This is based on the research “Visualizing Depth of Student Conceptual Understanding Using Subquestions and Alluvial Diagrams” with the results showing that misconceptions are common among students who answer FCI questions on (Q15) a truck breaking down on the road and (Q28) how the action and reaction forces to separate two children [12]. The research “Development and Validation of The Ray Optics in Converging Lenses Concept Inventory” with the results showed that this test instrument is valid and comprehensive to assess students' difficulties in determining shadows on converging lenses [14]. The research “Relating Simple Harmonic Motion and Uniform Circular Motion with Tracker” with the research results shows that the position (x and y coordinates) of an object undergoes regular circular motion according to a sinusoidal function against time [25]. The study “Inventory for the Assessment of Representational Competence of Vector Fields” with the results showed that using the RCFI test can reveal misconceptions and deficiencies, such as confusion in conventions for representing field lines and vector field plots [8]. As well as the research “Comparison of Labatorials and Traditional Labs: The Impacts of Instructional Scaffolding on the Student Experience and Conceptual Understanding” with the results showing that practicum activities using laboratories can encourage high levels of collaboration, engagement, and satisfaction among students, as well as deeper conceptual understanding of the phenomena being investigated [26].

However, these studies have not fully accommodated all misconceptions in one study, nor have they provided solutions to overcome them. Even though misconceptions are very important to overcome in order to improve student understanding. Therefore, there is a need for research that aims to describe the various difficulties of concept understanding and misconceptions in physics material, along with ways to overcome these misconceptions.

METHOD

Research Design

The research method used was a “Systematic literature review.” A systematic literature review is a research method for finding, evaluating, and interpreting significant research findings related to a research question, specific topic, or phenomenon [27] [28]. To identify, screen, test feasibility, enter data, analyse, and present in narrative form, this study applied the preferred reporting item technique for systematic reviews and meta-analyses (PRISMA). The flow carried out is identification, screening, eligibility, and inclusion objectively according to the results of the data reviewed in current articles related to the specified topic [29] [30].

Inclusion and Exclusion Criteria for Selection of Publications

In the inclusion and exclusion stage, there are seven steps carried out, namely: a) Articles indexed in the Scopus and Science Direct databases; b) Searching for articles on the Scopus and Science Direct databases based on the topic of Conceptual Understanding using the keywords Conceptual Understanding and Conceptual Understanding in Physics Learning; c) In the Scopus database the subject area is limited to physics and astronomy, while in Science Direct the subject areas are limited to social sciences; d) The literature studied is in the form of scientific articles in the form of English; e) The publication of articles is limited to the last five years, namely the range of 2018 - 2023. The literature studied is in the form of scientific articles in English; e) The publication of articles is limited to the last five years, namely, from 2018 to 2023.

Screening and Eligiblity Assessment for Data Analysis

Literature from the Scopus and Science Direct databases was filtered based on title, author, year, abstract, participants, objectives, research methods, and conclusions. There were 2,546 articles from Scopus using Conceptual Understanding and 11,854 articles from Science Direct using the keyword

Conceptual Understanding in Physics Learning. Of the 12,680 articles found, 30 were selected based on the research question in terms of title, year, abstract, keywords, participants, purpose, and comprehensive article substance. Details of the mapping from the Scopus and Science Direct databases are in Table 1.

Table 1. Article Search Mapping Results from Scopus and Science Direct Databases

No	Keyword	Database	Quantity
1	Conceptual Understanding	Scopus	181 Articles
2	Conceptual Understanding in Physics	Science Direct	1.539 Articles
	Total		**1.720 Articles**

Then, the articles from the Scopus and Science Direct databases are stored in the form of RIS files and analysed using the Vosviewer.exe application. Analysis using the Vosviewer.exe application aims to build and display bibliometric relationships between various variables and obtain publication metadata, novelty or novelty of research with bibliometric analysis [31].

PRISMA Flow Diagram

This research applies the PRISMA technique in searching articles through four stages: identification, screening, eligibility, and inclusion. Based on the screening results, text articles related to the theme of conceptual understanding were selected so that 65 articles from Scopus and 20 articles from Science Direct were obtained. Of the 85 articles then filtered again based on the participants studied, researchers only focused on students and students who study physics material, so 51 articles from Scopus were obtained and 16 articles from Science Direct. The final results of the literature articles obtained by researchers by the theme of conceptual understanding in physics are 21 articles from Scopus and 9 articles from Science Direct. A total of 30 articles selected for this study were entered into the Mendeley program. The articles were then exported to RIS format for bibliometric analysis using Vosviewer version 1.6.17. The results are presented in Figure 1 below.

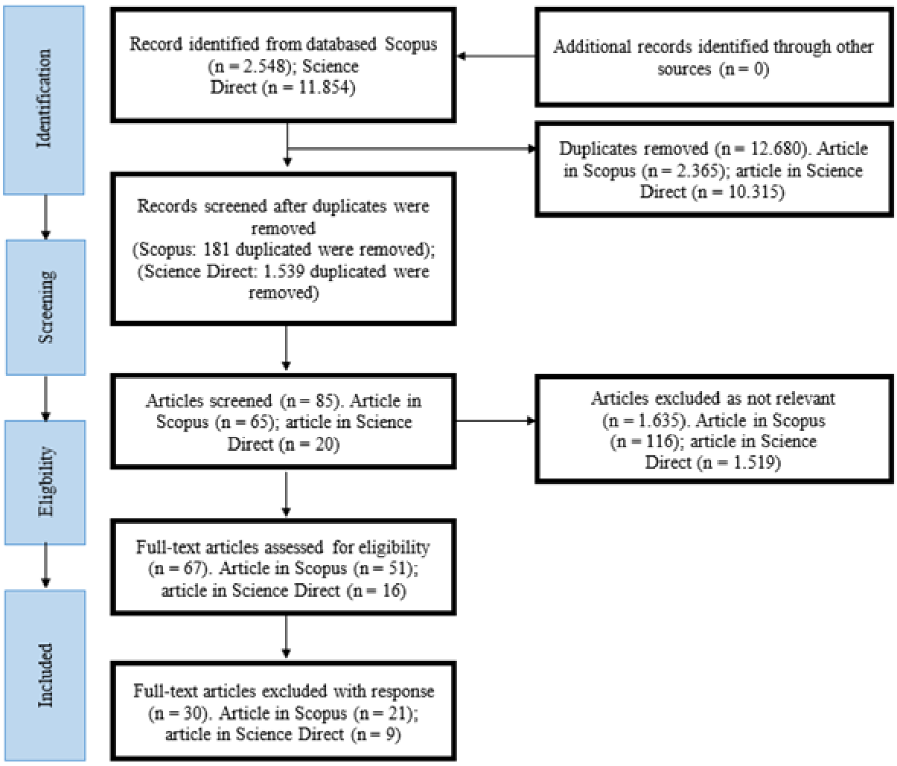

Fig 1. *PRISMA Flowchart for Systematic Review*

RESULTS AND DISCUSSIONS

Bibliometic Vosviwer Analysis: Network Analysis of the Keyword Cooccurrences

Based on the results of preliminary analysis related to conceptual understanding in physics using the Vosviewer program, it shows that conceptual understanding in physics is closely related to several other themes, such as misconceptions and students, while some keywords have a distant relationship with the theme are concept questions and introductory physics. The results are shown in Figures 2 and 3.

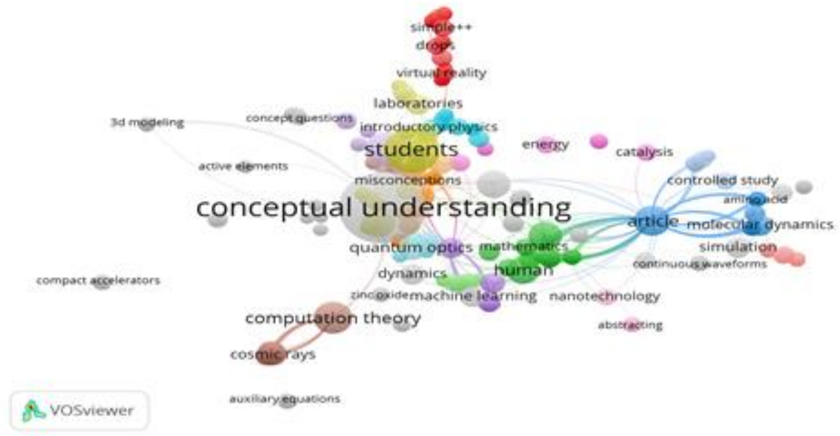

Fig 2. *Initial Network Visualization Based on Scopus Database*

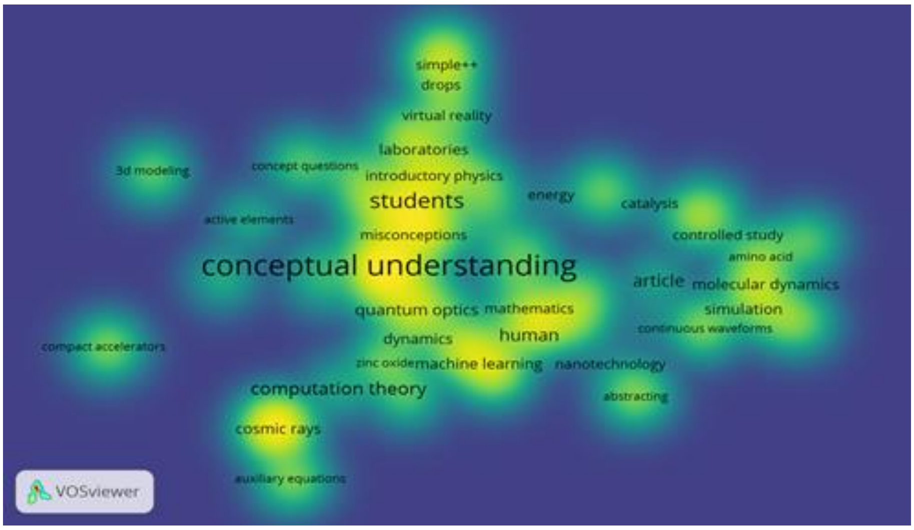

Fig 3. *Visualization of Article Distribution Based on Keyword from Scopus Database*

The literature review analysis consisting of 30 articles related to conceptual understanding in physics is grouped based on physics material, including vectors, kinematics, particle motion dynamics, fluids, waves, sound, light, temperature and heat, electricity and magnetism, quantum, astronomy, integral and differential, and physics practicum.

Understanding of concepts on the topic of vector

Conceptual understanding of the topic of vectors can be measured using the Representational Competence of Fields Inventory (RCFI) test instrument. The results show that using the RCFI test can reveal misconceptions and deficiencies, such as confusion in the conventions for representing field lines and field-vector plots [8].

Understanding of concepts on the topic of kinematics

Conceptual understanding of the topic of mechanics was conducted by presenting students with deductive reasoning chains and asking them to select inference statements that fit the chains in various topics, including mechanics as well as electricity and magnetism. The results showed that most students could correctly deduce the appropriate conclusion from the qualitative inferential reasoning chain, regardless of whether the chain was true or false, across a range of topics and institutions [9]. Conceptual understanding of the topic of circular motion is done by using simple experiments with trackers potentially included in physics classes to improve students' conceptual understanding. Some ways to implement experiments in the classroom are by giving video recordings to students about circular motion and then analysing the video using a tracker. The results show that the position (x and y coordinates) of an object undergoing regular circular motion corresponds to a sinusoidal function of time [10].

Understanding of concepts on the topic of particle motion dynamics

The relationship of high school preparation, college achievement, and noncognitive factors to students' physics conceptual understanding as measured by Force and Motion Conceptual Evaluation (FMCE) on Newtonian mechanics. The results showed that pretest scores fully influenced High School preparation on posttest scores in the regression analysis, while gender differences did not have much change [32]. The Force Concept Inventory (FCI) to measure students' conceptual understanding of Newtonian mechanics. The results show that the misconceptions that usually occur are in the application of Newton's Third Law [11].

The use of the Force Concept Inventory (FCI) test focused on three sub-questions derived from the development of previous questions related to how students analyse a ball falling from the top of a building (Q1), a truck breaking down on the road (Q15), and the magnitude of the action and correction forces to separate two children (Q28). The results showed common misconceptions among students who answered FCI questions on (Q15) and (Q28) [12]. Develop a conceptual framework to model students' knowledge structure using assessment tests covering Newton's Laws and Impulse and momentum. The results show that Chinese students have a higher level of understanding and a more integrated knowledge structure than US students, who have a transitional level of understanding and a fragmented knowledge structure and the impulse-momentum theorem is the most difficult concept to learn and shows the most deep conceptual knowledge [33].

Conceptual understanding on the topic of effort and energy was measured using a comic-based learning module; then students were given 50 multiple-choice questions adapted from the Science Motivation Questionnaire-II (SMQ-II) to determine changes in students' conceptual understanding. The results showed a significant increase in students' conceptual knowledge in Physics and four components of student motivation: intrinsic motivation, self-efficacy, self-determination, and value motivation [34].

Understanding of concepts on the topic of fluids

Conceptual understanding of the topic of buoyancy was measured using the dual process reasoning theory and accessibility framework to investigate students' reasoning approaches and difficulties in the context of buoyancy. The results show that learning modifications designed to remove the strong intuitive appeal of the first available response resulted in significant performance improvements without improving students' conceptual understanding of the required buoyancy concept [13].

Understanding of concepts on the topic of waves, sound, and light

Conceptual understanding in this study, students were guided to form three groups to study shadow formation through different learning modules, namely traditional ray model (Trad), luminous ray model (LRM), and virtual simulation with luminous ray model (VS+LRM). The results showed that both the luminous ray and traditional ray models improved students' conceptual understanding in image formation. In contrast, the use of the luminous ray model was much more effective and showed that VS+LRM was much more efficient than the traditional luminous ray approach [35]. A new test instrument to assess students' conceptual understanding of shadow formation with converging lenses using the Ray Optics in Converging Lenses Concept Inventory (ROC-CI) covers core concepts and common difficulties of students by presenting an assessment of students' conceptual understanding of shadow formation with converging lenses. The results show that this test instrument is valid and comprehensive for assessing the understanding of secondary school students, and it can be used as a formative or summative assessment at school or in a research setting [14]. Conceptual knowledge on the topic of light waves using the Light Interference Test (LIT) showed that students performed better on questions with typical contexts compared to questions with atypical contexts, indicating that students' knowledge structures are often fragmented and context-dependent and that students' performance also varies on different topics [15].

Students' conceptual understanding of light phenomena can be measured using the Light Phenomena Conceptual Assessment (LPCA), showing that there is a low understanding of light phenomena, which is related to the learning tools and strategies teachers use. Students were confused about the difference between reflection and refraction of light. They also had difficulty understanding total internal reflection and scattering of light [36].

Understanding of concepts on the topic of temperature and heat

Conceptual understanding of the topic of temperature and heat was addressed by designing and implementing a physical workshop using heat flux and temperature sensors to help undergraduate mechanical engineering students learn key heat transfer concepts in an active and hands-on way. Results in the first year showed that the workshop group performed significantly better on several test questions, especially those related to conduction, radiation and internal flow. In the second year, by modifying the workshops using videos, the results showed that this change did not improve the students' conceptual understanding, and in fact, it reduced their engagement and motivation [16].

Understanding of concepts on the topic of electricity and magnetism

A grounded theory approach was used to identify and categorise the common train of thought used by students; in this case, the researcher asked students to rank the current through the base, collector, and emitter terminals of a Bipolar Junction Transistor (BJT) emitter follower circuit. The results showed that most students could rank the currents correctly and apply the transistor current gain equation or Kirchoff's junction rule [37]. Conceptual understanding is measured using tests, the results show that the conceptual understanding of S1 students on the topic of magnetism is in the medium category [38]. The development of a new online video resource called Freshman Physics Classroom (FPC) to complement a calculus-based introductory physics course, specifically on electricity and magnetism, positively influenced students' conceptual understanding and problem-solving ability [17].

Application of Modified Module Analysis (MMA) and Modified Module Analysis-Partial (MMA-P). The results show a collection of misconceptions and naive conceptions about electricity and magnetism that students consistently apply after teaching introductory physics [18]. Researchers designed two versions of an open-ended questionnaire, one with the context of electricity and the other with magnetism. The results showed that some conceptual difficulties were context-dependent, such as confusion between force and field in electricity and the concepts of electricity and magnetism in magnetism [39]. The concepts of voltage and the difference between series and parallel circuits were the most difficult for most students, while students found it relatively easy to distinguish between open and closed circuits [40]. High school students' understanding of electrostatics shows that students have different conceptual difficulties in calculating electric flux and magnetic circulation in unsymmetrical field source distributions, such as two opposite point charges or currents [41]. AR visual representations stimulate students to think about different scientific ideas, make deeper connections between scientific concepts, and have a more active learning style with improved transitions between inquiry activities [42]. The study used semi-structured interviews with students, with results showing that the intervention positively impacted students' structural understanding of vector operators, ability to interpret divergence and curl in graphical representations of vector fields, and their conceptual understanding of Maxwell's equations in differential form [43].

Understanding of concepts on the topic of quantum

The conceptual and procedural knowledge framework was developed to classify the quality of students' conceptual and procedural knowledge in deriving and using Characteristic Equations (CE). Each has three levels of quality, namely shallow, medium, and deep. The results showed that most students showed deeper conceptual and procedural knowledge when using characteristic equations than when deriving characteristic equations; in addition, most students showed deeper procedural knowledge than conceptual knowledge in deriving Characteristic Equations (CE) [19].

Understanding of concepts on the topic of astronomy

Conceptual understanding of the topic of astronomy was conducted by instructing students to record and analyse astronomical observations with the naked eye for one semester (13 weeks). The results show that observing diaries is a positive learning experience, positively impacts students' conceptual learning, and improves students' perception of astronomy as a subject [20].

Understanding of concepts on the topic in integral and differentials

Conceptual understanding of differentials and integrals was measured in two ways, namely by providing conceptual analysis for both types of line integrals and a preliminary investigation into students' understanding of line integral expressions. The results show that some students seem to understand the individual parts of the integral expression based on one way of thinking, such as summing pieces or antiderivatives, while trying to understand the overall integral expression through a different way of thinking, such as the area under the curve [21].

Understanding of concepts on the topic in physics practicum

Conceptual understanding in physics through practicum activities shows that the use of virtual laboratories has a positive influence on students' conceptual understanding [22]. Virtual laboratories are as effective as physical laboratories in improving simple concepts. Still, physical laboratories are more effective than virtual laboratories in enhancing students' inquiry performance on several tasks, such as setting goals, reviewing concepts, planning, experimenting, and improving experiments [23]. Fostering conceptual understanding can be done through experimental activities that can be measured by comparing labatorials and traditional labs regarding students' learning experience and conceptual understanding of physics concepts. The results show that laboratorians usually encourage high levels of collaboration, engagement, and satisfaction among students, as well as a deeper conceptual understanding of the phenomenon under investigation [26]. Conceptual knowledge on physics practicum can be done by working in small groups. The results showed that students who reported working in small groups in each class experienced greater improvements in conceptual understanding of physics, in addition to the application of computer simulations, using laboratory equipment, and conducting in the laboratory, were also able to improve students' conceptual acquisition [24].

CONCLUSION AND SUGGESTION

The results of this systematic literature study show various difficulties and misconceptions in physics learning and ways to overcome them, including the difficulties and misconceptions of students in determining field-vector plots, which are overcome by using the RCFI test instrument, which contains ten single-choice items and two items each containing three true or false questions. Learners' difficulties in determining the shadow on a converging lens were addressed with the ROC-CI test instrument through the completion of a 15-item questionnaire with three main focuses: overall understanding of basic concepts related to converging lenses, understanding of specific concepts, and students' difficulty tendencies in this topic. Difficulties in determining the x and y coordinates of objects undergoing circular motion were overcome by experimental activities through experimental videos analysed using a tracker. Finally, conceptual understanding of physics can be improved through small group learning in each class that involves students in various science activities.

Based on the conclusions that have been described, it is hoped that this research can be useful and inspiring for further research to create an instrument or physics learning method that can overcome learning difficulties and misconceptions in other physics materials.

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