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Advancement of Conceptual Change in Physics Education from 2018-2024: A Literature Review

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Abstract

Conceptual change (CC) occurs when students move from incorrect to scientifically accepted ideas. This article presents an overview of 47 international journal articles on the journal index, theoretical framework, purpose, data analysis, and research recommendations published between 2018-2024. This review resulted in five statements: 1) indexation of the journal used by the source of conceptual change studies; 2) the theoretical framework utilized in conceptual change; 3) the objectives used in conceptual change research; 4) data analysis used in research methodology; and 5) recommendations for various studies used by researchers to develop further. Based on this study, the authors recommend future empirical studies related to using a more specific theoretical framework in intervention learning, exploring deeper conceptual changes in the affective and social domains and examining the relationship between the role of metacognitive strategies and conceptual change.

Keywords: conceptual change; literature review; physics education

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INTRODUCTION

Research on conceptual change has been carried out in many fields, such as history, mathematics, science, economics, and other scientific disciplines, including physics. Over the years, many reviews have compiled material from many different perspectives. In the reviewed literature, we complement the extensive collection of previous reviews by scrutinizing various important and in-depth studies on conceptual change research sources that are still relevant and published in the last five years with the dimensions and types of knowledge involved in conceptual change. This study uses a literature review technique with 47 articles available from Scopus, Springer, Elsevier, Eric and several academic publishing sites because of the difficulty in finding these databases. The inclusion criteria for the literature review were indexed by Scopus and Web of Science so that the data used was more relevant and published from 2018-2024. Conceptual change, physics education, and literature review are the keywords used in the paper.

Theoretical views of concept change and consistency of knowledge structure developed during this period, such that the original authors shared significant similarities in their theoretical perspectives on the basic process of conceptual change (Schellings et al., 2013). Conceptual change studies originated in the early 1980s due to studying alternative designs. Hewson and above all the Cornell group which included Posner (1980), laid the groundwork for research in this area. Thus, Posner (1980) used Kuhn and Lakatos' philosophical ideas about change in scientific theories of analogy to conceptual change an individual (Flegr et al., 2023; Treagust & Duit, 2008). Conceptual change identifies and clarifies that cognitive change is not about adding new knowledge or filling gaps in incomplete knowledge; instead, conceptual change transforms existing misconceptions into an accurate understanding of scientific concepts (Banda & Nzabahimana, 2023; Chi, 2005). In other words, a conceptual change occurs when students correctly understand scientific concepts and correctly use these scientific concepts to explain science (Chiu et al., 2019; Lynn et al., 2020). It involves significantly rearranging existing misconceptions in the mind (Neswary & Prahani, 2022; Noris et al., 2024).

When new concepts or empirical realities are presented to students, misconceptions they have raised during the learning process will lead to cognitive conflicts (Edelsbrunner et al., 2018; Mason et al., 2019). Crucially, students could feel misled and let down by their expectations (Addido et al., 2022b). Overconfident students lose interest in learning and become sluggish learners (Heddy et al., 2018). Students need help to build and expand their comprehension of the concepts they are learning (Lin et al., 2023; Oh et al., 2020). Furthermore, misconceptions affect pupils cumulatively from their foundational education until they attain a particular degree of proficiency (Anggoro et al., 2019; McLure et al., 2020). As a result, students who have misconceptions will find their creativity and problem-solving skills limited (Büyükbayraktar & Dilber, 2022; Potvin et al., 2020). Therefore, a conceptual change is urgently needed to meet the needs of 21st-century learning science, especially in physics.

Over the past ten years, the research on conceptual change has drawn criticism for many instructional approaches. Reviews provide an overview of these didactic intervention implementations (Addido et al., 2022a). Despite this, there are still not many literature reviews on physics education. Inhibition and concept learning in physics have been covered in previous reviews models of conceptual change in scientific learning have been covered in previous reviews and suggested strategies to encourage conceptual change in force and motion (Cassidy & Ahmad, 2021; Mclure et al., 2020). Conceptual changing pedagogy in earth and space sciences and conceptual metaphors (Zuccarini & Malgieri, 2022). In addition, we reviewed the literature to provide an overview of the current application of conceptual change research in physics education as part of our planned research in this field.

The goal of physics education in the twenty-first century is to develop deep conceptual understanding and advanced reasoning abilities to influence conceptual change (Leuchter et al., 2020). However, many traditional education systems use repeated problem-solving strategies to teach in-depth conceptual knowledge, which is rare rare (Brock & Taber, 2020). Numerous models and definitions have been developed to explore and characterize the stages and evolution of students' conceptual knowledge in conceptual understanding and learning (Nincarean Eh Phon et al., 2019). For instance, students who enroll in physics classes frequently have profound and consistent insights that are different from those of specialists (Liaw et al., 2021). Since physics is a set of concepts, excerpts from natural phenomena arise from events that happen in everyday life (Thurn et al., 2020). This is often a misconception or alternative conception (Kaniawati et al., 2021). Conceptions held by these students are context-dependent; they are distinct knowledge pieces firmly embedded in particular settings (McLure et al., 2020a). A literature survey was conducted for this study to get specific information about physics education in conceptual change (Syuhendri, 2021).

A literature review section is one result of a literature review. Conducting research involves several steps, one of which is a review of the literature (Younis & Khaleel Younis, 2021). Despite the criticism that they restrict the possible outcomes, systematic reviews (Eshach et al., 2018). Research from the past or present can be summed together and presented in a literature review (Gil-Perez & Carrascosa, 1990). Critical evaluation, summarization, and description of pertinent data are done (Andriani, 2022; List & Sun, 2023). Researchers must evaluate the literature critically to contribute information and arrange it to show the gaps they hope to fill (Chiu et al., 2019). A review is essential to map the field, better understand concepts, and inform relevant stakeholders of insights that will aid policymaking and further research (Yuruk et al., 2009). The literature was selected for its novelty and discussion of key issues related to big data and served our research objectives.

This article discusses conceptual changes in physics education (PCC), which are highlighted by numerous criteria based on a review of keywords and titles. Misconception, conceptual change model, trajectories, multidimensional conceptual change, conceptual strategy, seasoning change, long-lasting conceptual change, conceptual survey, and ontological conceptual change with an emphasis on the cognitive, social, and affective aspects of that change are a few of the keywords used. These three aspects can produce a comprehensive student’s achievement.

Publication years range from 2018 to 2023, with a recent focus on reviews. Furthermore, our corpus mainly includes research results from several leading journals, including Scopus and Web of Sciences (WoS). To fill these gaps, a review was conducted using a number of empirical studies to answer four questions:

1. What is the profile of conceptual change studies?
2. What is the most widely used theoretical framework for conceptual change in research studies from 2018-2013?
3. What are the objectives of conceptual change research from 2018-2024? the objectives used in conceptual change research
4. What data analysis is used in the conceptual change methodology in 2018-2024?
5. What are the recommendations for research studies from 2018-2024?

Associated with existing reviews, this paper draws on physics education's disciplines and educational levels to provide a more holistic and evaluative view of conceptual change. Therefore, the outcomes of this analysis will improve conceptual change theory, thoroughly identify new issues in the field, identify existing gaps in the literature previously, and provide educational implications to relevant contributors. The theoretical framework used in PCC is depicted in the following Figure 1.

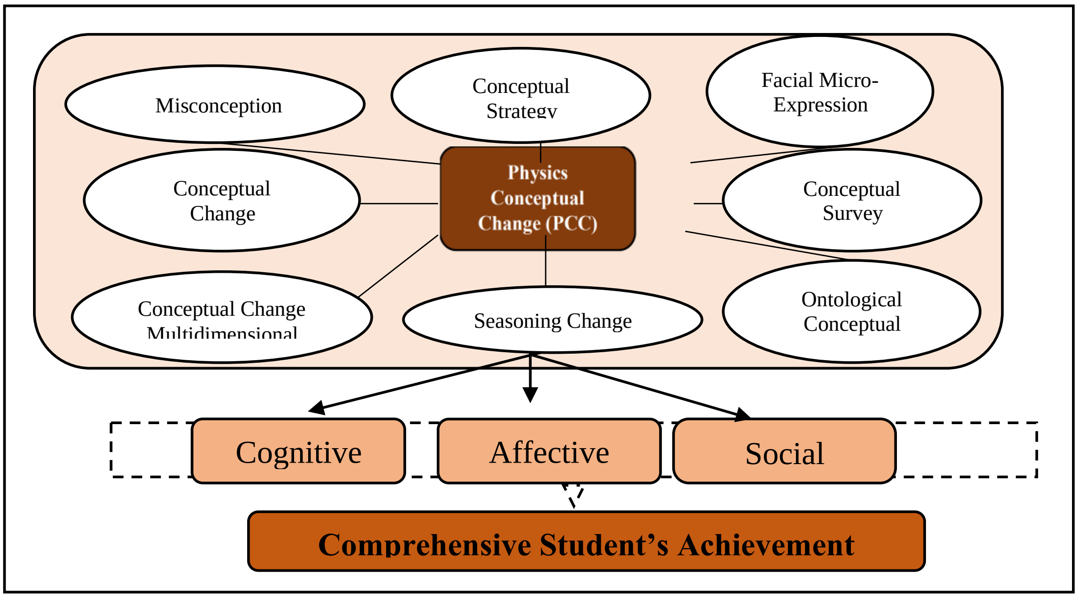

Figure 1 Theoretical framework of PCC

METHOD

The authors conducted a study by collecting reviews from three main sources. First, the authors conducted a manual search for conceptual change in physics education articles on various journal sites, including ERIC, Springer, Scopus and Elsevier, which were published from 2018—2024. We select publishers indexed by Scopus and Web of Science (WoS). The keywords used are conceptual changes in physics education. Second, the list of studies produced from the first phase is identified as valid. Identification results from the ERIC database found 100 articles, and other searches (Scopus, Springer and Elsevier) found 50 articles. Furthermore, screening and eligibility processes were carried out so that 38 journals were reviewed. Nine additional articles were added because the author intends to produce a more accurate and relevant study. The following table 1 lists the details of the process used to review the final 47 international journals' worth of articles.

Table 1 The Journals Selected for Examination

Journal Name	f	Indexed by	H-Index
British Journal of Educational Technology (Q1)	1	Scopus & WoS	102
Bulletin of Electrical Engineering and Informatics (Q3)	1	Scopus	16
Education sciences (Q2)	4	Scopus & Wos	30
Eurasia Journal of Mathematics Science and Technology Education (Q2)	3	Scopus	44
European Journal of Science and Mathematics Education (Q3)	1	Scopus	3

Journal Name	f	Indexed by	H-Index
Frontiers in education (Q2)	1	Scopus & Wos	43
Int J of Sci and Math Educ (Q1)	1	Scopus & Wos	45
International Journal of Educational Psychology (Q2)	1	Scopus & Wos	14
International Journal of Emerging Technologies in Learning (Q1)	1	Scopus	30
International Journal of Research in Education and Science (Q4)	1	Scopus	4
International Journal of Science Education (Q1)	4	Scopus & Wos	115
Journal of Astronomy & Earth Sciences Education	1	Wos	
Journal of Cognitive Enhancement	1	Wos	
Journal of Engineering Education (Q1)	1	Scopus & Wos	113
Journal of Hunan University (Natural Sciences) (Q2)	1	Scopus	17
Journal of Positive Psychology & Wellbeing (Q1)	1	Scopus	9
Journal of research in science teaching (q1)	1	Scopus & Wos	139
Journal of Science Education and Technology (Q1)	1	Scopus & Wos	66
Journal of Turkish Science Education (Q3)	1	Scopus	19
Learning and Individual Differences (Q1)	1	Scopus & Wos	89
Participatory Educational Research (PER) (Q3)	2	Scopus	5
Physical review physics education research (Q1)	4	Scopus & Wos	30
Physics Education (Q2)	1	Scopus	32
Problems of education in the 21stcentury	1	Wos	
Research in Science & Technological Education (Q1)	1	Scopus & Wos	34
Research in Science Education (Q2)	3	Scopus & Wos	56
Science & Education (Q1)	2	Scopus & Wos	121
Smart Learning Environments (Q1)	1	Scopus & Wos	20
Teaching in Higher Education (Q1)	1	Scopus & Wos	62
Turkish science education (Q2)	3	Scopus	19

Review Process Procedure

The following procedure is used to conduct a review of articles used for literature reviews, as shown in Figure 2.

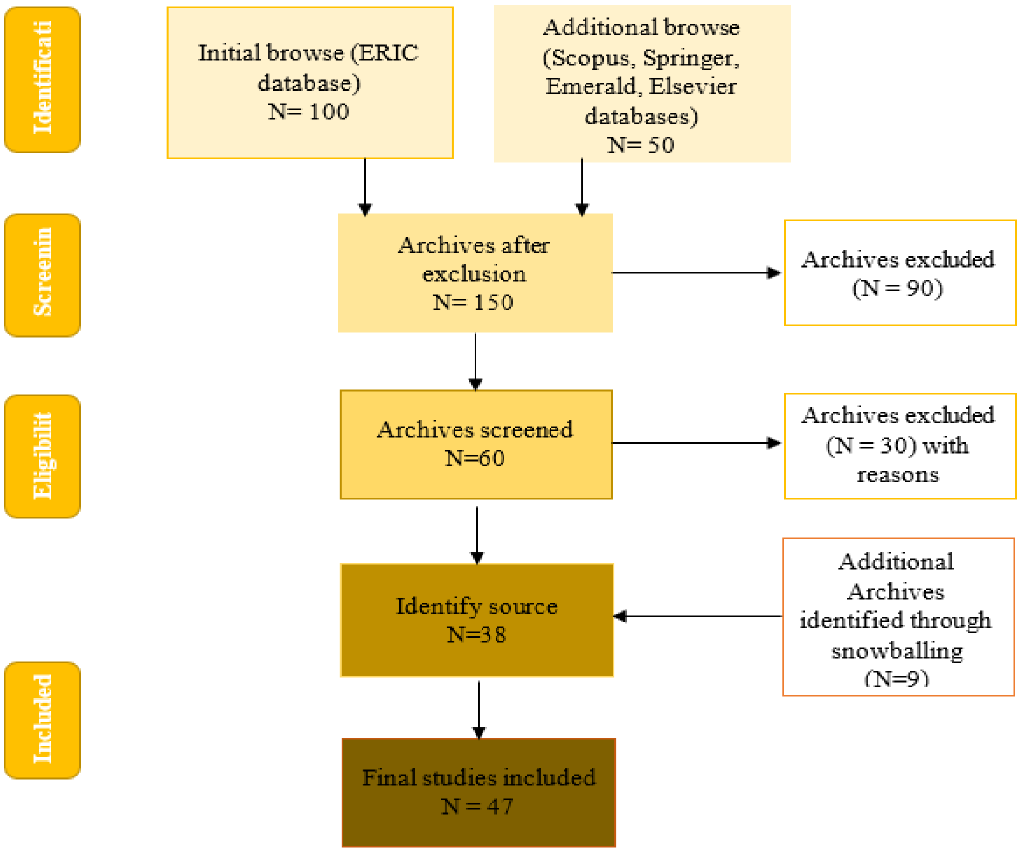

Figure 2 Flowchart of the review process based on Maher et al (2009)

Studies in the field of physics education, conceptual change mentioned in the keyword or title, articles published in English between 2018 and 2023, the Scopus or WoS article index, and articles not derived from proceedings or literature reviews are some of the primary criteria we use when choosing which articles to review. Consequently, only 47 research studies were included in the data compilation. Furthermore, even though they fall under the science category, subjects outside of educational physics are not included. To keep this review manageable, data gathered from relevant studies was arranged into an electronic database. Information on the theoretical framework for conceptual transformation, study objectives, analysis of pertinent data used, journal review source index, and suggestions from article reviews are all included in this.

Data analysis was done using qualitative data analysis with Excel software for the 47 articles studied. After the data is processed, it is shown as graphs, tables, pie charts, bar charts, and maps. The data is also processed as percentages and frequencies. The resulting data were then analyzed using descriptive qualitative analysis, which explained each section discussed in the data found and linked to previous findings relevant to what was found. To make this study feasible, data from linked studies has been arranged in an electronic database. This contains details about the author's nation, publication journal country, year of publication, participant, content, theoretical framework, tool data analysis, statistic data analysis, research purpose, and recommendations for future research. To find gaps in the themes of the existing literature, the author examines the similarities between the theoretical framework and the variable approach.

RESULT AND DISCUSSION

In science education, where students frequently have diverse conceptions of biology, physics, chemistry, mathematics, and engineering that conflict with the scientifically recognized beliefs that the educational program aims to impart, the conceptual transformation has been examined extensively (Djudin, 2021). Influential conceptual researchers, such as Putri, diSessa, Duit & Treagust, and Vosniadou have been successful in transforming students' misconceptions into the proper scientific concepts in physics education. This study was reviewed over the course of six weeks. Every Monday for the first four weeks, the first author sent the peer-review activity report for 12 publications to the other researchers. The papers that have been examined over the last two weeks have been gathered. The authors discovered several narrowly focused theoretical and methodological advancements in this regard. They are articulated in the four claims that follow, each of which is backed up by the review's findings:

1. Physics is a scientific discipline that is receiving more attention, especially in terms of the conceptual changes seen from research studies spread across various countries and the year of publication.
2. The theoretical framework developed has progressed, which adopts Vosniadou's, Posner's, and Chi's theoretical framework, discussing general conceptual, ontological and model changes
3. This study aims to examine cognitive, motivational, and metacognitive aspects of assessment development and explore the factors that influence conceptual change.
4. Data analysis used mostly SPSS software and ANOVA statistical tests
5. Recommendations for further research are to develop more metacognitive, social, and affective aspects of instructional learning in physics education at various levels and to explore more within the theoretical framework developed in conceptual change research.

An overview of the shared traits among the studies in this review is given in this section.

The Research Distribution by Country on Conceptual Shifts in Physics Education

The dispersion of physics education research on conceptual change by country indicated that the United States of America has the most researched region, while Palestine, Saudi Arabia, Netherlands, Landau, and the Philippines are the least researched countries. United States of America has the most distribution of publications because the American higher education system's objective is to promote student achievement and prepare for global competitiveness by promoting excellence in education and this is supported by the statement the United States of America as a world super-power (Siantuba et al., 2023). The distribution of conceptual change research based on the author's country is shown in Figure 3.

Figure 3 The dispersion of conceptual shifts in research in physics education by author country

Research on Conceptual Change in Physics Education: A Distribution Based on Published Countries

Based on journal publishing countries, the most frequently published journals related to conceptual changes that always exist in the discussion are the United Kingdom and Turkey. In contrast, Indonesia, Lithuania, Cyprus, and Austria are the least distributed journals that examine conceptual changes. In many countries, the United Kingdom and Turkey are centres of science education and curricula (Xiao et al., 2020). Furthermore, the UK is one of the leading countries in research trends in educational technology (Taşlıdere, 2021). The distribution of conceptual change research by journal publication country is shown in Figure 4.

Figure 4 Research on conceptual change in physics education: a distribution based on published countries

Number of Publications per Year

After conducting a literature review of 47 conceptual change journals, the following graph shows the number of publications per year, as shown in Figure 5.

Figure 5. Number of Publications per Year

Most publications regarding conceptual changes were made in 2018 and 2021, specifically in physics education. This happened because those two years were the beginning and the last year of COVID-19. Since the COVID-19 pandemic outbreak, there have been many changes and adjustments specifically in education at all levels around the world, switching from conventional to virtual learning, which in turn caused the teachers and students to face obstacles in the studying process (Li et al., 2022; Al-Rsa ' I et al., 2020).

Participants

Based on the literature review, the participants involved in conceptual change articles are various (see Figure 6).

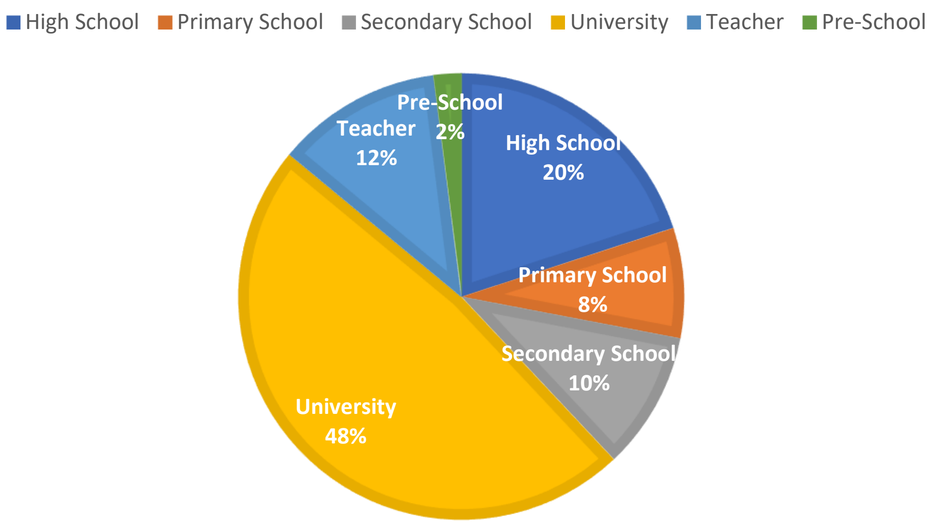

Figure 6 Participants

According to diagram participants, undergraduate students from various majors—not just physics education—were the focus of most of the research. Preschool, elementary, junior high, high school and instructor participants were all included in the research. Even though science ideas were taught at lower levels, very few participants were chosen from future primary and secondary school teachers. (Spatz et al., 2020). Thus, it is necessary to evaluate teachers and prospective teachers evenly regarding conceptual changes at various levels (Velasco et al., 2022).

Physics Content

Recently, the content used and studied in conceptual changes has been mostly studied on several materials, including force, electricity, and climate change. Studies of physics concepts in general are also widely carried out. Because of these abstract concepts, students trust research intuition or sensory perception (Putri et al., 2022; Chancey et al., 2021). Very few researchers have conducted studies on the concept of thermodynamics. Moreover, from 2018 to 2023, research has yet to show the concept of electrodynamics. There are often misconceptions when viewed from the concept of electrodynamics because the material is very abstract to study (Gao et al., 2020; Fan et al., 2018). The following is a classification of physics material widely employed in conceptual change investigation, as shown in Figure 7.

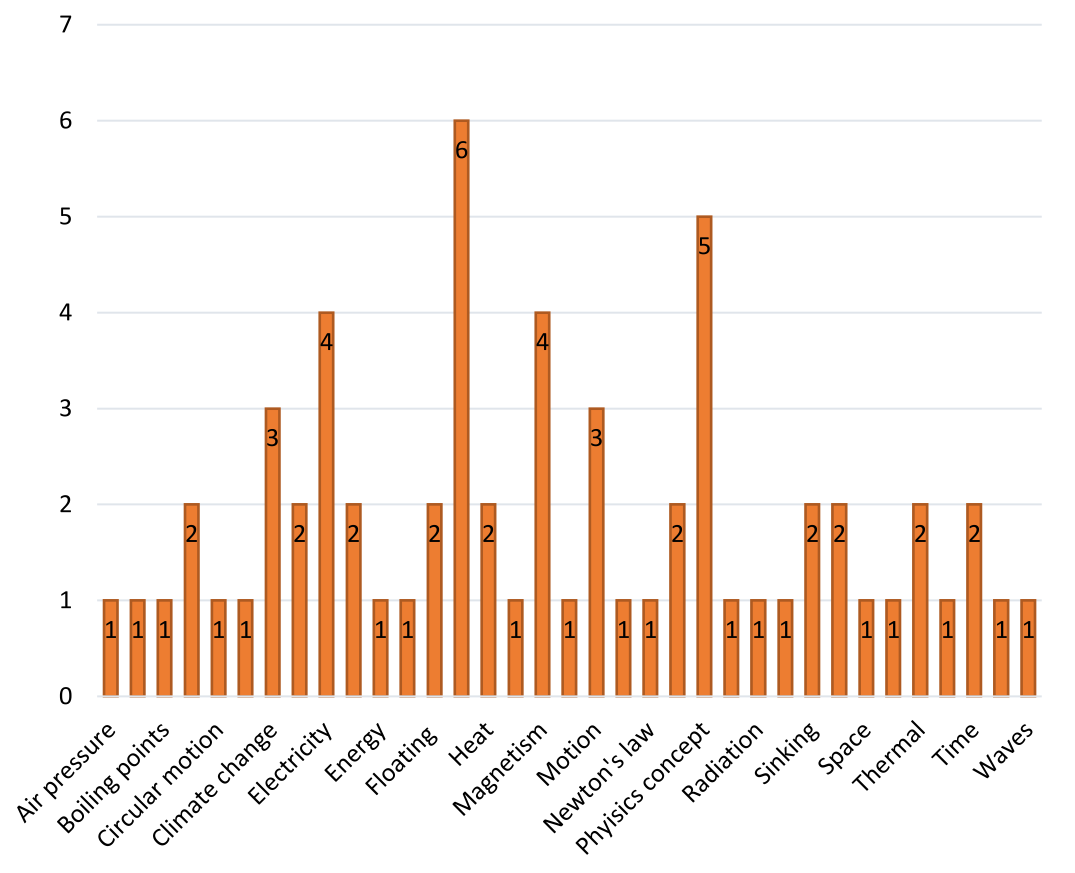

Figure 7 Physics content

Theoretical Framework of Conceptual Change

Considering the conceptual change articles' literature review, the following is the theoretical framework used in the last five-year study, as shown in Figure 8.

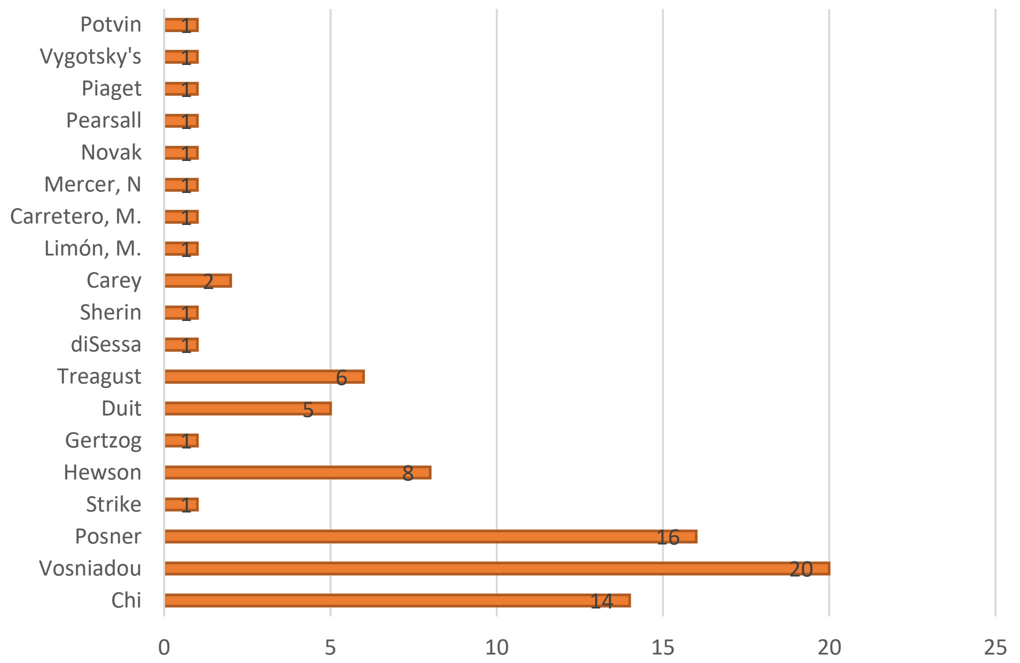

Figure 8 Theoretical framework of conceptual change

The conceptual transition from a cognitive framework has been the subject of almost all research studies. In these investigations, the conceptual change model put forth by Vosniadou, Chi, and Posner. dominated the theoretical perspective. Posner et al.'s theory discusses a broad conceptual change model, Vosniadou's theory captures and models the conceptual change process, and Chi et al. discusses ontological category shift. However, many additional studies have also been conducted. Because they offer specific examples of concepts that the authors likewise regard as fundamental—such as offering practical recommendations for education—these models are crucial to comprehending the area (Jiang et al., 2018; Lemmer et al., 2020). Vosniadou's framework theory explains the process of translating concepts into expert-like knowledge structures. According to Vosniadou's theory, individuals develop progressively complex mental models as they learn about a topic, progressing from simple synthesis to scientific comprehension (Ezema et al., 2022).

According to Chi, students' knowledge is organized into ontological and conceptual categories. Change comes from the classification, i.e., identifying or assigning a concept to a category that belongs to a student's point of view. After being classified, a concept can "inherit" its characteristics and properties, allowing learners to make many inferences and attributions about a new concept or phenomenon (Li et al., 2023). Posner assert that the first lesson should make pupils unhappy with their perceptions. The conceptual shift put out by Posner is based on two frameworks: the philosophy of science and development and awareness psychology (Piaget's work) (Coştu & Ayas, 2005). To ensure that students fully comprehend the material, a new, simple topic should be presented afterwards. Third, the new idea needs to make sense, be compatible with existing knowledge, and help students with difficulties comparable to those they are now facing (Wade-Jaimes et al., 2018). Vosniadou's theoretical framework is widely used because it is relevant and new in the development of conceptual changes.

Data Analysis Tools

Researchers often use various software, including quantitative analysis, such as SPSS, Microsoft Excel, Mplus, R, PASW, and AMOS. In addition, software such as Graph, Dedoose and n-Vivo are used in the qualitative analysis. SPSS has been most dominantly used in the research trend of conceptual change in physics education from 2018 to 2023. SPSS has a fairly high statistical analysis ability because, in addition to providing convenience in calculations, it is also able to analyze research with more variables (Zuccarini & Malgieri, 2022; Saouma et al., 2018). The data analysis tool used in conceptual change research is shown in Figure 9.

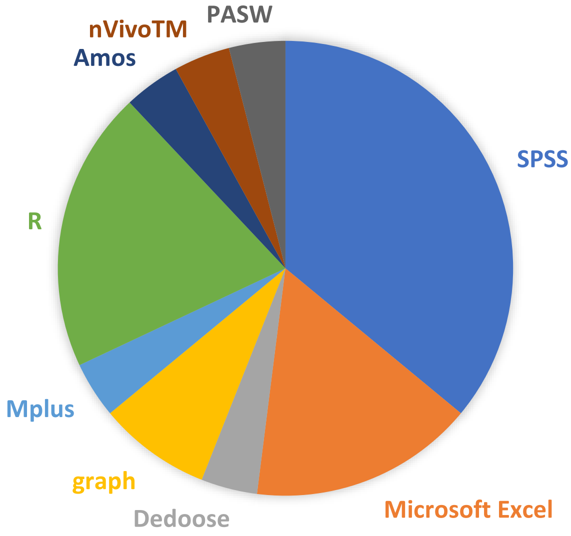

Figure 9 Tools data analysis of research conceptual change

Data Analysis Statistics

Research on conceptual changes in the last five years has used ANOVA and ANCOVA statistical tests. These statistical tests are popularly used because of their capability to identify many influences and are experimental. Experimental research in this study focuses on education, so ANOVA and ANCOVA tests were used. Research in education always progresses from year to year in analysis and experimentation (Mclure et al., 2020). In the past five years, conceptual change articles have utilized various statistical data analyses, as seen in Table 2.

Table 2 Statistic data analysis of research conceptual change

Statistic quantitative	Anova, Ancova, Chi-square, Manova, Regression, Correlation, Spearman's rho, Kendall tau b correlation, t-test, Percentage, Kaiser-Meyer-Olkin, Cronbach's alpha, intercorrelations, Mcnemar test, Shapiro-Wilk test
Statistic qualitative	Segments, Analysis qualitative, Analysis inductive, Category, Comparative Analysis, Meta-analysis, Variety of representations, Diagrammatic analyses and Descriptive

The Research Objective of Conceptual Change in Physics Education

The research objective of conceptual change in physics education articles is to investigate cognitive, affective, and metacognitive aspects and the factors that influence conceptual change and assessment development**.** Initially, many researchers investigated conceptual changes in the cognitive aspect (Cassidy & Ahmad, 2021). However, the trend of recent studies is increasingly expanding on other aspects instead. The following is the grouping of conceptual change research objectives from 2018-2023, as shown in Table 3.

Table 3 Purpose research conceptual change in physics education

No	Purpose
1.	Investigate cognitive aspects using instructional approaches.
2.	Investigate motivational and social aspects associated with other variables.
3.	Explore metacognitive aspects
4.	Develop conceptual change assessments.
5.	Explore factors that influence conceptual change.

Suggestions for Future Research Drawn from the Literature

The authors have acknowledged the need for research on conceptual changes in physics education and have invited further empirical investigations that focus on a more detailed examination of the theoretical framework that underpins students' conceptual changes. For example, according to Chi, the ontological aspect is described more deeply in all cognitive, emotional, attitudinal and metacognitive aspects. As in research on the ontological category shift in entropy on capturing and modelling conceptual change in Vosniadou. The relationship between the theoretical framework and the instructional approach explains why the current study uses many texts as research control variables. Advances in technology have made many researchers use interactive and computer simulations in classroom learning with an instructional approach.

Focus on assessing the conceptual changes of teachers and students to prepare students who fully understand physics concepts. From the results of several studies regarding conceptual change learning for preschool professional teachers (Kaur et al., 2020). who explained the effect of conceptual change being trained on teachers at seminars and explains the introduction of Newton's laws to teachers and developing Newton content for junior high Student school. In addition, an in-depth study is needed to determine why the studied articles are mostly about climate change and fashion and rarely apply conceptual changes to the preschool and elementary school levels.

The studied articles also recommended finding out why most research on conceptual change uses SPSS and its relationship with the instruments used in the research. In addition, the ANOVA statistical test is more dominantly used in research. In addition, looking for reasons for research objectives is important to understanding why research focuses more on investigation, implementation, development, and the factors that influence conceptual change. Very few studies have focused on investigating affective, metacognitive, and motivational aspects and only on cognitive aspects.

CONCLUSION

Recent studies on conceptual change have used Vosniadou's theoretical framework more specifically to develop, capture and model conceptual change. In addition, Chi's theory further explores the ontological category shift, while Posner's theory focuses on general conceptual change. This theoretical framework develops several domains that explore cognitive features and metacognitive, emotional, motivational and affective features associated with various instructional learning methods such as AR, analogies, novels, objection texts, models, pictures, and teaching materials. Learning is more exploratory when creating models, tests, and guidelines to assist students' conceptual transitions from preschool to teacher levels. In supporting more accurate research, SPSS and the ANOVA statistical test are still popular tools. Future conceptual change research can be more accurate and carried out with various approaches that can significantly impact students' conceptual changes.

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