International Journal of Current Educational Research
Homepage: https://www.journal.iel-education.org/index.php/ijocer
Email: ijocer@iel-education.org
p-ISSN: 2961-8517; e-ISSN: 2961-8509

IJOCER, Vol. 3, No. 1, June 2024

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A Literature Review on Conceptual Change: How Does it Contribute to Science Education?

Mohd Zaidi Bin Amiruddin[1]*, Achmad Samsudin[1], Andi Suhandi[1], Ida Kaniawati[1], Adam Hadiana Aminudin[2], Bayram COŞTU[3], Suliyanah[4], Titin Sunarti[4], Amira Ezzati Binti Mohd Irfan[5], Muhammad Guntur Purwanto[6]

[1]Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Universitas Kebangsaan Republik Indonesia, Bandung, Indonesia
[3]Yildiz Technical University, Istanbul, Turkey
[4]Universitas Negeri Surabaya, Surabaya, Indonesia
[5]Universiti Teknologi MARA (UITM) Cawangan Sarawak, Sarawak, Malaysia
[6]University of Minnesota, Twin Cities, United States

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DOI: https://doi.org/10.53621/ijocer.v3i1.267

Sections Info

Article history:
Submitted: January 21, 2024
Final Revised: June 6, 2024
Accepted: June 8, 2024
Published: June 30, 2024

Keywords:
Conception;
Conceptual Change;
Literature Review;
Nvivo;
Science Education.

ABSTRACT

Objective: Conceptual change is a research trend that continues to develop with various innovations being carried out. The research aims to conduct a literature study on conceptual change and how it contributes to science education. **Method:** The data was collected by searching for literature sources for articles using specific criteria. Ten articles were synthesized in more depth to answer questions from the research conducted. **Result:** The results of this research state that methodology and assessment tools influence the form and objectives of research data to be achieved both qualitatively and quantitatively. Apart from that, the concepts in science education are more focused on the physics concepts contained in it. In addition, the findings from these ten articles have a positive impact on science education, especially on material rich in concepts. **Novelty:** In this way, in making changes to students' conceptions, it is necessary to carry out preliminary studies related to the profile of students and the sample group that you want to research so that it can become a reference for the direction of the research you want to complete.

INTRODUCTION

Understanding is a mental process of adaptation and transformation of knowledge. Based on Gagne's taxonomy, understanding is at the level of verbal information (Drigas & Mitsea, 2021). According to Bloom's taxonomy at the comprehension level, Anderson's (1982) taxonomy at the level of declarative knowledge, Merrill's taxonomy at the remember paraphrased level, and Reigeluth's taxonomy at the level of understanding relationships-relationship. This explanation indicates that understanding requires prerequisite knowledge at a lower level and is a prerequisite for achieving knowledge at a higher level, such as application, analysis, synthesis, evaluation, insight, and one's wisdom (Agathangelou & Charalambous, 2021; Akoka et al., 2023; Cegarra-Navarro et al., 2023; Ghafar, 2020; Metsäpelto et al., 2022; van Dijk et al., 2020).

Gardner et al. (2004); Masgoret and Gardner (2003), stated that there are at least three factors as the main obstacles for students in achieving understanding, namely: (1) the selection of learning methods that tend to tolerate unitary ways of knowing, (2) the substance of the curriculum which tends to be contextual, and (3) the formulation of objectives learning is rarely oriented towards achieving in-depth understanding. A learning system that does not provide opportunities for students to understand essential science concepts will give rise to misunderstandings or misconceptions. Labels of misconceptions among students will persist and increase if they are not supported by sourcebooks that contain conceptual changes. The books currently circulating are full-content books, rarely discussing and exploring misconceptions among students. In the book, only scientific concepts are presented without first explaining the possibilities in which many students will experience misconceptions (Bouchée et al., 2022; Chen et al., 2020; Jarrett & Takacs, 2020; Qian et al., 2019; Runnalls & Hong, 2020).

In learning, preconceptions play a significant role in achieving scientific conceptions. In reality, in the field, teachers tend to focus the learning system on efforts to convey knowledge to students without paying attention to students' prior knowledge (Chen & Tsai, 2021; Prasetyo et al., 2021; Wang & Yoon, 2021). Students' preconceptions are generally misconceptions; if this continues to be allowed, it will hinder the formation of scientific conceptions. According to Vosniadou (2019, 2020), learning that does not pay attention to students' preconceptions will make these misconceptions more complex and stable. Misconceptions do not only occur during the learning process in the classroom but also have an impact when a student does practical learning (Amiruddin et al., 2024).

One thing that can be done is learning, which aims to make conceptual changes. Several studies have been carried out using the conceptual change model (Garcia et al., 2021). Conceptual learning models provide opportunities for students to undergo cognitive conflicts and connect physics skills with thinking skills. Garcia et al. (2021), carried out research by comparing conceptual change learning models with conventional learning models. Syuhendri (2017), applies the conceptual change learning model to Newton's material for students majoring in physics education. Apart from that, several studies of misconceptions in science education (Moodley & Gaigher, 2019), physics (Mufit et al., 2020), chemistry (Reina et al., 2022), and biology.

This study conducted an in-depth literature analysis to identify the best methodologies, assessment tools and most relevant content areas from the 10 articles reviewed. Thus, this study not only provides the latest information related to conceptual change research results but also provides practical guidance to implement them effectively in the context of science education, which is expected to improve conceptual understanding and reduce misconceptions among students. From this explanation, it is crucial to apply the conceptual change model, especially in lessons that have a lot of basic concepts, such as in science education (Aksit & Wiebe, 2020; Ketelhut et al., 2020; Markula & Aksela, 2022; Muñoz-Campos et al., 2020; Vosniadou et al., 2020). The application of this conceptual change model can be realized by developing research that focuses on student cognition. In this way, it is fascinating to study basic information through literature studies before carrying out follow-up actions on implementing research in the field. The specific aim of this study is to provide the latest information related to the results of conceptual change research and how it contributes to science education. Several questions (Q) that must be answered in this research are as follows:

Q1. What methodology, assessment tools, and content areas are discussed in the reviewed article?

Q2. What is the contribution of the reviewed article to science education?

RESEARCH METHOD

This research is descriptive qualitative research that collects literature review data. According to Lacey et al. (2011); Mengist et al. (2020), a literature review is a systematic method for synthesizing research works produced by researchers. The data used in the literature review are types of articles that have been published with the keyword "Conceptual Change." The stages carried out in collecting article sources are as follows: (1) Creating research questions, (2) determining inclusion criteria (Title AND Abstract AND Keyword) see Table 1, (3) Using Scopus and Scholar databases, (4) Coding articles, (5) synthesize articles according to the research question.

Table 1. Inclusion criteria for conceptual change.

Category	Criteria
Type Publication	Articles Journal
Publication Year	2010-2023
Field of Study	Science Education
Keyword	TITLE-ABS-KEY (conceptual AND change AND in AND science AND education)

Based on predetermined criteria, the author selected ten articles that were most linear with the research questions. Then, the article was analyzed and visualized using the Nvivo 12.0 software. After that, from the ten articles, a sequence was created with the following equation:

$$\% = \frac{Number\ of\ parts}{Total\ Number} x\ 100$$

To make it easier for readers to understand this research step by step, the following research steps are presented in Figure 1.

Figure 1. Research step.

RESULTS AND DISCUSSION

Results

The results that have been obtained will be presented by the order of the questions that have been created. The form of visualization presented is the result of assistance from Nvivo. Apart from that, the previous data was processed using Excel to make it neater and more systematic.

Q1. What methodology, assessment tools, and content areas are discussed in the reviewed article?

One of the important parts of research is the methodology and assessment tools used to obtain research data (Busetto et al., 2020; Taherdoost, 2021). In this case, as many as ten articles were reviewed and mapped according to the methodology, assessment tools, and content area discussed. The methodology, assessment tools, and content area used, which is presented in Figure 3.

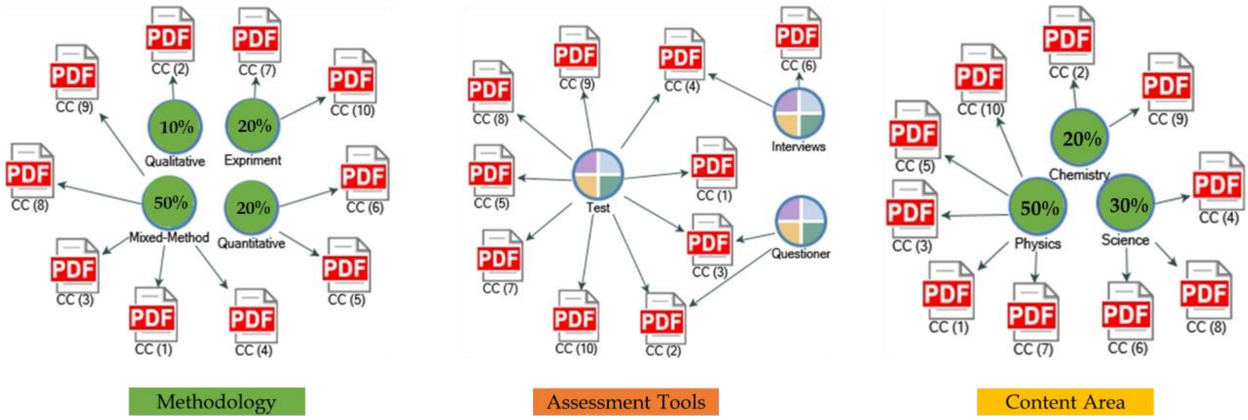

Figure 3. Methodology, assessment tools, and content area used.

Q2. What is the contribution of the reviewed article to science education?

To see in detail the contribution of the articles discussed in science education, the following is a study of the results of ten articles. That way, the information obtained is valid and appropriate to what has been obtained from the research that has been carried out. The following results are presented in Table 2.

Table 2. Contribution of conceptual change to science education.

Author	Finding	Recommendation
(Kaçar & Balım, 2021)	• The inquiry-based learning method has positive effects on learners' academic achievement and conceptual understanding • Inquiry-based learning also contributes to the development of students' conceptual understanding	• Trials need to be carried out in different locations to ensure more depth regarding the effectiveness of the argument-driven inquiry method.
(Hakim & Kadarohman, 2020)	• This research can map students' misconception profiles • Misconceptions occur in students with high, medium, and low ability levels.	• The need for further research to reduce student misconceptions
(Addido et al., 2022)	• Be found to correlation positive between understanding conceptual • Writing predictions and explanations before the lesson positively influenced participants' conceptual understanding	• The need to consider using in-depth interviews and rigorous qualitative methodology to explore participants' ideas about conceptual change models and their influence on conceptual change
(Tseng et al., 2023)	• Collaborative argumentation has a delayed but lasting effect on conceptual change in science education in a U-shaped pattern. • Collaborative argumentation can provide opportunities for change in cognitive, ontological, epistemological, and intentional aspects	• Further research should be conducted to examine the relationship between sequential patterns of argumentative dialogue and lasting conceptual change
(Uwamahoro et al., 2021)	• Laboratory experiences, supplemented by digital media, have a positive impact on students' understanding of geometric optics • Participant students with the Phet Lab group are superior compared with other groups.	• Combining PhET simulations and YouTube videos as learning aids in physics education

Author	Finding	Recommendation
(Falloon, 2019)	• The selected simulations effectively support students' procedural knowledge • The effectiveness of simulations in supporting students' knowledge and understanding of circuit concepts, but also emphasizes the need for teacher guidance and clarification to ensure accurate learning outcomes	• explore the specific instructional strategies that work best with different videos or simulations and how they interact with the overall curriculum
(Siantuba et al., 2023)	• Condition experimental facilitate change conceptual • The potential of designing inquiry-learning environments that address student misconceptions	• Future studies should investigate whether similar results can be obtained in other science domains as well.
(Madaiton et al., 2022)	• Classes that use CCFI get better grades students demonstrated a conceptual shift in their conception of eclipses from a naive understanding to a scientifically accurate concept	• Future research could replicate this research investigation by fully adopting the framework and implementing it in other science topics and other disciplines to validate the level of effectiveness and other features of the CCFI
(Okumus et al., 2020)	• There were no statistically significant differences between the groups at the start of the study • Cooperative learning groups (STAD and RWA) higher than individual learning (IL) groups at the end of the study • This cooperative learning method encourages positive attitudes, improves interpersonal skills, and provides additional learning resources within the group	• Recommended using cooperative learning methods, such as Students Team Achievement Divisions (STAD) and Reading-Writing-Application (RWA), for similar research.
(Maknun & Marwiah, 2022)	• Application CCM can lower student misconceptions • Misconceptions can be reduced because CCM learning involves changing existing conceptions and finding new concepts that can be understood and make sense.	• The necessity of large-scale trials to further prove the effectiveness of CCM in reducing misconceptions

Discussion

Conceptual changes in science education are essential for learning science. However, it can be a complicated process, especially in science education, where many concepts are complicated, contentious, or riddled with false beliefs. Traditional teaching approaches to assisting students in reorganizing their commonsense ideas and understanding the conceptual frameworks of scientific theories have been unsuccessful (Georgiou, 2020). Therefore, to improve science education, teachers must use effective teaching strategies that acknowledge students' assumptions (Aas, 2022; Bishop & Durksen, 2020; García-Carmona, 2020; Mandinach & Schildkamp, 2021; Stokhof et al., 2020) and allow them to educate for conceptual transformation and understanding

The conceptual change encourages science education to be more relevant, inclusive, and responsive to the changing needs of society and advances in science and technology. It also aims to produce students who are more competent, capable of critical thinking, and ready to face increasingly complex global challenges. Credible resources, such as scientific research, pedagogical guides, and modern textbooks, have helped shape these changes in science education (Allchin & Zemplén, 2020; Bencze et al., 2020; Walan, 2020; Zidny et al., 2020). In addition, a concept is something of knowledge that is embedded in one's mind and mentality. According to Sands (2014), a particular concept depends on how the concept is understood concerning other concepts that have a close relationship between the concepts. This has been researched by Taber (2015), who states that "concepts can be understood concerning several other concepts and not only cover hierarchical relationships but are broader than that. The illustration is shown in Figure 2 (Taber, 2019).

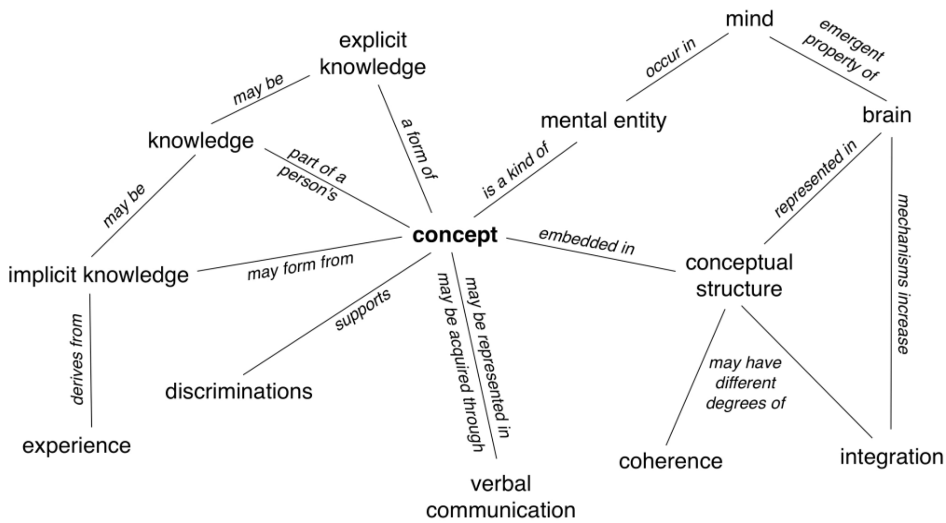

Figure 2. Network of concept.

In science education, concepts are not foreign, but understanding the concepts given requires high-level thinking skills, so there is no understanding of the concepts obtained (Hyun et al., 2020; Maknun, 2020). This is because science education consists of biology, chemistry, physics, and astronomy, which are rich in concepts, so it is essential to deepen and understand them. Apart from that, the concepts in a material often relate to other concepts such as learning biology-physics, chemistry-physics, and several more. One of the philosophers of science said:

> *"Three diseases plague and may forever plague our conceptual outfit: shortage of rich concepts, abundance of poor ones, and vagueness of all except the strictly formal ones."*

This indicates that the topic of conceptual change is very complex. Conceptual change is fundamental to science learning, which suggests science educators and science education researchers need models to address and investigate conceptual change effectively. According to Taber, (2019), conceptual change is as follows.

> *"Conceptual change is, strictly, any change in someone's conceptualizations, but the research focus is often on shifts from alternative to more canonical conceptualizations."*

In line with this, it is important to know how methodology, assessment tools, and content areas are discussed in Figure 3. Based on the information in Figure 3, there is CC coding, which has Conceptual Change articles with numbers representing the order of papers reviewed. There are three types of methodology used by the ten articles reviewed. For files CC7 and CC10 (Experiment), CC1, CC3, CC4, CC8, and CC9 (Mixed-Method), CC2 (Qualitative), and CC2, CC5, and CC6 (Quantitative). In this case, we know that 50% of the ten articles discussed used mixed-method methodology. Qualitative, quantitative, and mixed-method research methods are used to suit the purpose of the research, the type of data collected, and the desired analytical approach. Qualitative research focuses on understanding social or cultural phenomena from the participants' perspective, with descriptive data such as interviews, observations, and text analysis (Khoa et al., 2023; Muzari et al., 2022; Thelwall & Nevill, 2021; Tomaszewski et al., 2020; Tümen & Ahmed, 2021). This is suitable for understanding the meaning or interpretation of experiences or behaviors, especially when the research topic still requires further exploration and aims to develop new theories or concepts. Meanwhile, quantitative research focuses on objective measurement and statistical analysis, with numerical data (Bloomfield & Fisher, 2019). This method is appropriate when the research calls for generalisation from sample to population, testing of hypotheses or relationships between variables, and collection of data that can be measured and compared objectively. Furthermore, mixed methods combine qualitative and quantitative approaches in one study to get a more comprehensive picture (Creswell, 1999). Mixed methods are essential because they allow researchers to combine qualitative and quantitative approaches (Åkerblad et al., 2020; Granikov et al., 2020; Guetterman et al., 2021; Mukumbang, 2021; Strijker et al., 2020), thus providing a more comprehensive and in-depth picture of a phenomenon. Thus, the selection of research methods should be tailored to the purpose of the study, the type of data required, and the analytical approach to be used.

We can see the assessment tools used by the research in each article—the assessment tools interviews used by (CC4 and CC6) whose respective methodologies are Mixed-method and Quantitative. Then, for the assessment tools, a questionnaire was used by CC2 and CC3, with the methodology being Mixed-Method and Qualitative. Additionally, for assessment tools the test used by CC1, CC2, CC3, CC4, CC5, CC7, CC8, CC9, and CC10 with each methodology can be seen in Figure 3. If we examine it in detail, it can be seen that some articles use two assessment tools. This is because there are various methodologies, so to obtain valid and accurate data, it must use appropriate linear tools. The use of assessments in the form of tests, interviews, and questionnaires also plays an important role as it allows researchers to collect diverse and comprehensive data (Hennink & Kaiser, 2022; Henriksen et al., 2022; Hilaikal & Ayu, 2023; Holtom et al., 2022; Khan & MacEachen, 2022). Tests can provide objective and quantitative data on respondents' abilities or knowledge, while interviews allow researchers to delve deeper into individuals' views, feelings, and experiences in a qualitative manner (Mahdi et al., 2019). Questionnaires, on the other hand, allow data to be collected from a large number of respondents in an efficient and standardized way. By combining these three methods, researchers can obtain a more complete and accurate picture of the phenomenon under study, as well as increase the validity and reliability of research findings.

In science education, there are several related materials, such as chemistry, physics, and biology. This is because science covers several material elements. Based on the information in Figure 3, it can be seen that of the ten articles discussed, there are three material contents, namely chemistry (2 articles), physics (5 articles), and science (3 articles). Highlights to the ten articles reviewed, physics dominates the content area discussed. This is one of the reasons why there is more research concerning physics content on conceptual change than others.

To see the distribution of how the contribution of conceptual change distribution in science learning, the summary is presented in Table 2. Based on the findings and recommendations of the results in Table 2, it is known that conceptual change scans are carried out by developing products, developing questions, and implementing models learning appropriately. Conceptual change impacts a better understanding of conception, which is already on one person. This is in line with research conducted by Li et al. (2023); Löhr (2023), stating that through conceptual change, students understand and know a concept better and make it meaningful learning. That contribution to conceptual change impacts understanding more complex concepts for a person or a group. That way, existing research can be maximized by the recommendations of the articles reviewed to become helpful research for the public.

CONCLUSION

Fundamental Finding: Based on the research results that have been discussed, it can be concluded that conceptual change has an impact on science learning, especially on material that has a concept that is quite complicated to understand. Additionally, the use of methodology and assessment tools influences the level of depth of study that is done in obtaining data. Implementing conceptual change can be accelerated by developing products using method learning appropriately, and developing instrument tests that are linear to the concepts discussed. In building students' conceptions, it is necessary to use their learning resources and environment. **Implication:** This literature review can be used as a form of information to educators regarding the importance of conceptual change in education in making decisions to implement learning that is in accordance with the character of students. In addition, this study provides an overview of how conceptual change contributes to the conception of the learners themselves. **Limitation:** This research limits the database search with the keywords TITLE-ABS-KEY (conceptual AND change AND in AND science AND education) with the criteria presented in Table 1**. Future Research:** It is hoped that development and implementation forms from articles that have been discussed can be adopted on scientific concepts that have not been researched.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia with ***Pendidikan Magister Menuju Doktor untuk Sarjana Unggul (PMDSU)*** Batch VII, which has provided funding support and opportunities [Contract Number: 082/E5/PG.02.00.PL/2024].

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***Mohd Zaidi Bin Amiruddin, S.Pd. (Corresponding Author)**
Postgraduate Programme of Science Education,
Universitas Pendidikan Indonesia
Jl. Setiabudhi No. 229, Bandung, West Java, 40154, Indonesia
Email: mohdzaidi@upi.edu

Dr. Achmad Samsudin, M.Pd.
Physics Education Programme,
Universitas Pendidikan Indonesia
Jl. Setiabudhi No. 229, Bandung, West Java, 40154, Indonesia
Email: achmadsamsudin@upi.edu

Prof. Dr. Andi Suhandi, M.Si.
Science Education Programme,
Universitas Pendidikan Indonesia
Jl. Setiabudhi No. 229, Bandung, West Java, 40154, Indonesia
Email: andi_sh@upi.edu

Prof. Dr. Ida Kaniawati, M.Si.
Science Education Programme,
Universitas Pendidikan Indonesia
Jl. Setiabudhi No. 229, Bandung, West Java, 40154, Indonesia
Email: kaniawati@upi.edu

Adam Hadiana Aminudin
Department of Physics
Universitas Kebangsaan Republik Indonesia
Jl.Terusan Halimun No. 37, Bandung, West Java, 40263, Indonesia
Email: adamhadianaaminudin@mipa.ukri.ac.id

Prof. Dr. Bayram COSTU
Department of Chemical Education
Yildiz Technical University
Yildiz, Beşiktaş/İstanbul, 34349, Turkey
Email: bayramcostu@gmail.com

Suliyanah, M.Si.
Physics Education Programme
Univeristas Negeri Surabaya,
Jl. Lidah Wetan, Surabaya, East Java, 60213, Indonesia
Email: suliyanah@unesa.ac.id

Dr. Titin Sunarti
Physics Education Programme
Univeristas Negeri Surabaya,
Jl. Lidah Wetan, Surabaya, East Java, 60213, Indonesia
Email: titinsunarti@unesa.ac.id

Amira Ezzati Binti Mohd Irfan
Faculty of Business and Management
Universiti Teknologi MARA (UITM) Cawangan Sarawak
Jalan Meranek, Kota Samarahan, Sarawak, 94300, Malaysia
Email: 2022884182@student.uitm.edu.my

Muhammad Guntur Purwanto
University of Minnesota
Department of Curriculum and Instruction STEM Education Program
320 Learning and Environmental Sciences 1954 Buford Ave. St. Paul, MN, 55108, United States
Email: purwa007@umn.edu