How Effective Is Duo CCM-Based Learning Product Development in Reducing Elementary Students' Misconceptions on States of Matter?

Wahyu Kurniawati[1], Muhammad Yazid Fatkhul Mujib[2], Assita Azka Qatrunnada[3], Nova Putri Anugrah[4], Vivian Nikadinata[5], Edwin Airlangga[6]

[1] Universitas PGRI Yogyakarta, Yogyakarta, Indonesia
*Email: wahyukurniawati@upy.ac.id

Abstract. Misconceptions in elementary science learning, particularly on the topic of states of matter, remain a significant challenge that hinders students' conceptual understanding. This study aims to analyze the effectiveness of integrating five Duo CCM-based learning products in reducing students' misconceptions. The research employed a Research and Development (R&D) approach using the 4D model (define, design, develop, and disseminate). The developed products include MatterPlay teaching materials, Flip n Learn Cube media, Fun Matter Lab worksheets, reconstruction worksheets, and RolePlay Chat-based instruments. The subjects were fourth-grade students from SDN Pojok and SDN Mejing 2. Data were collected through pre-test and post-test and analyzed using paired sample t-test and N-Gain. The results showed a significant difference between pre-test and post-test scores ($p < 0.05$). The N-Gain score of 0.6243 was categorized as moderate, indicating improved conceptual understanding and reduced misconceptions. These findings demonstrate that Duo CCM-based learning products effectively facilitate conceptual change in elementary science learning.

Keywords: Misconceptions, Duo CCM, Elementary Science, States of Matter

1. Introduction

Science and Social Studies (IPAS) instruction at the elementary school level has an important role in building students' conceptual understanding of natural phenomena and everyday life. According to Darmawati & Mustadi [1] science education emphasizes not only mastery of content but also the development of critical thinking and problem-solving skills. Additionally, students are trained to connect the concepts they learn to real-life situations in a contextual manner [2]. One of the fundamental concepts that must be understood is the concept of the states of matter, which serves as the foundation of science learning. According to Kasanah & Setiyawati [3] an inaccurate understanding can lead to misconceptions among students, which in turn can cause difficulties in understanding the concept of changes in matter and other natural phenomena. Therefore, science education must be designed meaningfully so that students can build a correct conceptual understanding from an early age.

However, in reality, teaching the concept of the physical form of objects still faces various challenges, particularly the emergence of misconceptions among students. A misconception is an error in conceptual understanding characterized by inaccurate definitions, inappropriate use of concepts, and misunderstandings regarding the relationships between concepts [4]. Tsania & Kurniawati [5] revealed that students still struggle to fully grasp science concepts, while Prastyani & Kurniawati [6] emphasized

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that the prevalence of misconceptions is high and influenced by prior conceptions as well as limited conceptual understanding. This is reinforced by the results of diagnostic tests at Pojok Elementary School and Mejing 2 Elementary School, which showed misconceptions regarding the types of states of matter at 67%, the characteristics of states of matter at 54%, and changes in the state of matter at 65%. This situation indicates that students are not yet able to construct scientific conceptual relationships, and the misconceptions that form tend to be persistent, potentially hindering the understanding of more complex scientific concepts.

To address these issues, a learning approach is needed that can systematically facilitate students' conceptual change. One approach that can be used is the Duo CCM-Based Science Learning Model, which is a combination of the Cognitive Conflict Model and the Conceptual Change Model. Through this model, students are presented with phenomena that contradict their initial understanding to generate cognitive conflict that drives conceptual improvement [7]. Based on research conducted by Addido et al [8] the conceptual change approach is effective in helping students replace their initial misconceptions with more scientifically sound concepts. Furthermore, cognitive conflict has also been shown to enhance conceptual change through students' active engagement and critical thinking processes [9]. Therefore, the implementation of this model requires support from integrated learning materials to ensure that each stage of the learning process proceeds optimally.

Accordance with this, five Duo CCM-based learning products were developed, consisting of "MatterPlay" instructional materials, the "Flip n Learn Cube" learning tool, the "Fun Matter Lab" worksheets, the "Word Search" reconstruction worksheet, and the "RolePlay Chat" based detection and evaluation instrument. These five products are designed to support every syntax in the learning model, ranging from the detection, experimentation, concept formulation, discussion, reconstruction, to evaluation stages. The design of products integrated with this learning syntax is crucial to ensure coherence between learning activities and the process of students' knowledge construction [10]. In line with this, according to Suyono et al. [11] the use of various forms of such integrated learning products has the potential to increase student engagement while strengthening conceptual understanding in science learning. Thus, the development of Duo CCM-based learning products not only functions as a learning support tool but also as a means to facilitate students' conceptual change processes more systematically.

This research is important because misconceptions among elementary school students not only result in poor conceptual understanding but also have the potential to hinder the learning process at later stages. A study conducted by Guerra-Reyes et al. [12] hows that misconceptions can impede conceptual change and affect understanding of advanced material. Furthermore, research by Tunga et al. [13] reveals that misconceptions tend to be persistent, difficult to change, and have long-term impacts on students' learning processes. Therefore, misconceptions need to be systematically identified and reduced so as not to hinder the development of students' conceptual understanding.

Based on the above discussion, this study aims to analyze the effectiveness of integrating five learning products within the framework of the Duo CCM-Based Science Learning Model to reduce elementary school students' misconceptions regarding the physical states of matter. This study is expected to contribute to the development of science education that is more systematic, integrated, and oriented toward improving students' conceptual understanding.

2. Method

The type of research used is Research and Development (R&D). The development model used in this study is based on the 4D model, which consists of the define, design, develop, and disseminate stages [14]. The flowchart of the 4D development model stages applied in this study is presented in Figure 1. The stages in the 4D model include needs analysis, product design, the development process, and the dissemination of the learning product [15].

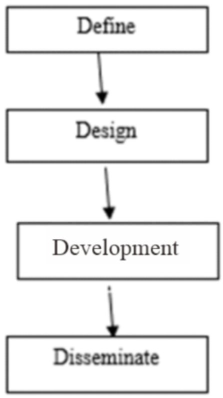

Figure 1. Flowchart of the stages of the 4D development model

The define stage was conducted to analyze the underlying issues, including needs analysis, student characteristics analysis, concept analysis, and learning objective analysis regarding the topic of states of matter. This stage aimed to identify students' misconceptions regarding the concepts of types, characteristics, and changes in the states of matter. The design phase involves the development of Duo CCM-based learning products, including the MatterPlay instructional material, the Flip n Learn Cube media, the Fun Matter Lab worksheets, the "Finding Words" reconstruction worksheet, and the RolePlay Chat detection and evaluation instrument. The products are designed in accordance with the syntax of the Duo CCM-Based Science Learning Model to support students' conceptual change processes. The development stage was conducted through validity and effectiveness tests. The validity test was performed by experts to obtain feedback and improvements for the developed products, while the effectiveness test was conducted to determine the products' ability to reduce students' misconceptions through the administration of pre-tests and post-tests. The dissemination stage was carried out on a limited basis through the distribution of products to teachers and the publication of research results in the form of scientific articles.

The subjects of this study were fourth-grade elementary school students at Pojok Elementary School and Mejing 2 Elementary School. Details on the number of research subjects at each school are presented in Table 1.

Table 1. Research Subjects

No	School	Number of Subjects
1	Mejing 2 Elementary School	28 students
2	Pojok Elementary School	17 students

This study utilized quantitative data obtained from diagnostic tests, specifically pre-tests and post-tests. This data was used to determine the effectiveness of the learning product in reducing students' misconceptions regarding the physical states of matter. The assessment data was then subjected to preliminary analysis tests, namely the normality test and the homogeneity test. Next, the data were analyzed using a paired sample t-test to determine the difference in learning scores before and after the use of the product. Additionally, an analysis was conducted using NGain scores to assess the effectiveness of the Duo CCM-based product. The NGain calculation was performed using the following formula

$$NGain = \frac{Posttest\ score - Pretest\ score}{Ideal\ score - Pretest\ score}$$

The NGain scores were then analyzed to determine the extent of improvement in students' understanding. The criteria for determining NGain score categories are presented in Table 2.

Table 2. Criteria for Interpreting N-Gain Results

N-Gain Score	Category
g > 0,7	High
0,3 ≤ g ≤ 0,7	Medium
g < 0,3	Low

Source: [16]

3. Result

1. Prerequisite Tests

Before testing the hypotheses, prerequisite tests were conducted, including tests of normality and homogeneity. These tests were designed to ensure that the data met the assumptions of parametric statistics, so that the analysis could be conducted accurately and validly. The results of the normality test are presented in Table 3.

Table 3. Results of the Normality Test

Test of Normality			
	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest	.980	45	.609
Posttest	.966	45	.212

Based on Table 3, the results of the normality test show that the significance value for the pretest was 0.609 and for the posttest was 0.212, both of which are greater than 0.05. This indicates that the data are normally distributed and thus meet the assumptions for parametric analysis.

Next, a homogeneity test was conducted to determine the equality of variances among the data groups. The results of the homogeneity test are presented in Table 4.

Table 4. Results of the Homogeneity Test

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Pretest dan Posttest	Based on Mean	2.238	1	88	.138

Based on Table 4, a p-value of 0.138 (> 0.05) indicates that the data exhibit homogeneous variance. Thus, the research data meet the criteria for hypothesis testing.

2. Hypothesis test

Once the data were found to meet the prerequisites for analysis, a hypothesis test was conducted using a paired-sample t-test to determine the difference between the pretest and posttest scores. The results of the test are presented in Table 5.

Table 5. Results of the Paired Samples t-Test

Paired Sample T-Test		
	df	Sig. (2-tailed)
Pretest-Posttest	44	.000

Based on Table 5, the significance value (Sig. 2-tailed) of 0.000 (< 0.05) indicates that there is a significant difference between the students' pretest and posttest scores.

3. NGain Analysis

To determine the extent to which the reduction in misconceptions contributed to improved student learning outcomes, an N-Gain analysis was conducted. The results of this analysis are presented in Table 6.

Table 6. NGain Test Results

Descriptive Statistic					
	N	Minimum	Maximum	Mean	Std.Deviation
NGain_Score	45	.08	.96	.6243	.19737

Ngain_ Percent	45	8.33	96.30	62.4299	19.73675

Based on Table 6, the average N-Gain value is 0.6243, which falls into the medium category. The minimum value of 0.08 and the maximum value of 0.96 indicate variation in the improvement of students' learning outcomes.

4. Discussion

The results of the study indicate that Duo CCM Science-Based Learning Model is effective in improving students' conceptual understanding. This effectiveness is demonstrated not only by significant differences between pretest and posttest scores but also by learning gains classified as moderate based on N-Gain analysis. These findings suggest that the designed learning process does not merely convey information but is capable of facilitating conceptual change in students.

Conceptually, the Duo CCM Science-Based Learning Model integrates two main approaches cognitive conflict and conceptual change structured within a systematic learning framework [7]. In the initial stage, namely the misconception detection stage, students' prior understanding is identified using diagnostic instruments. The instrument used in this stage is a role-play chat detection test. According to Qatrunnada et al. [17]detection tests play a crucial role in uncovering students' initial concepts, whether they are correct or still involve misconceptions. The presence of this instrument is key to ensuring that learning begins from the actual state of students' understanding.

The next stage is the experimental stage. At this stage, learning is supported by the integration of MatterPlay interactive teaching materials, the Flip n Learn Cube learning media, and worksheets. The teaching materials are used to build initial conceptual understanding, the learning media present concrete phenomena in an engaging way, while the worksheets facilitate experimental activities through direct observation. The integration of these three instruments creates a learning experience that is not only informative but also exploratory, while being designed to present concrete phenomena that do not align with students' initial predictions, thereby inducing cognitive dissonance. This aligns with the view of Hidayatullah et al. [18] who state that presenting phenomena that contradict students' prior understanding is effective in triggering cognitive conflict and promoting conceptual change toward a more scientific understanding. Through these activities, students are likely to experience cognitive conflict when their observations do not match their prior understanding, thereby prompting them to re-examine their existing concepts.

Both the formulation and discussion stages are supported by the use of worksheets as the primary tool. During the formulation stage, worksheets help students organize their experimental results and draw preliminary conclusions. Meanwhile, during the discussion stage, worksheets serve as a reference for exchanging ideas and arguments among students. According to Firtsanianta & Khofifah (2022) the use of worksheet can create a more varied and engaging learning environment, as well as encourage student participation. This indicates that the instrument serves not only as a worksheet but also as a thinking tool that encourages students to analyze and reflect on the concepts being studied.

The next stage is reconstruction, which is at the core of the conceptual change process. Reconstruction is a strategy capable of guiding students' conceptual understanding toward accurate scientific concepts [19]. At this stage, a reconstruction sheet is used as the primary instrument. The reconstruction sheet is designed to confront students' initial understanding with correct scientific concepts, thereby facilitating the process of replacing erroneous concepts with more accurate ones. Through this activity, students not only receive new information but also actively reconstruct their knowledge structures based on a more scientific understanding.

The final stage, evaluation, is conducted using an assessment instrument to measure students' level of conceptual understanding after completing the entire learning sequence. Evaluation is a crucial component of education that serves to assess the effectiveness of the learning process and provide constructive feedback to both teachers and students [20]. This instrument serves to determine the extent to which conceptual changes have occurred and the effectiveness of the learning that has been implemented.

The integration of syntax and instruments in this learning process is a key factor supporting the success of the Duo CCM Science-Based Learning Model. Each instrument plays a specific and complementary role in supporting the learning stages, ranging from the identification of misconceptions to the evaluation of learning outcomes. This integration makes the learning process more structured, systematic, and focused on improving conceptual understanding.

5. Conclusion

Based on the research findings, it can be concluded that science education in elementary school plays a crucial role in building students' conceptual understanding, particularly regarding the physical states of matter, a topic that often leads to misconceptions. The use of the Duo CCM Science-Based Learning Model, integrated with five learning products (MatterPlay, Flip n Learn Cube, Fun Matter Lab Worksheets, Word Search Worksheets, and the RolePlay Chat instrument), has proven to be quite effective in improving conceptual understanding while reducing students' misconceptions. This is demonstrated by the results of a paired-sample t-test, which showed a significant difference between the pretest and posttest (sig. $0.000 < 0.05$), as well as an N-Gain value of 0.6243, which falls into the medium category. Thus, the integration of learning products based on the Duo CCM Science-Based Learning Model is capable of having a positive impact on reducing students' misconceptions regarding the topic of states of matter. This study confirms that learning designed to be structured, interactive, and oriented toward conceptual change can help students build a more accurate and meaningful scientific understanding.

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