Journal of Turkish Science Education, 2024, *21*(2), 212-231.
DOI no: 10.36681/tused.2024.012

Journal of Turkish Science Education
http://www.tused.org
© ISSN: 1304-6020

Correcting grade 11 students' misconceptions of the concept of force through the conceptual change model (CCM) with PDEODE*E tasks

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ABSTRACT
This study aims to reconstruct Grade 11 students' misconceptions about force through the Conceptual Change Model (CCM) making use of Predict, Discuss, Explain, Observe, Discuss, Explore, Explain (PDEODEE) tasks. This study was conducted using a mixed-method approach. The participants in this study were 65 students (33 students in the experiment class—13 males and 20 females, and 32 students in the control class—12 males and 20 females) from a high school in Bandung, Indonesia. The instrument test used is the Four-Tier Test-formed Force Concept Inventory (4TT-FCI) with 8 question items. Three analyses were carried out: an analysis of students' misconception profiles during the pre-test and post-test, the reconstruction of students' misconceptions analysed based on percentage and codification using Great Change (GC), Not Change (NC), and Un-Great Change (U-GC). The improvement in students' conception was carried out using N-Gain with three categories (Low, Moderate, and High). The results show that the students' conception profile during the pre-test and post-test still detects misconceptions. However, these misconceptions can be ameliorated using CCM with PDEODEE tasks because the highest conceptual change is in the Misconceptions category (GC= 34.5) and the lowest is in the Un-Code category (U-GC= 2.4). The increase in the correctness of the conception was measured in the experimental class at 0.73 (High category), and the control class is 0.42 (Moderate Category).

RESEARCH ARTICLE

ARTICLE INFORMATION
Received: 31.10.2022
Accepted: 31.07.2023

KEYWORDS:
Misconception, force concept, conceptual change model (CCM) with PDEODE*E tasks.

To cite this article: Samsudin, A., Zulfikar, A., Saepuzaman, D., Suhandi, A., Aminudin, A.H., Supriyadi, S., & Coştu, B. (2024). Correcting grade 11 students' misconceptions of the concept of force through the conceptual change model (CCM) with PDEODE*E tasks. *Journal of Turkish Science Education, 21*(2), 212-231. DOI no: 10.36681/tused.2024.012

Introduction

Students' prior knowledge has gradually become recognised as a decisive aspect of science learning. According to this perspective, prior knowledge shapes the meanings derived from teaching.

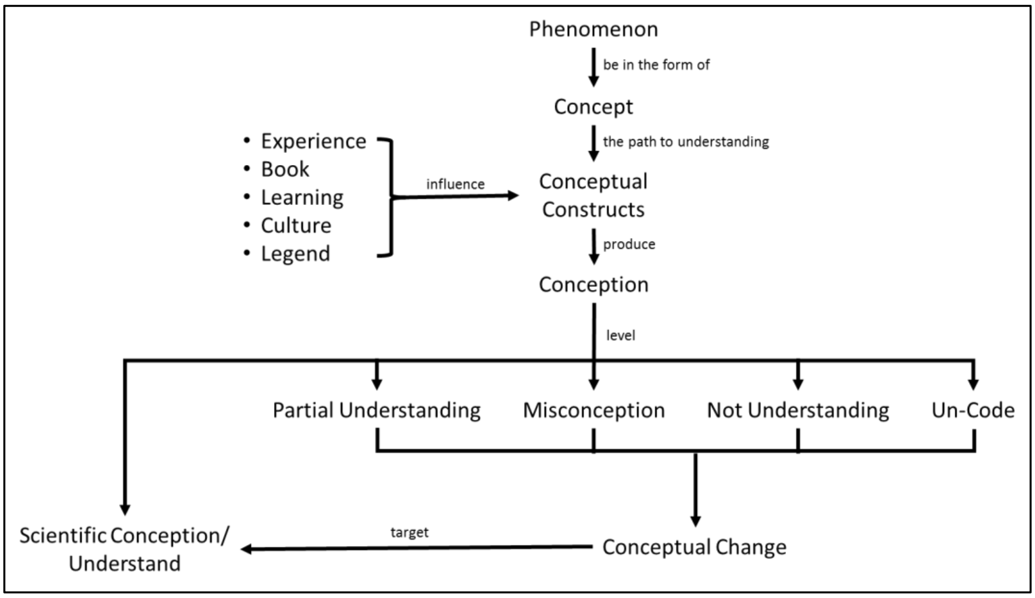
Instruction that does not build upon existing knowledge and understanding is likely to fail in producing meaningful learning (e.g. Kaniawati et al., 2021; Leinonen et al., 2013; Mutohhari et al., 2021; Temiz & Yavuz, 2014; Turgut & Gurbuz, 2012). One type of prior knowledge critical to students is conceptual change because the conceptual change comes about as a result of the learning so is not 'prior', which is very important in the learning process. Enhancing students' conceptual understanding of scientific concepts is a stated goal of science teaching, one of them in physics (Chen et al., 2013; Laurenty et al., 2021; Ozkan & Selcuk, 2016; Author et al., 2017; Wibowo et al., 2017). Therefore, teachers need to understand in advance how students' conceptions or ideas are held before engaging in the learning process. Ideas held by students before lessons are referred to as pre-conceptions, which are now recognised as common barriers to understanding science (e.g. Clement et al., 1989; Handhika et al., 2015; J. W. Lin et al., 2016; S. Y. Lin & Singh, 2015; Topalsan & Bayram, 2019).

There is a wide range of pre-conceptions among students that can be obstacles in the learning process, such as alternative conceptions, anchoring conceptions, and misconceptions (e.g. Ekawati et al., 2021; Gurel et al., 2015; S. Y. Lin & Singh, 2015; Lucariello et al., 2014). Alternative conceptions are ideas that may conflict with established scientific theories. The issue with the term "alternative conception" is that it can be wrongly interpreted to mean that all ideas are equally valid in all contexts, which is not true (Author et al., 2019; Aslan & Demircioğlu, 2014; Clement et al., 1989; Dinçer, 2017; Kaltakçi & Didiç, 2007). Anchoring conceptions represent an intuitive understanding that deviates from accepted physical theories. This understanding is concrete rather than abstract and is self-assessed; the strength of the belief is determined by the individuals rather than by expert consensus. The focus of this study is on students' misconceptions, which are persistent, intuitive conceptions in students' awareness that hinder the acquisition of correct concepts (e.g. Kaltakçi & Didiç, 2007; Larkin, 2012; Leinonen et al., 2013; Premo et al., 2019; Turgut & Gurbuz, 2012).

Students' misconceptions are their conceptions that contradict logically recognised concepts (e.g. Adimayuda et al., 2020; Kaltakçi & Didiç, 2007; Prince et al., 2012; Shute et al., 2013; Zhou et al., 2016). Hammer (1996) described misconceptions as firmly held and entrenched, diverging from experts' conceptions, impacting students' understanding of phenomena and scientific explanations. Shift general descriptors of misconceptions up Overcoming misconceptions requires a grasp of scientific interpretations. Figure 1 illustrates the process of understanding students, which has been summarised from several studies related to conception.

Figure 1

Process of students understanding



In Figure 1 there is one aspect that influences students' conceptions, namely legend. This is because Indonesia has a variety of ethnicities and cultures, so that sometimes natural phenomena are associated with local legends whose stories have been passed down from generation to generation. Erroneous concepts hinder students' understanding and their explanations of occurrences. While misconceptions may yield partially accurate predictions of some phenomena, their explanatory power is more limited than that of scientific conceptions. The emphasis on adopting a scientific perspective implies that students' misconceptions must be addressed and replaced with thoughts that have better explanatory power, explicitly, scientific conceptions. This can be a relatively intricate cognitive process and may involve transitional conceptions between scientific conceptions and misconceptions, perceived as "stepping stones" toward required learning. Therefore, it could be said that students' misconceptions are concepts that are either not fully scientific or not at all. This happens in several physics' concepts, one of which is the concept of force.

The understanding of the concept of force is crucial as it is one of the fundamental topics that students must comprehend to build a strong foundation for learning more advanced physics topics. An example of a misconception related to action-reaction forces is the assumption by students that, on an object resting on a surface, both the weight and the normal force constitute an action-reaction force pair.

The weight on objects serves as the action force, while the normal force acts as the reaction force arising from the surface. The misconception becomes evident when lifting the object: without contact with the surface, the weight persists, but the normal force ceases to exist. If the normal force were the reaction force to the weight (as the action force), it should persist even when the object is not on the surface, given the continued presence of weight. Additionally, students' misconception is evident in the arrow force depiction on the object on the surface. This depiction is incorrect, as the arrow force for weight should originate from the centre point of the object, as shown in the middle section for homogeneous objects with regular shapes.

Students' misconceptions about force may arise from various factors, such as teaching methods, school facilities, or the use of non-student-centred media or models. In this context, the role of the teacher is crucial in shaping student performance (Kaltakçi & Didiç, 2007). The teacher serves as the orchestrator of the learning process in the classroom, and employing conventional methods like the lecture method may not align with the nature of science in physics. Hence, teachers must be creative and innovative in conducting the learning process, including the application of learning models to reduce misconceptions and facilitate the development of better conceptions.

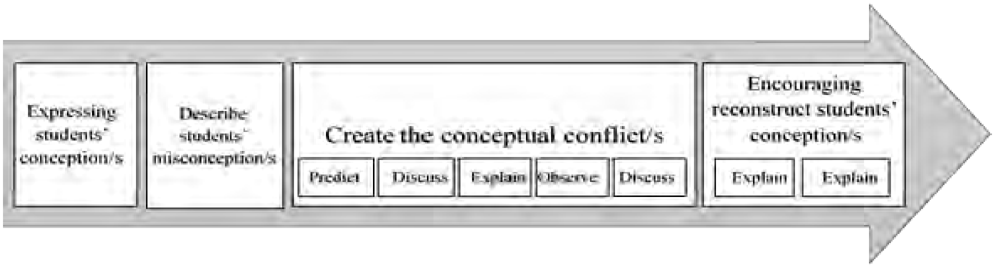
Numerous studies have indicated that a conceptual change strategy is effective in altering students' misconceptions (Chen et al., 2013; Eryilmaz, 2002; Heddy & Sinatra, 2013; Ozkan & Selcuk, 2016; Author et al., 2017; Author et al., 2020). The conceptual change strategy, developed by Posner et al. (1982), is based on four stages: Dissatisfaction, Intelligibility, Plausibility, and Fruitfulness. Dissatisfaction implies that students must recognise the inadequacy of their current conceptions. Intelligibility ensures that students gain a reasonable understanding of the new conception. Plausibility involves students discovering the new interpretation/conception's logic and being able to depict it in their observations. Lastly, Fruitfulness means that students' new conceptions must be applicable, enabling them to address similar issues with their newfound understanding.

The Conceptual Change Model (CCM), initially developed by Posner et al. (1982), was further refined into a model designed to alter existing conceptions, particularly students' misconceptions. The CCM consists of four phases, based on the conceptual change strategy by Posner et al. (1982) and expanded by Hewson & Thorley (1989), as follows: a) Expressing students' conceptions, aimed at understanding students' pre-conceptions, especially their misconceptions; b) Describing students' misconceptions with the intent that students can realise the truth related to their initial conceptions and can provide clarification and revision; c) Creating conceptual conflicts in students' conceptions to facilitate openness to accepting changes to their conceptions; and d) Encouraging the reconstruction of students' conceptions so they can compare their initial conceptions with correct scientific concepts to achieve more scientific conceptual changes.

The phases of this learning model require specific learning steps to support the CCM. The chosen learning steps are the Predict, Discuss, Explain, Observe, Discuss, Explore, Explain (PDEODEE) strategy developed by Author et al., (2017). The PDEODEE learning strategy consists of Predict, Discuss, Explain, Organise, Discuss, Explore, and Explain, developed from PDEODE (Predict, Discuss, Explain, Organise, Discuss, Explain) proposed by Savander-Ranne & Kolari (2003), as well as Costu (2008). This integration of PDEODEE tasks with the implementation of the CCM can be executed within the PDEODEE strategy phases. Consequently, the learning steps of CCM with PDEODE*E tasks are depicted in Figure 2.

Figure 2

*Diagram of conceptual change model (CCM) with PDEODE*E task*



Accordingly, these steps were applied to the students in this study of misconceptions on force. Therefore, the aim of this study was to reconstruct Grade 11 students' misconceptions about force through the Conceptual Change Model (CCM) making use of Predict, Discuss, Explain, Observe, Discuss, Explore, Explain (PDEODEE) tasks. The research questions as the focus of this study are as follows:

1. What is the profile of students' misconceptions as shown by the pre-test and post-test?
2. What, if any, conceptual changes occur after the implementation of the CCM with PDEODE*E Tasks?
3. How to improve students' conceptions through the CCM with PDEODE*E Tasks?

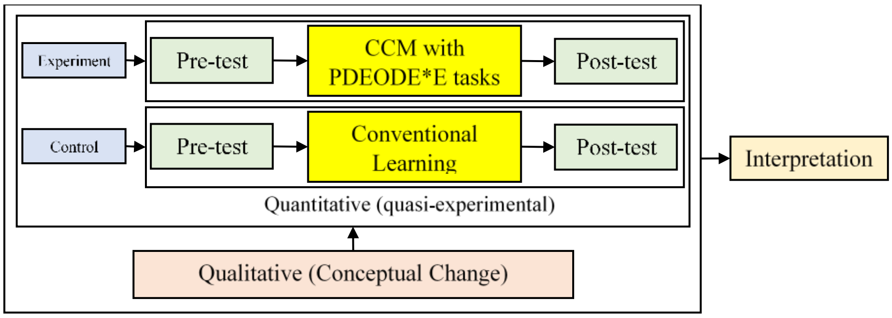
Methods

Design

The research design employed is the mixed methods design with the embedded experimental model. This design allows for a comprehensive analysis by combining quantitative and qualitative data (Creswell, 2014). The quantitative aspect utilises a quasi-experimental design with a non-equivalent (pre-test and post-test) control-group design. This design involves conducting the same pre-test and post-test in both experimental and control classes, with the treatment applied only in the experimental class (Creswell, 2014). The schematic representation of the design is illustrated in Figure 4, adapted from (Creswell, 2014; Wolf et al., 2015). Meanwhile, the control class uses conventional learning, where the strategies commonly used are using the scientific approach in Indonesia: observing, questioning, experimenting, associating, and communicating (Figure 4). The design used can be seen in Figure 3.

Figure 3

Embedded mixed-methods scheme in research



To gather pre-test and post-test data, students were divided into two distinct classes: the experimental class and the control class. The experimental class underwent the Conceptual Change Model with Predict, Discuss, Explain, Observe, Discuss, Explore, Explain (PDEODEE) tasks, while the control class. Treatments (CCM with PDEODEE Tasks and conventional learning) were applied after the pre-test and before the post-test. These learning activities occurred twice a week for 45 minutes each over three weeks.

The treatment in this research involved implementing CCM with PDEODEE tasks. The learning steps for CCM with PDEODEE tasks related to force consist of four main steps incorporating PDEODEE phases. The steps of CCM with PDEODEE tasks are detailed in Table 1. Meanwhile, qualitative descriptive analysis was conducted based on codification and percentage to map the reconstruction of students' misconceptions on the concept of force.

Table 1

*Learning activity through conceptual change model with PDEODE*E tasks*

Learning Activity	The Conceptual Change Model with PDEODE*E Tasks		Descriptions
	CCM	PDEODE*E	
I	Expressing students' conception		▪ Unveil students' conceptions on force based on the result of pre-test.
II	Describe students' misconception		▪ Describe students' misconceptions on the force based on the result of pre-test.
III	Create the conceptual conflict	Predict	▪ Students predict what will happen based on the demonstrations about force that shown by the teacher.
		Discuss	▪ Students discuss about their predictions in group.
		Explain	▪ Students explain the results of the group discussion.
		Observe	▪ Students observe the whole demonstrations about force that shown by the teacher.
		Discuss	▪ Students re-discuss in group based on the whole demonstrations force that has been observed,
IV	Encouraging reconstruct students' conception	Explore	▪ Students do the exploration activities in group to get more accurate information about the force by doing the experiment.
		Explain	▪ Students explain their finding based on the exploration activities about the force.

Participants

The sampling frame for this study consists of high schools in Bandung City. Cluster Random Sampling, specifically random class sampling, was employed to select participants for the study. A total of 65 students participated, with 33 students in the experimental class (13 males and 20 females) and 32 students in the control class (12 males and 20 females), all from Grade 11 and within the age range of 16-18 years. The experimental class received treatment through the implementation of CCM with PDEODE*E tasks (refer to Table 1). On the other hand, the control class underwent normal learning, wherein the scientific approach, a standard learning method in Indonesia, was utilized (refer to Figure 4) (Hasan, 2018; Setiawan & Wilujeng, 2016; Zaim, 2017).

Figure 4

Scientific approach

In the scientific approach, there are 4 stages that must be carried out, namely observing, questioning, experimenting, associating, and communicating. At the observing stage, students are asked to observe phenomena (real or virtual). Furthermore, students were asked to question about their lack of understanding of the concept of the phenomenon presented. After the questions are collected, then students carry out the experiment that has been prepared. Students then associate the experimental results with their concept. Then, students were asked to communicate the results of their experiments in front of the class. The respondents were chosen purposely of two different eleventh classes for be given a pre-test and post-test.

Instrument

Diagnostic test instruments that utilized to investigate students' misconceptions on force in this research is the Force Concept Inventory (FCI) with the number of 8 items with four main concepts: 1) Action-reaction force; 2) Centripetal force; 3) Frictional force, and 4) Rope force. The FCI items has been transformed into the form of four-tier test, consequently the instrument diagnostic test is named the Four Tier Test-formed FCI (4TT-FCI). The multi-tier, and in this case four-tier instrument was used because it had previously been shown to be a reliable indicator of students' conceptions (e.g. Kiray & Simsek, 2021; Taban & Kiray, 2021; Yang & Sianturi, 2021).

The 4TT-FCI diagnostic test instrument was administered to the participants during the pre-test and post-test activities to measure students' misconceptions on the force in question. Before awarded to the participants, the 4TT-FCI has been judged by 3 experts (two physics lecturers in the University, and one physics teacher in the High School) as the evaluation step on the development steps. Validity technique had been utilized Content Validity Index (VCI) by Polit & Beck (2006) which gave the validity score 0.87. This score indicated that the instrument diagnostic test has the high validity. In order to strengthen the 4TT-FCI appropriateness, the reliability and validity of the instrument also calculated based on students' testing activity. The result shown that the reliability is high which 0.75 as the coefficient reliability (Parish & Guilford, 1957) and the validity also in the high category with the 0.79 as the validity score. One of the 4TT-FCI items development is shown in Figure 5.

Figure 5

One of 4TT-FCI instrument diagnostic test items development

15.1. In the Figure 9, student “a” has a mass of 95 kg and student “b” has a mass of 77 kg. they sit in identical office chairs facing each other. Student “a” places his bare feet on the knees of student “b”, as shown. Student “a” then suddenly pushes outward with his feet, causing both chairs to move.

Figure 9

During the push and while the students are still touching one another:

A. neither student exert a force on the other.
B. student “a” exerts a force on student “b”, but “b” does not exert any force on “a”.
C. each student exerts a force on the other, but “b” exerts the larger force.
D. each student exerts a force on the other, but “a” exerts the larger force.
E. each student exerts the same amount of force on the other.

15.2 Your confidence level associated answers on Question 15.1:

A. Sure B. Not Sure

15.3. Your reason related to choice of answers in Question 15.1:

A. Students "b" only accept the force from student "a".
B. There is the action-reaction force as a result of both students direct contact, with the direction of the resultant force in the direction of student "a".
C. There is the action-reaction force as a result of both students direct contact, with the direction of the resultant force in the direction of student "b".
D. There is the action-reaction force as a result of both students direct contact.
E. other reason: ……………………………………………………………………………………..…… …………………………………………………………………………………………………… ……………………………………………………………………………………………………

15.4. Your confidence level associated answer options 15.3 numbers:

A. Sure B. Not Sure

At the first tier (Tier-1), there are the question that had been taken from FCI items. In the tier-1, there are 5 options that contain one correct answer and four incorrect answers. At the tier-2, there are questions about respondents’ sureness related to the answers in tier-1. Meanwhile, the tier-3, there are question about students’ reason on the response options at the tier-1 with a semi open-ended format. At this tier, there are five possible answers to the last selection (E) in the form of an open-ended format, consequently students be able to give the other reasons that are not in the previous four reasons. At this tier-3, there is one correct answer and three wrong answers. However, there is also a selection of questions that had not been contained the correct answer (at the third tier). Hence, the students who have a good concept can justify the selection (E) in accordance with their own language. And the last is the tier-4 that contain the same question as in tier-2, there is questions about students’ sureness related to their answer option (reason) in the tier-3.

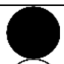
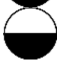
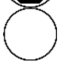
Data Analysis

Profile of Students’ Misconceptions on Pre-test and Post-test

The marking key that was utilised to determine students' conceptions profile based on the diagnostic test instruments 4TT-FCI had been adapted from (Zulfikar et al., 2019) and designated in the Table 2.

Table 2

The responses combination table of the four tier test

Category	Score	Symbol	Tier-1	Tier-2 Levels of Sureness	Tier-3	Tier-4 Levels of Sureness
Understanding	2		O	S	O	S
Partial Understanding	1		O	S	O	NS
			O	NS	O	S
			O	NS	O	NS
			O	S	X	S
			O	S	X	NS
			O	NS	X	S
			O	NS	X	NS
			X	S	O	S
			X	S	O	NS
			X	NS	O	S
			X	NS	O	S
Misconception	0		X	S	X	S
Not Understanding	0		X	S	X	NS
			X	NS	X	S
			X	NS	X	NS
Un-Code	0		If there is the tier of missed/ multiple answers/ the questions are treated as though they had not been answered at all.			

Note. O = The true answer; X = The wrong answer; S = Sure; NS = Not Sure

The category of misconceptions obtained when respondents give the wrong answer to the tier-1 and tier-3, but they are sure of their chosen answer by the selected sureness options in the tier-2 and the tier-4. The categorisation in Table 3 was carried out for the pre-test and post-test data. The aim was to identify the students' misconception profile during pre-test and post-test. Meanwhile, to calculate the percentage of students who experience misconceptions (MS) during the pre-test and post-test was calculated.

Conceptual Changes in Reconstructing Students' Conception after the Implementation of the CCM with PDEODE*E Tasks

The conceptual change for a student is marked by the change of the students' level conceptions based on the difference percentage based on post-test and pre-test. The conceptual changes categorisation shown by Table 3.

Table 3

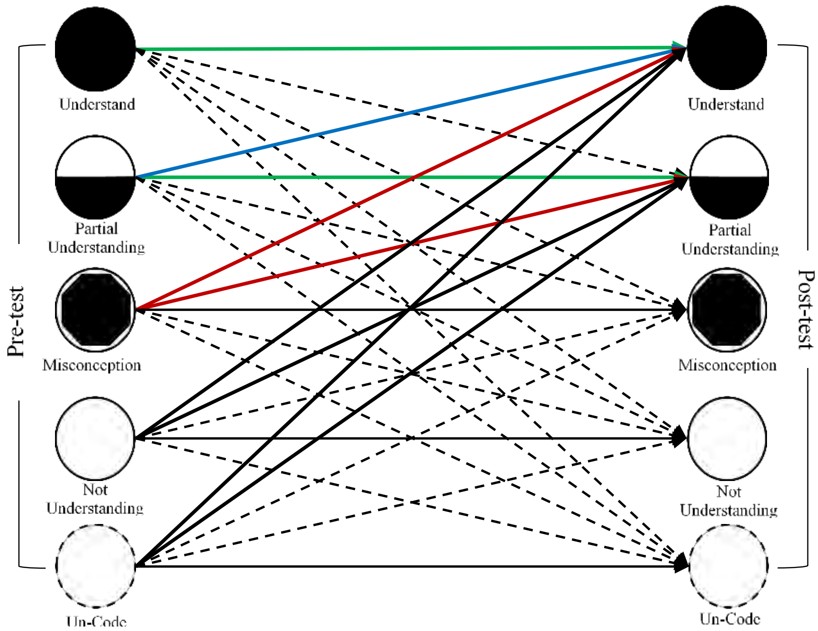
Interpretation of students' conceptual changes

No	Conception Level Change (%)	Category	Interpretation
1	Understand	+	Great Change (GC)
		0	Not Change (NC)
		-	Un-Great Change (U-GC)
2	Partial Understanding	+	Great Change (GC)
		0	Not Change (NC)
		-	Un-Great Change (U-GC)
3	Misconception	+	Un-Great Change (U-GC)
		0	Not Change (NC)
		-	Great Change (GC)
4	Not Understanding	+	Great Change (GC)
		0	Not Change (NC)
		-	Un-Great Change (U-GC)
5	Un-Code	+	Great Change (GC)
		0	Not Change (NC)
		-	Un-Great Change (U-GC)

In analysing the students' conceptual change, the percentage of students' level conceptual change presented by the change as in the symbol form Figure 6.

Figure 6

The possibility of students' level conception change profile



Based on the conceptual change possibility, Overall, the results will be categorized by type on the Table 4.

Table 4

The types of student conceptual change

Change Direction	Type of Change	Interpretation
	Complementation (Cp)	Great Change (GC)
	Revision (R)	
	Construction (Ct)	
	Static type I (St-I)	Not Change (NC)
	Static type II (St-II)	
	Disorientation (Do)	Un-Great Change (U-GC)

Table 4 shows the existence of 6 types students' conceptual changes viz Complementation (Cp), Revision (R), Construction (Ct), Static type I (St-I), Static type II (St-II), and Disorientation (Do) (Lappi, 2013). reference needed. Types Cp, R, and Ct are included in the GC interpretation due to changes in conception for the better. Types St-I and St-II are included in NC because no changes have occurred. However, there is no change in St-I, it is still in good conception compared to St-II. Meanwhile, the Do type is an unexpected change because the changes that occur do not improve the concept.

Improvement of Student Conception

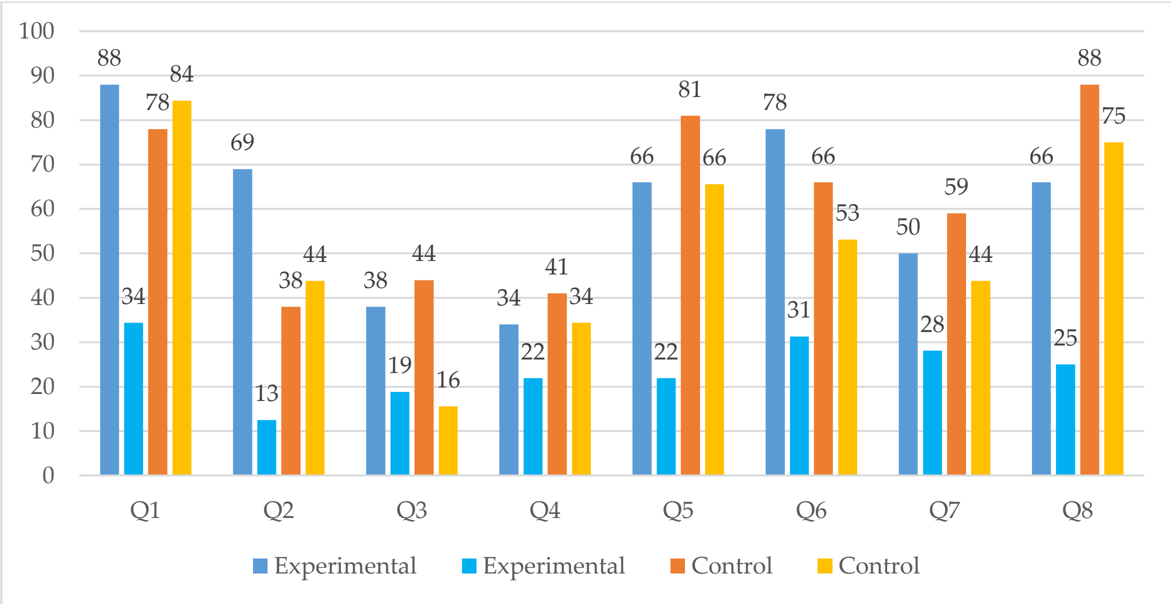
The increase in the accuracy of students' conceptions was analysed by N-gain <g> (Hake, 1998), with categories: 1) Low ($g \le 30\%$); 2) Moderate ($30\% < g \le 70\%$), and; High ($70\% < g$). This analysis is used to identify improvements that occur after treatment is given.

Results and Discussion

The profile of students' misconceptions was unveiled by examining the students' level of conceptions based on the scores from the pre-test and post-test, employing the 4TT-FCI instrument. The revelation of students' conception profile provided crucial information about the quantity and nature of student misconceptions for further analysis. Five levels of conception were utilized in this study: Understanding, Partial Understanding, Misconception, Not Understanding, and Un-Code. Understanding students' conception levels is essential for gaining insights into the focus of the discussion. The students' conception profile was extracted based on the pre-test and post-test results using the diagnostic test instrument 4TT-FCI. The percentage profile of students based on the results of the pre-test is depicted in Figure 7.

Figure 7

The percentage of students' misconceptions on experimental and control class based on pre-test and post-test results



Referring to Figure 7, it is evident that in the experimental class, the highest percentage of misconceptions lies in question number Q1, specifically addressing the concept of Action-Reaction Force, with a percentage of 88%. This implies that 28 out of 33 students in the experimental class hold a misconception regarding the concept of Action-Reaction Force. In the control class, the most prominent misconception is observed in question number 8, also related to the Action-Reaction Force, with each number accounting for 88%. Consequently, 28 students in the control class harbour misconceptions about the force and the influence of Action-Reaction Force. This aligns with Bao & Fritchman (2021) findings, which indicate that there are numerous misconceptions about Newton's Laws, particularly the Third Law. Various studies have also highlighted misconceptions about Newton's laws in general (e.g. Bao & Fritchman, 2021; Fratiwi et al., 2017; Mongan et al., 2020). Thus, the prevalence of misconceptions regarding the concept of action-reaction force is not surprising.

On the contrary, the lowest percentage of misconception in the experimental class is observed in question number Q4, pertaining to the concept of centripetal force, with a percentage of 34%. This implies that 11 out of 33 students in the experimental class have misconceptions about centripetal force. In the control class, the least misconception is noted in question Q2, which is related to the concept of centripetal force, with a percentage of 38%. Thus, 13 out of 32 students in the control class hold misconceptions about centripetal force.

Furthermore, the highest percentage of misconceptions in the experimental class is found in Question 1, dealing with the concept of action-reaction force, with a percentage of 34%. This finding aligns with the pre-test results, albeit with a different number of students—11 out of 33. Similarly, in the control class, the highest percentage of misconceptions is found in Question 1, with a percentage of 84%. This indicates that 27 out of 32 students in the control class have misconceptions regarding the concept of action-reaction force.

In summary, the analysis reveals that misconceptions persist across all questions related to force concepts, both during the pre-test and post-test. Dealing with misconceptions is acknowledged as a challenging task, with studies recognizing the difficulty of completely eliminating them (e.g. Dinçer, 2011; Mubarak & Yahdi, 2020; Resbiantoro et al., 2022; Soeharto & Csapó, 2021).

Conceptual Changes in Reconstructing Students' Conception after the Implementation of the CCM with PDEODE*E Tasks

The change in students' conceptions is evidenced by the difference in the percentage levels of the experimental class students' conceptions based on the pre-test and post-test. The details of the percentage change in the level of students' conceptions are presented in Table 5.

Table 5

Percentage of students' conceptual changes

Q	Understand			Partial Understanding			Misconception			Not Understanding			Un-Code		
	C (%)	Type	Intp	C (%)	Type	Intp	C (%)	Type	Intp	C (%)	Type	Intp	C (%)	Type	Intp
Q1	50,0	+	GC	3,1	+	GC	-53,6	-	GC	0,0	0	NC	0,0	0	NC
Q2	9,4	+	GC	59,1	+	GC	-56,5	-	GC	-9,9	-	GC	-3,1	-	GC
Q3	12,5	+	GC	12,8	+	GC	-19,2	-	GC	-3,1	-	GC	-3,1	-	GC
Q4	21,9	+	GC	9,3	+	GC	-12,1	-	GC	-13,0	-	GC	-6,3	-	GC
Q5	15,6	+	GC	34,0	+	GC	-44,1	-	GC	-6,0	-	GC	0,0	0	NC
Q6	18,8	+	GC	12,3	+	GC	-22,1	-	GC	-3,1	-	GC	-6,3	-	GC
Q7	18,8	+	GC	30,8	+	GC	-46,7	-	GC	-3,6	-	GC	0,0	0	NC
Q8	25,0	+	GC	-0,1	-	U-GC	-21,9	-	GC	-3,2	-	GC	0,0	0	NC
Average	21,5	+	GC	20,2	+	GC	-34,5	-	GC	-5,2	-	GC	-2,4	-	GC

Note. Q = Question Number, C = percentage change in conception level, Intp = interpretation, GC=Great Change (expected changes), U-GC= Un-Great Change (unexpected changes), NC= Not Change (do not change).

Referring to Table 5, changes in the level of students' conceptions are evident for each question, represented by the Expected Change (GC). The highest percentage change in the level of understanding is observed in question number 1, which addresses the concept of action-reaction force, with a percentage of 50.0%. This is that 16 students have upgraded their conception to achieve a full understanding.

For Partial Understanding, nearly all questions exhibit changes in interpretation according to GC, except for question 7, which shows unexpected changes (U-GC). Question 7 deals with the force of frictional swipe, indicating a slight decrease in students' conceptions by 0.1%. The highest percentage change in Partial Understanding is found in question 2, which focuses on centripetal force, with a percentage of 59.1%. Approximately 19 students have upgraded their conception to reach the level of Partial Understanding.

At the Misconception level, the percentage change in all questions aligns with the expected change, indicating a reconstruction of misconceptions in students. The most significant change is observed in question 2, related to centripetal force, with a substantial percentage of 56.5%. This suggests that 21 students underwent a reconstruction of misconceptions, adopting a better conception.

For the Not Understanding level, the most substantial percentage change is noted in question 8, which pertains to action-reaction force, with a percentage of 18.9%. As for the Un-Code level, the most significant change occurs in question 4, concerning centripetal force, with a percentage change of 6.3%. To facilitate further analysis, the data on the percentage change in misconceptions (presented in Table 5) is visualised in the form of a bar chart in Figure 8.

Figure 8

Percentage change misconceptions students

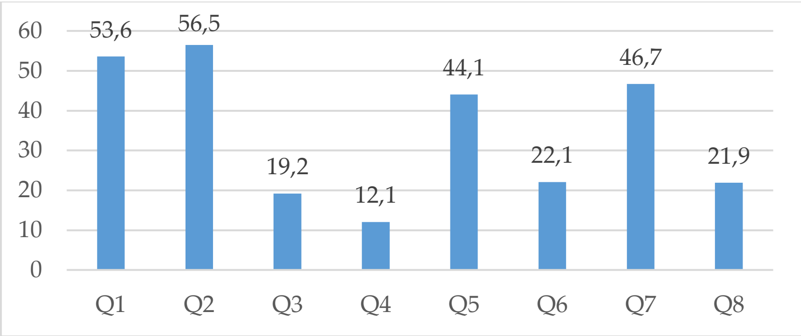
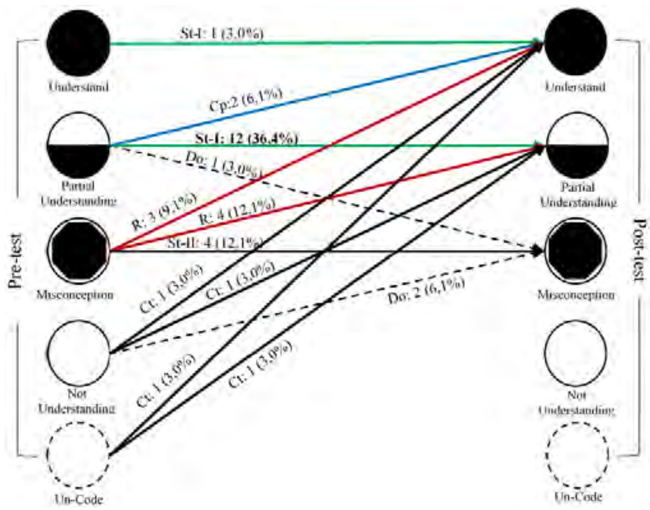


Figure 8 illustrates the most substantial misconception changes occurring in question number 2, amounting to 56.5%. Question 2 addresses the concept of centripetal force, indicating that 21 out of 33 students underwent a reconstruction of misconceptions related to the Centripetal force concept. Conversely, the smallest misconception changes are observed in question number 4, also concerning centripetal force, with a percentage of 12.1%. This suggests that the reconstruction of misconceptions about the concept of centripetal force in question 4 involved four out of 33 students. Overall, the average percentage change in the level of misconceptions is considerable, reaching 34.5%. The analysis indicates that the changes in misconceptions align with the expected changes (GC) for all questions. This finding is consistent with prior research (Author, et al., 2021), which incorporated PDEODEE tasks with other models to effectively reconstruct students' misconceptions. The implementation of this approach, theoretically, enables students to construct their own understanding and effectively address misconceptions (Ramadhani et al., 2020; Rodriguez & Towns, 2021; Üce & Ceyhan, 2019). The students' conceptual change is comprehensive, covering concepts such as Action-reaction force, Centripetal force, Frictional force, and Rope force. However, for illustrative purposes, an example for Centripetal Force is presented in this section.

In the 4TT-FCI instrument, the concept of centripetal force is found in Questions 2, 3, and 4. The conceptual change in this matter exhibits expected changes (GC). An example of the changes in students' conceptions regarding the concept of Centripetal force is provided in Figure 9.

Figure 9

Students' Conceptual Change on Centripetal Force in Problem No. 4



In Figure 9, the distribution of students' conceptual changes for Question 4 (Centripetal Force) is illustrated. The highest percentage is observed in the St-I type, amounting to 36.4%, indicating consistency at the level of conception Partial Understanding. This implies that a substantial portion of students maintained a consistent and improved understanding of the concept at the Partial Understanding level.

On the other hand, the reconstruction of misconceptions is noted at 9.1%, signifying the transformation of misconceptions into a complete understanding (Understand). Additionally, 12.1% of students experienced changes that led to a state of Partial Understanding. This indicates a positive shift in students' comprehension levels, suggesting an improvement in their understanding of the Centripetal Force concept.

The distribution of students across different types of conceptual changes for Question 4 is further detailed in Table 6, providing a comprehensive overview of the shifts in students' conceptions following the intervention.

Table 6

Distribution of students on any type of change in conception to question 4

Type of Change	Pre-test	→	Post-test	Category	Distribution of Students
St-I	●	→	●	S	SE5
Cp	◒	→	●	S	SE19, SE20
St-I	◒	→	◒	S	SE2, SE3, SE6, SE11, SE13, SE16, SE17, SE18, SE24, SE30, SE31, SE33
Do	◒	→	◉	Ds	SE21
R	◉	→	●	S	SE27, SE28, SE29
R	◉	→	◒	S	SE1, SE9, SE10, SE23
St-II	◉	→	◉	Ds	SE7, SE8, SE12, SE22
Ct	○	→	●	S	SE4
Ct	○	→	◒	S	SE32
Do	○	→	◉	Ds	SE25, SE26
Ct	◌	→	●	S	SE14
Ct	◌	→	◒	S	SE15

Students SE17 is one of the students who are in the St-I type of consistency at the level of conception Partial Understanding on question 4. Students have the consistency of conception in the concept of centripetal force of the impact of the loss of the centripetal force on the ball that is moving in a circle by a rope. Students SE17 has the conception that the path of the offending object is a circular path perpendicular to the rope.

Reconstruction misconceptions on this matter are characterised by the type of change R and reach the level of conception Understand and Partial Understanding. Reconstruction of misconceptions into the conception level Understand of 9.1% is made up of students SE27, SE28 and SE29. While at the conception level reconstruction become Partial Understanding, the percentage is 12.1% composed of students SE1, SE9, SE10 and SE23. For example, occur in students' misconceptions SE9 which states that the ball loose from the rope when moving in a circle will take a circular path anyway. This is because students SE9 assumption that the ball tends to maintain its motion. But after learning activities with CCM with PDEODE*E task, going on the reconstruction of misconceptions become better conception.

Improvement of Student Conception

Table 7 presents the results of the awarding of the score and the calculation of the N-Gain in the experimental class and control class.

Table 7

N-Gain value on experimental class students and control class students

Experimental Class			Control Class		
Student	<g>	Interpretation	Student	<g>	Interpretation
SE1	0,8	High	SC1	0,5	Moderate
SE2	0,9	High	SC2	0,6	Moderate
SE3	0,8	High	SC3	0,2	Low
SE4	0,7	High	SC4	0,1	Low
SE5	0,9	High	SC5	0,5	Moderate
SE6	0,8	High	SC6	0,6	Moderate
SE7	0,6	Moderate	SC7	0,5	Moderate
SE8	0,8	High	SC8	0,1	Low
SE9	0,9	High	SC9	0,1	Low
SE10	0,4	Moderate	SC0	0,5	Moderate
SE11	0,9	High	SC1	0,8	High
SE12	0,8	High	SC2	0,8	High
SE13	0,8	High	SC3	0,6	Moderate
SE14	0,6	Moderate	SC4	0,1	Low
SE15	0,8	High	SC15	0,5	Moderate
SE16	0,8	High	SC16	0,4	Moderate
SE17	0,5	Moderate	SC17	0,2	Low
SE18	0,8	High	SC18	0,5	Moderate
SE19	0,6	Moderate	SC19	0,3	Low
SE20	0,8	High	SC20	0,2	Low
SE21	0,4	Moderate	SC21	0,2	Low
SE22	0,9	High	SC22	0,8	High
SE23	0,2	Low	SC23	0,2	Low
SE24	0,9	High	SC24	0,7	High
SE25	0,8	High	SC25	0,4	Moderate
SE26	0,9	High	SC26	0,6	Moderate
SE27	0,8	High	SC27	0,2	Low
SE28	0,8	High	SC28	0,5	Moderate
SE29	0,3	Low	SC29	0,1	Low
SE30	0,9	High	SC30	0,1	Low
SE31	0,8	High	SC31	0,8	High
SE32	0,8	High	SC32	0,8	High
SE33	0,6	Moderate	-	-	-
Average	0,73	High	-	0,42	Moderate

Note. Description: SE = students in experimental class; SC = students in the class control

Improved students' conceptions after the implementation of CCM with PDEODE*E tasks can also gotten from the comparison of the average N-Gain value in the experiment and the control class that shows the value of 0.73 and 0.42. Based on the mean of the N-Gain value, the interpretation obtained at the "High" for the experiment class and the "low" for the control class. Thus, it can be said that the implementation of CCM with PDEODE*E tasks can improve student conception. Table 8 shows the results of the calculation of the data in Table 8, obtained a quantity of students based on their interpretation of the value N-Gain.

Table 8

Percentage of the N-Gain value interpretation on experiment and control class

Interpretation	Experimental Class		Control Class	
	Number of Students	Percentage (%)	Number of Students	Percentage (%)
High	24	73	6	19
Moderate	7	21	13	41
Low	2	6	13	41

Table 8 suggests that the experimental class tend to be better than the control class in relation to understanding of the force concept. In the experiments class, interpretations which shows an increase in dominance is the "High" i.e. interpretation of 73%. In the control class, the predominant were “Moderate” and "low" with the same percentage with 41% from both. This is in line with (Azizah et al., 2019; Gao et al., 2020; Author et al., 2020), which used conceptual change in learning to reduce misconceptions. The efficacy of PDEODE*E tasks in also maximising the reduction of misconceptions has also been demonstrated before (Rahmi et al., 2019).

Conclusion

Based on the research questions posed, three questions must be answered. There were still misconceptions identified by the post-test. However, there was a change in conceptions that occurred after the implementation of the CCM with PDEODE*E tasks. The highest conceptual change is in the Misconceptions category (GC= 34.5) and the lowest is in the Un-Code category (U-GC= 2.4). The increase in the correctness of the conception was measured in the experimental class at 0.73 (High category), and the control class is 0.42 (Moderate Category). Thus, it can be said that the implementation of the CCM with the PDEODE*E task can reconstruct students' conceptions for the better. This finding has implications for practitioners or teachers in providing alternative learning models that can reconstruct students' conceptions for the better. However, this study did not focus on other factors besides improving students' conceptions, and this may be a limitation of this study.

Acknowledgements

Thanks to DRPM Kemendikbud Ristek which has supported the funding of this research.

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