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Remediation of Misconceptions Vocational High School Students on the Concept of Static Fluids using the Conceptual Change Model

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Abstract: Many Vocational High School students have misconceptions, particularly about the concept of static fluid. Many factors contribute to students' misconceptions, one of which is that the teaching strategy used is still teacher-centered. To address these issues, researchers attempted to apply Conceptual Change Model (CCM) learning to the static fluid concept. The research method used is pre-experiment with a Group Pretest-Posttest design. A pre-experimental study was conducted on one group of students (the experimental group) without a comparison group (the control group). The subjects of this study were 30 Vocational High School students in Bandung City. Identification of misconceptions using the Three-Tier Test (3T) technique. A formula adapted from the normalized gain calculation was used to calculate the decrease in the number of students with misconceptions. The 3T identification results showed a decrease in the number of students who have misconceptions about each static fluid concept with an average score of 0.79. It decreases the number of students who have misconceptions that are included in the high category. Applying the CCM learning to Vocational High School students can reduce the number of students who have misconceptions about the concept of static fluid. Misconceptions were decreased because CCM learning involved changing existing conceptions and discovering new concepts that could be understood and made sense. This demonstrates that CCM learning can be a viable alternative for remediating misconceptions.

Keywords: Conceptual Change Model*,* misconception, remediation, vocational high school

1. Introduction

Learning physics at Vocational High Schools aims to help learners understand physics concepts, develop science and technology, and gain self-confidence as a prerequisite for continuing education at a higher level in their vocational field (Maryanti & Nandiyanto, 2021). In Indonesia, physics has been taught since Elementary and Junior High School through Natural Science subject. Physics are fundamental sciences that support the development of vocational high school students' skill competencies following the vocational field. For example, the concept of static fluid is a fundamental concept to support the competence of Mechanical Engineering and Civil Engineering skills. Learning science is essential to study in a vocational school and must be put correctly in the curriculum because it helps to develop students' information and competencies (Hidayat et al., 2020; Rosina et al., 2021; Maryanti et al., 2021a; Maryanti et al., 2021b). This is in line with the opinion of Docktor & Mestre (2014) that students have created their knowledge which is referred to as preconception. A misconception occurs when a student's preconceptions contradict scientific understanding (Turgut et al., 2011). In physics, misconceptions are defined as incorrect meanings, misuse, misclassification of examples, and false hierarchical relationships between concepts. Misconceptions and a lack of understanding of physics concepts are issues in physics learning at Vocational High Schools.

Many factors can cause students to experience misconceptions (Sozblir, 2003) and they can be grouped into students, teachers, textbooks, contexts, and teaching methods. Teachers who have misconceptions are the cause of misconceptions

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in students (Cibik & Dikken, 2008). The cause of the teacher's misconceptions could be a lack of conceptual mastery, ineffective teaching methods, or poor teacher attitudes. Another factor that causes misconceptions is textbooks (Gonen & Kocakaya, 2010). Students frequently memorize concept definitions without paying attention to the relationship between concepts when studying physics concepts, so that new concepts do not enter the network of concepts that already exist in students' brains and have no meaning. This is common among most students, including teachers, who frequently encounter misconceptions at school. This study focused on the teaching, which is consistent with observations made in several vocational schools in the city of Bandung Indonesia where physics learning is informative; students gain concepts based on information from the teacher; the teacher frequently brings up mathematical equations and arithmetic problems, making it difficult for students to understand physics concepts and their relationships with natural phenomena (Marwiah, 2014).

Some physics learning misconceptions revolve around the concept of static fluid experienced by Vocational High School Students. One of the common misconceptions about fluids is that as the depth of the liquid increases, so does the magnitude of the buoyant force. When the number of liquid increases, the magnitude of the buoyant force increases, and when the number of liquid decreases, the magnitude of the buoyancy decreases (Kiray et al., 2015). Ozkan & Selcuk (2015) found the misconception that the buoyant force experienced by a sinking object and a floating object is equal to the weight of the object. Cepni et al. (2011) stated that sinking objects move less liquid than floating objects, that heavy objects move more liquid than light objects, and that the volume of liquid determines whether an object sinks.

A misconception is a term that refers to the difference in thinking between a person's concept and the concept of scientific theory determined by experts (Putri et al., 2021). Misconceptions occur because of differences in the understanding formed by students with the facts explained in literature (Nandiyanto et al., 2022). Misconceptions that emerge regularly can impede the formation of scientific concepts in students and teachers (Chaniarosi, 2014). Misconception refers to a concept that is incompatible with the scientific understanding or understanding accepted by experts in the field (Maryanti et al., 2022). Students misconceptions obstruct further learning, preventing new knowledge from being properly integrated (Costu et al., 2009). Misconceptions can cause students to misunderstand scientific phenomena. Misconceptions will become a hindrance for students in the next learning process if they are not immediately remedied. As a result, it is critical to identify misconceptions so that efforts can be made to improve the learning process and arrange remediation activities to correct misconceptions in learning physics. The goal of remediation activities is to improve student learning issues (Rasim et al., 2021).

Misconceptions must be carefully identified so that teachers can implement the best learning method. To determine whether students have misconceptions, extensive identification is required. Chu et al. (2009) stated that one way to find out misconceptions is a two-tier test. A two-tier multiple-choice test is a test tool that is effective at diagnosing misconceptions and is simple to assess. However, Caleon & Subramaniam (2010) stated that the two-tier test cannot explore students' beliefs about their conceptions. Another shortcoming of the two-tier test is that it cannot differentiate between incorrect answers caused by a lack of knowledge and errors caused by misconceptions. The two-tier test cannot differentiate between the correct answer because students understand the concept and the correct answer because they guess. To complete the two-tier test, some researchers developed a technique for identifying misconceptions, specifically a three-tier test (3T) based on the students' conception criteria. The 3T is a multiple-choice test that is divided into three stages. The first stage consists of a question that assesses students' understanding of a concept. The reasons for the answers in the first stage are discussed in the second stage. The second stage includes five options, one of which is in the blank column. It is used to determine whether students have misconceptions that are not listed in the literature. The third stage is the level of certainty, which includes "sure" and "not sure". The 3T is expected to be more accurate than the one-tier or two-tier diagnostic tests in identifying students' misconceptions (Gurcay & Gulbas, 2015). The 3T allows teachers and students to identify misconceptions to provide an overview to the teacher of the student's mastery of the material that has been delivered, and students will correct their misconceptions with scientific concepts or change the wrong concept to the right concept. The 3T can be considered a more valid and reliable instrument for assessing achievement or misconceptions (Pesman & Eryilmaz, 2010). The 3T is a reliable and valid measuring tool for determining students' conceptual understanding and misconceptions (Taslidere, 2016).

After identifying the misconceptions that students encountered during physics lessons, the next step is to formulate solutions to resolve the misconceptions. Learning in vocational education is not similar to learning in general education. The difference between learning in vocational education and general education is viewed as a function of the learning method, learning activity in vocational education involves more practical work and learning by doing (Jalinus et al., 2019; Ana, 2020). Many alternative learning strategy solutions that teachers can use to achieve optimal learning include the Conceptual Change Model (CCM) learning also known as the conceptual change learning model. Innovative learning based on the constructivist paradigm helps students to internalize, reshape, or transform new information.

CCM defines learning as changing existing conceptions (i.e., beliefs, ideas, or ways of thinking) so that learning is more than just gathering new facts or learning new skills (see http://epltt.coe.uga.edu/index.php?title=Conceptual_Change). Furthermore, before conceptual restructuring can occur, students must be dissatisfied with existing conceptions and seek out new concepts that are understandable, make sense, and provide a benefit. The CCM has six learning steps (see http://saiwood.com/the-conceptual-change-model/), namely: (1) identification of misconceptions: presenting conceptual and contextual problems, (2) identification of misconceptions:

exposing beliefs, (3) confrontation of misconceptions: denial and demonstration strategies, analogies, or counter-examples, (4) concept accommodation: scientific proof of concepts and principles, (5) concept development: applying the new concepts they have, and (6) expansion of understanding: broadening the understanding and application of knowledge in a meaningful way.

The objective of this study was to achieve an overview of the decrease in the number of vocational high school students who understood the concept of static fluid as a result of using CCM learning. The novelty of this study is the implementation of CCM learning in vocational high schools on the concept of static fluid, which has not been widely used. This study was conducted to reduce the number of students who have misconceptions about physics lessons. Management of students who have misconceptions will result in increased mastery of physics concepts for vocational high school students.

2. Method

The research method applied was pre-experimental, which means that the study was conducted on a single group of students (the experimental group) without a comparison group (the control group). This method was chosen as it was consistent with the research objective, which was to determine the profile of the decline in students' misconceptions, so the control group was not needed. The subjects of this study were all grade eleven students in one of the state Vocational High Schools in the city of Bandung. The research subjects consisted of 30 students: 28 male students and 2 female students. The research design used was a one-group pretest-posttest design, which involved administering a pretest and then intentionally and systematically administering treatment to one class group, specifically in the form of CCM learning, followed by a posttest at the end of the study.

The research instrument in the form of a conceptual understanding test that is integrated with the 3T technique is used as a pre-test and post-test. The research instrument used had been tested for validity and reliability. The research instrument used had been validated and reliable. The item validity test is done by calculating the correlation of the item score with the total item score. The results of the correlation analysis are then compared with the criteria. The results of the item validity test are indicated by the correlation values ranging from 0.31 to 0.93, which are in the low to high category. The research instrument used is a multiple-choice test, so the reliability coefficient calculation uses the KR 21 formula. The instrument reliability was 0.96, which falls into the high category. Through this test, it is expected to find out a decrease in the number of students who have misconceptions about static fluid material. This diagnostic and concept comprehension test consists of 36 multiple-choice questions. Of the 36 questions, 19 questions are a matter of identifying misconceptions (diagnostic tests) with three levels of 3T. The first level is multiple-choice, the second level is multiple choice in the reasons form of the first level, and the third level is the 3T confidence index with a scale of 0-5 which is used to distinguish students who understand concepts, misconceptions, do not understand concepts and errors. To support researchers in their assessments, the confidence index has been simplified into two scales, namely 0 and 1. If students select 0 it means unsure, while selecting 1 indicates certain or sure of the questions in layers 1 and 2.

2.1 Treatment Procedure

The CCM learning virtual simulation media-assisted implementation aims to reduce the number of vocational students who have misconceptions about the concept of static fluid. This learning implementation is carried out in seven meetings, each consisting of two lesson hours or two times forty-five minutes. The details of the learning implementation are as follows:

(i) The Pre-test was to determine students who have misconceptions.
(ii) The Implementation of CCM learning virtual simulation media-assisted was to explain hydrostatic pressure.
(iii) The first Post-tests was to analyze the decrease in students' misconceptions about hydrostatic pressure.
(iv) The Implementation of CCM learning virtual simulation media-assisted was to explain Archimedes' law.
(v) The Second post-tests was to analyze the decline in students' misconceptions of Archimedes' law.
(vi) The Implementation of CCM learning virtual simulation media-assisted was to explain Pascal's law.
(vii) The third post-tests was to analyze the decline in students' misconceptions of Pascal's law.

During the CCM learning virtual simulation media-assisted implementation, observations were made by filling in the things observed in the observation sheet to determine the learning model’s performance. Based on the results, it is known how the activities of students and teachers occur during the learning process.

2.2 Data Analysis

The process of identifying students' misconceptions used 3T with two levels of confidence options. Students are categorized as understanding the concept of the assessment results show that the first and second tiers are correct and sure. If the first tier is correct and the second tier is incorrect, or vice versa, but the third tier is sure, then the student is categorized as a misconception. If the first and second tiers are correct but not sure, then the student is classified as guessing. Students' answers were then grouped into answer categories (see Table 1).

Table 1 - Categories and types of 3T answers

Student Conception Criteria	Types of Answers Each tier		
	1st tier (Answer)	2nd tier (Reason)	3rd tier (Confidence)
Understand the concept	Correct	Correct	Sure
Misconception	Correct	Incorrect	Sure
	Incorrect	Incorrect	Sure
Error	Incorrect	Correct	Sure
Lack of Knowledge	Correct	Correct	Not sure
	Incorrect	Correct	Not sure
	Correct	Incorrect	Not sure
	Incorrect	Incorrect	Not sure

Data processing was conducted to assess the decrease in the number of students who had misconceptions. Analyzing data with an equation adapted from the normalized gain developed by Hake (1998), which is in equation (1):

$$\Delta M(\%) = \frac{\%\,pretest - \%\,posttest}{\%\,pretest - \%\,ideal} \text{ x } 100\% \qquad (1)$$

where ΔM is the decrease in the number of students who have misconceptions, % *Pretest* is the percentage of students who experienced misconceptions before being given treatment, % *Posttest* is the percentage of students who experience misconceptions after being given treatment, and % ideal is the ideal condition for the occurrence of misconceptions (0%). To find out whether there is an average difference (similarity) between two pieces of data, namely students who experience misconceptions before and after learning CCM, the average test is carried out. The testing technique uses paired sample t-test.

3. Results and Discussion

3.1 Misconception Analysis Results

The 3T technique was used to identify the students' misconceptions in this study based on the results of their pretest and posttest. The collected data were then analyzed for each item, along with the 3T value. Table 2 shows the results of the 3T recapitulation, which distinguishes between students who have misconceptions, understand concepts, do not understand concepts, and make errors.

Table 2 - Recapitulation of 3T results

misconception number	Question Number	% Number of Students with Misconceptions		% Number of Students Who Understand the Concept		% Number of Students Does not Understand the Concept		% Total error students	
		pretest	*posttest*	*pretest*	*posttest*	*pretest*	*posttest*	*pretest*	*posttest*
1	1	6.7	0.0	90.0	100	3.3	0.0	0.0	0.0
2	2	50.0	13.3	10.0	76.7	30.0	3.3	10.0	3.3
3	3	90.0	20.0	0.0	73.3	3.3	3.3	6.7	3.3
4	4&19	66.7	15.0	9.9	80.0	15.0	5.0	8.3	0.0
5	5.7	66.5	16.7	25.0	81.7	6.7	1.7	1.7	0.0
6	6	46.7	10.0	46.7	90.0	6.7	3.3	0.0	0.0
7	8	66.7	16.7	16.7	83.3	16.7	0.0	0.0	3.3
8	9	56.7	13.3	20.0	80.0	23.3	0.0	0.0	3.3
9	10	46.7	10.0	26.7	70.0	26.7	3.3	0.0	13.3
10	11&17	43.5	5.0	31.7	90.0	23.3	1.7	3.3	1.7
11	12	80.0	23.3	6.7	73.3	10.0	3.3	3.3	0.0
12	13&16	38.3	8.3	45.0	85.0	10.0	5.0	6.7	1.7
13	14	23.0	3.3	53.3	80.0	20.0	3.3	3.3	10.0
14	15	50.0	10.3	0.0	86.7	26.7	0.0	23.3	3.3
15	18	23.3	6.7	33.3	73.3	23.3	6.7	20.0	13.3

According to the data in Table 2, the percentage of students who have misconceptions in the posttest with the highest percentage is in misconception numbers 3 and 11, with each percentage of students having misconceptions of 20.0% and 23.3%. The causal factor is still the large percentage of students who have misconceptions on misconception number 3 because students are still influenced by everyday experiences, when swimming their body weight feels lighter than when on land. Despite the teacher's explanations in the third (confront beliefs) and fourth (concept accommodation) stages, students continue to believe that their conception is correct. This is in line with the opinion of Lee et al. (2003). Students may disregard the anomaly of circumstances demonstrated in the experiment and still believe that their perception is correct. Students will attempt to explain the cognitive conflicts they are experiencing by making their conceptions make sense. The causal factor is still the large percentage of students who have misconceptions on misconception number 11 because the teacher demonstrates the media through video shows that some students cannot see clearly in the third stage (confront beliefs). To address these issues, teachers are becoming more selective in their selection of learning media.

3.2 Decrease in the Number of Students with Misconceptions

An overview of the data on the decrease in the number of students who have misconceptions about the static fluid concept is presented in Table 3. According to Table 3, all of the concepts tested on the static fluid concept saw a decrease in the number of students who had misconceptions after using the CCM learning. The average reduction in the number of misconceptions is 0.79, which falls into the high category. All misconceptions that exist in each static fluid concept cause changes in students' perceptions. CCM learning is based on constructivist understanding as an alternative solution to learning physics to achieve conceptual understanding and problem-solving abilities. Baser (2006) shows that the post-test average score of students in the experimental class is higher than the control class at the end of learning about temperature and heat concepts.

Statistical tests are required to boost students' confidence who have misconceptions. Statistical testing was performed by comparing the average score of students' misconceptions before treatment and students' misconception scores after CCM learning treatment. The paired sample t-test is used to determine the average difference. Calculations were performed using Windows version 16 of the Statistical Package for the Social Sciences (SPPS). Detailed information on the use of SPSS is explained elsewhere (Afifah et al., 2022). Table 4 shows the test results.

Table 3 - Decreasing the number of students with misconceptions about the concept of static fluids

Misconception number	Question Number	% of Students with Misconceptions		ΔM	Category
		% $M_{pretest}$	% $M_{posttest}$		
1	1	6.7	0.0	1.00	High
2	2	50.0	13.3	0.73	High
3	3	90.0	20.0	0.78	High
4	4&19	66.7	15.0	0.78	High
5	5&7	66.5	16.7	0.75	High
6	6	46.7	10.0	0.79	High
7	8	66.7	16.7	0.75	High
8	9	56.7	13.3	0.77	High
9	10	46.7	10.0	0.79	High
10	11&17	43.5	5.0	0.89	High
11	12	80.0	23.3	0.71	High
12	13&16	38.3	8.3	0.78	High
13	14	23.3	3.3	0.86	High
14	15	50.0	10.0	0.80	High
15	18	23.3	6.7	0.71	High
		Mean		0.79	High

Table 4 – Testing the difference in the average decrease in misconceptions

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
misconceptions pre-test scores - misconceptions post-test scores	7.56667	3.73874	.68260	6.17060	8.96273	11.085	29	0.000

The difference between the pre-test and post-test misconception scores is significant, according to the results of the average difference test at the 95% significance level shown in Table 4. This demonstrates that CCM learning has a 0.79 reduction in misconceptions. This means that CCM learning in physics lessons for vocational high school students on the concept of static fluid has positively impacted by reducing misconceptions by 0.79, which is considered high. In particular, the number of students with misconceptions about each static fluid concept has decreased in the high category. Detailed information is in the following:

(i) The number of students who experienced the misconception on “the maximum pressure in a liquid is right in the middle because it will get a total pressure from above, below and from the side” decreases with the high category marked by ΔM of 1.00.
(ii) The number of students who believed that "hydrostatic pressure depends on the shape of the vessel in which the liquid is in" decreased with the high ΔM of 0.73
(iii) The number of students who experienced the misconception that "the weight of an object in air is greater than the weight of an object in a liquid" decreased with the high category marked by ΔM of 0.78.
(iv) The number of students who experienced the misconception "things float in water because they are lighter than water" decreased with a high category marked by ΔM of 0.78.
(v) The number of students who experienced the misconception "mass/weight is the only factor that causes objects to sink/float" decreased with the high category marked by ΔM of 0.75.
(vi) The number of students who experienced the misconception that "objects of the same material will experience a different position (sink/float) when put into the water if the object is of different shape" decreases with the high category marked by ΔM of 0.79.
(vii) The number of students who experienced the misconception that “the thickness of an object will determine its position (sink/float) when it is inserted into a liquid” decreases with a high category marked by ΔM of 0.75.
(viii) The number of students who experienced the misconception "surface area of an object immersed in a liquid determines the sinking/floating object" decreased with a high category marked by ΔM of 0.77.
(ix) The number of students who experienced the misconception that "a closed container containing an object whose position is immersed in a liquid will sink if a light object is inserted into the container" decreases with the high category marked by ΔM of 0.79.
(x) The number of students who experienced the misconception "sink/float an object in a liquid is determined by the volume of the liquid" decreases with the high category marked by ΔM of 0.89.
(xi) The number of students who experienced the misconception that "an object with holes in its position will sink when immersed in a liquid" decreased with a high category marked by ΔM of 0.71.
(xii) The number of students who experienced the misconception that “the volume of an object is a determinant of the sinking/floating position in a liquid” decreased with a high category marked by ΔM of 0.78.
(xiii) The number of students who experienced the misconception that “an object that floats in a vessel filled with water will sink if the water vessel is shaken” decreased with a high category marked by ΔM of 0.86.
(xiv) The number of students who experienced the misconception that "the larger the part of the object that floats indicates the greater the buoyant force acting" decreases with the high category marked by ΔM of 0.80.
(xv) The number of students who experienced the misconception that fluid pressure always points downwards' decreased with a high category marked by ΔM of 0.71.

Implemented CCM learning can help students overcome misconceptions and can be explained as follows. Before being confronted with a state of cognitive conflict, students with misconceptions were asked questions that could explore the misconceptions that exist in their cognition, and the answers they provided demonstrated their level of belief. Following that, students were confronted with cognitive conflict, in which there was a conflict between students' initial conceptions and scientific conceptions (new concepts). For example, buoyancy is determined by the volume of the submerged object rather than the volume that floats. When asked about the concept, many students responded confidently that the buoyant force was determined by the volume of the floating object. This response resulted from an incomplete understanding of the concept, which they had previously believed. This response and level of certainty indicated that many of them had misconceptions.

When students were exposed to virtual demonstrations in the form of PhET shows, their perceptions and beliefs begin to shift. PhET simulations are interactive simulations of science and math concepts created by the University of Colorado Boulder. Students can run these simulations, manipulating different aspects of a construct to understand science and mathematics concepts. Depending on the simulation, students may also be able to collect, graph, and analyze data to conclude their own. Following the PhET show, all students stated that the buoyant force was determined by the volume of the submerged object, rather than the volume that floated. Students recognize that their perception is incorrect. Because of the existence of this conceptual conflict, students may become dissatisfied with their conceptions, allowing for significant concept changes in students following scientific conceptions. To ensure that the concept changes in students are consistent, the concept is reinforced at the scientific explanation stage with the help of learning videos. Following treatment, it was discovered that misconceptions still exist in all static fluid concepts, albeit with a lower percentage of misconceptions. This demonstrates that most students experience remediation of misconceptions about static fluid after using CCM learning.

4. Conclusion

The outcomes of identifying student misconceptions about the concept of static fluid are quite diverse. The findings of this study revealed 15 misconceptions about the static fluid that students at Vocational High School had during physics lessons. Researchers attempted to use CCM learning to correct the misconceptions that the students had. The model implementation was successful in reducing the 15 misconceptions experienced by students. The decrease in misconceptions ranged from 0.71 to 1.00, with an average decrease of 0.79 falling into the high category. According to these findings, applying CCM learning to Vocational High School students can reduce the number of students who have misconceptions about the concept of static fluid. This demonstrates that CCM learning can be a viable alternative for correcting misconceptions.

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