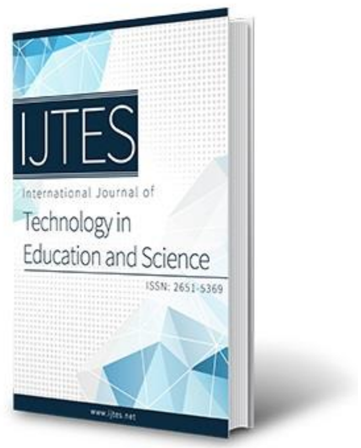

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Conceptual Change based on Virtual Media (CC-VM) versus POE Strategy: Analysis of Mental Model Improvement and Changes on Light Wave Concepts

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Abstract

The purpose of this study is to analyze the mental model of improvement and changes on light wave concepts with Conceptual Change based on Virtual Media (CC-VM) x POE strategy. The method used is mixed methods with embedded design. The sample consisted of 30 students (with an age range of 16-17 years) in one of the schools in Subang, Indonesia. The instrument used is 15 questions with a four-tier format, which consists of the concepts of Light Waves. Data analysis was carried out by entering students' answers in the mental change category (Acceptable Change (AC), No Change Positive (NCP), No Change Negative (NCN), and Not Acceptable Change (NAC)), then calculations to improve the mental model with the equation Normal Change <c> (with high, moderate, low, and negative categories). Meanwhile, the change in the mental model is identified by a percentage for each change. As a result, the increase in mental models is dominated by the "moderate" category (65%) and the lowest is the "high" category (15%). The category of mental changes was dominated by AC (74%) and the category of the least changes was found in NCP (3%).

Introduction

Conceptual change approach put forward by Posner et al. (1982). This approach represents a point of view that is based on the views of Piaget and Zeitgeist but has been improved upon by Posner and his colleagues (Özkan & Selçuk, 2013). The reason for this approach, which is an alternative strategy derived from Piaget's principles of absorption, regulation, and balancing, is to empower students to clear misconceptions from their minds, and instead learn scientific knowledge. While absorbing, learners compare concepts with their old knowledge, including more information to rebuild. Conceptual change can be demonstrated by increasing students' conceptual understanding of correct scientific concepts and overcoming unscientific misconceptions (Lau et al., 2011; Syuhendri, 2017).

One application of the conceptual change approach is the conceptual change text (e.g. Azizah et al., 2019; Chen et al., 2017; Suhandi et al., 2017; Turgut & Gurbuz, 2012). The text of conceptual change is based on the theory of conceptual change put forward by Posner et al. (1982). Conceptual change text is a text that warns students about the possibility of alternative conceptions, provides scientific explanations, and shows contradictions between alternative conceptions and scientific concepts (Yürük & Eroğlu, 2016). Conceptual change text is a text that presents a conflict between misunderstanding and scientifically correct information. In the text of conceptual change, students are first made sure to realize their misconceptions. After that, the reason for the misconception is explained through examples and reasons. Learners feel that their knowledge is insufficient in explaining new situations they encounter and conceptual change is ensured by showing them scientifically correct concepts. (Fratiwi et al., 2020).

The conceptual change text used in the classroom is applied in the following steps: (1) Common misconceptions that students have are identified. (2) Students are asked to make predictions about certain situations to present inconsistencies between alternatives and scientific conceptions. (3) Evidence is provided to show that their conception is wrong. (4) The text explanation phase involves the explanation of scientifically correct concepts (Chambers, SK; Andre, 1997). Many studies have shown that conceptual change texts help students to change students' alternative conceptions in various topics (e.g. Çetin, Ertepinar, Geban, 2015; Putri et al., 2022; Yenilmez, Tekkaya, 2006).

Conditions that are carried out to eliminate misconceptions and form scientific concepts include: dissatisfaction (dissatisfaction), things that can be understood (intelligibility), things that make sense (plausibility), success (fruitfulness) (Posner et al., 1982). The conceptual change text used in this study was designed according to the four items mentioned earlier. First, the concept of a conceptual change text is determined. After completing this process, questions that will activate students' misconceptions are asked. In the second part, common misconceptions about the topic are presented and the reasons for these misunderstandings are explained. In the third part, detailed information is given about the reasons why this misunderstanding is not correct. In the last part of the text, scientific information about the misconceptions is presented to the students. However, the current situation allows that the conversion of conception can be assisted using various media, one of which is virtual media.

Virtual media is digital media that uses computer technology for various learning purposes. According to Zacharia and Constantinou, virtual media is divided into two types, namely virtual labs and virtual videos (e.g. Kirby et al., 2002; Lee, 2015; Liu, 2010; Zacharia, & Constantinou, 2008). Based on this, virtual media is digital media that utilizes the use of computer technology for various learning purposes. Virtual media can be in the form of text, video, audio, visual, and virtual laboratories.

Virtual media that is designed to be used in experimental activities is called a virtual laboratory or abbreviated as virtual lab. These types of virtual media, both virtual labs and virtual videos, can improve students' ability to understand concepts, improve science process skills, enable students to create ideas and understand complex theories. Students who use virtual media such as virtual laboratories as learning media have a higher ability to understand and present the material they learn (Aldrich, 2009). The same thing was also conveyed by (Magyar, Žáková, 2010) in his research which states that the motivation of students to be more active in participating in learning and developing various skills can be increased by the use of virtual laboratories.

The use of virtual media can help students build concepts related to physics concepts including the concepts of speed and acceleration in parabolic motion. The use of virtual media, in this case, in virtual lab activities, is effective in helping students build concepts so as to improve conceptual understanding of the concept of color dispersion in light wave material (e.g. Aydin et al., 2021; Lähdesmäki & Maunula, 2022; Paje et al., 2021). Virtual media in the form of a virtual lab can also help students in the process of converting conceptions into scientific conceptions (Wibowo et al., 2017). Virtual media can be composed of conceptual change text (CCT) and conceptual change lab (CCLab). In its implementation, the various approaches contained in the virtual media for changing the concept need to be complemented by using certain strategies in learning.

One example is when using the text approach to changing conceptions, several studies that use texts to change conceptions are carried out only through the process of reading the text, not through the learning process. If the learning process is not carried out, the information obtained is only based on the text read without any observation process through experimentation, and there is no discussion process. Similar to the use of a virtual laboratory activity approach, such as the use of computer simulations in forming students' mental models, learning strategies are used so that it is easier for students to construct their knowledge (e.g. Kaniawati et al., 2021; Talan, 2020; Zhao et al., 2022).

Mental models are the essence of meaningful learning to understand and know the reasons for how a system works or a concept is built, an individual needs to build a mental model of this system/concept. Mental model is an internal representation of students' conceptual understanding (Batlolona, 2020). Mental models are defined as representations of individual knowledge, acting as analogous structures of situations or processes (Oh, & Park, 2014). Mental models are also associated with knowledge structures, which are built by individuals to explain and understand a phenomenon (Pasco, & Ennis, 2015). Functionally mental models are similar to computer simulations, which allow students to process knowledge in predicting outcomes (e.g. Liu, Lin, & Tsai, 2020; Peechapol, 2021; Xie & Guo, 2022). Mental models provide information about the conceptual framework that students build in learning physics. Mental models developed in the minds of students can inform teachers about the structure of their knowledge.

Mental models play an important role in the learning process, teachers can guide students to independently build students' knowledge through their mental models. Learners use their mental models to reason, understand, explain, describe, and predict phenomena based on their knowledge. Thus, it can be concluded that the mental model is a conceptual picture possessed by students which is built from perceptions or conceptions that are used to understand, explain and describe abstract and complex phenomena as a result of cognitive processes. Therefore, we need a learning strategy to change the conception, one of which is Predict-Observe-Explain (POE).

Various studies on conceptual change texts reveal that concept change texts help students experience changes in concepts related to photosynthesis better than doing learning using traditional text versions (e.g. Mikkilä-Erdmann, 2001; Yazbec et al., 2019). Traditional texts are texts (teaching materials) taken from contemporary science textbooks that are widely used in schools. Traditional texts are often difficult to understand and cannot change students' conceptions effectively. Traditional texts also do not emphasize the improvement of experienced misconceptions. One way that can be done to change students' conceptions is to use conceptual change text. However, the use of written text alone does not attract the attention of students and is less effective in the learning process. The effect of conception-altering texts on teaching concepts can eliminate misconceptions compared to traditional texts in several studies (Yumuşak et al., 2015). At the end of this study, it was found that the concept modifier text (CCText) was more effective than traditional texts in teaching concepts and eliminating misconceptions (Yumuşak et al., 2015).

One way to make students more active in the learning process is to conduct experimental or practicum activities. Experimental or laboratory activities that are oriented to conceptual change are called conceptual change labs or CC-Labs. The CC-Lab can be used in activities that facilitate the concept change process. This activity allows students to build and modify their own concepts through in-depth exploration activities.

The purpose of changing students' conceptions and making students more active needs to maximize various things. One of them is by combining text, videos, animations, images and simulations (laboratory activities) into a medium that can be accessed both at school in limited face-to-face learning and can be accessed when learning from home. This can be done with virtual media. The combination of conceptual change text, conceptual change lab and conceptual change-based virtual media produces a conceptual change virtual media or virtual media conceptual change (VM-CC). The use of virtual media needs to be supported by learning strategies that can direct the learning process. One strategy that can be used is the Predict, Observe, Explain (POE) learning strategy.

The combination of POE strategy and virtual media conceptual change can be presented using the schema shown in Figure 1.

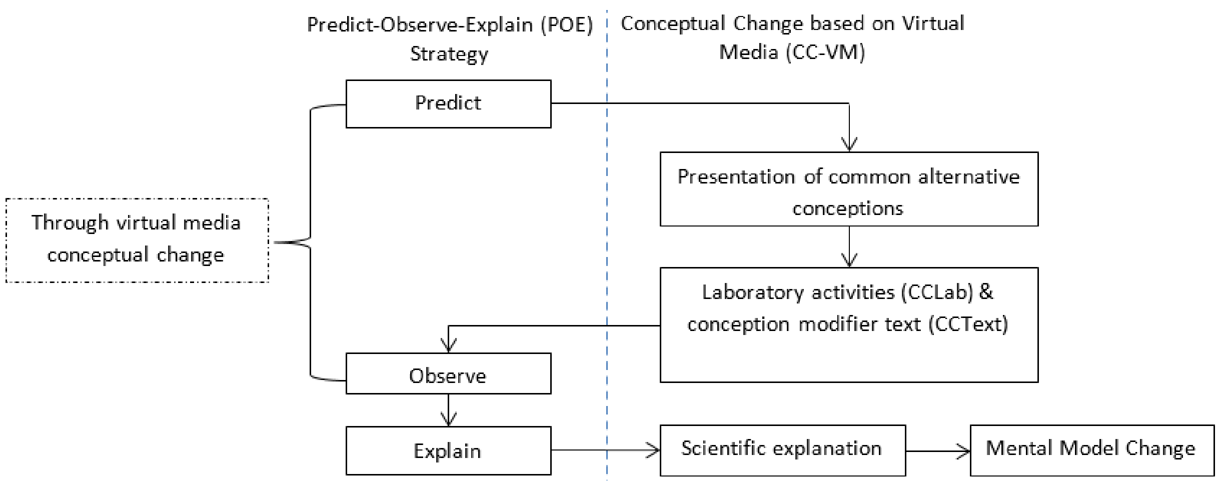


Figure 1. CC-VM versus POE Strategy

It can be seen in Figure 1 that CC-VM can be implemented using a POE strategy. Where, the stage begins with the Predict stage, and ends with Explain so as to get a scientific explanation of the concepts being studied. Meanwhile, the virtual media used, as in the Predict stage, can be seen in Figure 2. Based on this explanation, the purpose of this research is to analyze the mental model of improvement and changes on light wave concepts with Conceptual Change based on Virtual Media (CC-VM) x POE strategy.

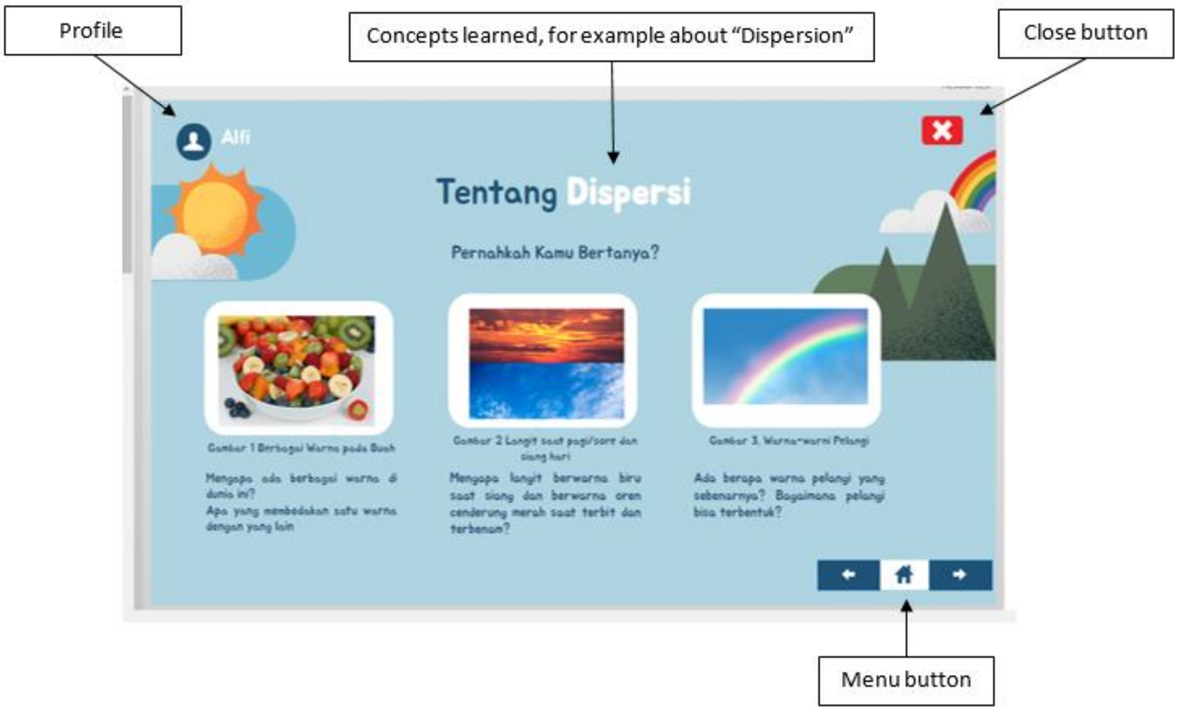


Figure 2. Example of Virtual Media on CC-VM

Method

This study uses a mixed methods research method consisting of a combination of quantitative research and qualitative research. Mixed methods is a procedure for collecting, analyzing, and "mixing" quantitative and qualitative methods in one study or a series of studies to understand a research problem (Creswell, 2012). The basic assumption is that the use of quantitative and qualitative methods, in combination, provides a better understanding of the research problem and question than the methods themselves (Creswell, 2012).

The research design used in this research is embedded design. The purpose of this design is to obtain qualitative and quantitative data simultaneously, but one data serves as a support for other types of data. The priority of the embedded experimental model design is to build quantitatively (experimental studies) while qualitative data sets are subject to (obedient) in these experimental studies. Both types of data, both qualitative and quantitative, were collected in an embedded experimental model design to answer research questions that require different types of data.

Sample

The sample in this study is one class in a school in Subang, West Java for the 2021/2022 academic year with a total of 30 students (with an age range of 16-17 years). The sampling technique is by purposive sampling. The samples studied were students who would study the material of light waves. This is because there are several teachers in class XI and make learning uneven in terms of material, so the selected sample is a class whose next material is light wave material. The location areas that are sampled in this research can be seen in Figure 3.

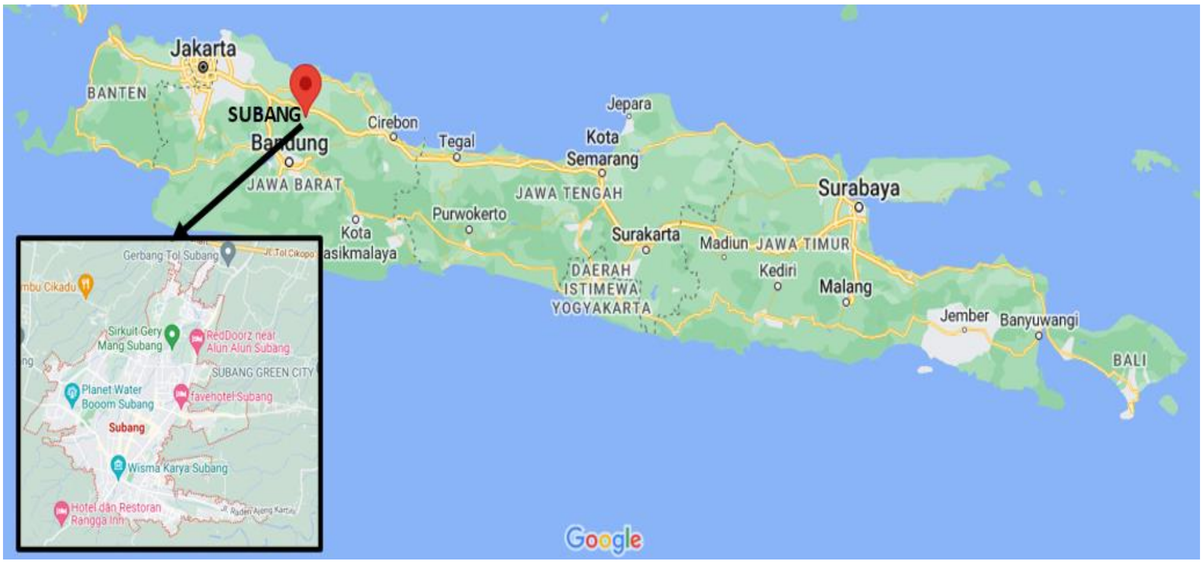


Figure 3. Subang, Jawa Barat (Source: Google map)

Instruments

The instrument in the four-tier test format is one of the instruments used to diagnose the level of conception and mental models of students on a physics concept. In the four-tier test instrument, the teacher can:

(1) distinguish the level of confidence in the answers and the level of belief in the reasons chosen by students so that they can explore deeper about the strength of students' conceptual understanding,

(2) diagnose misconceptions experienced by students more deeply,

(3) determine the parts of the material that require more emphasis,

(4) plan better learning to help reduce students' misconceptions.

In addition, the teacher can also map the mental models of students based on the results of the analysis of students' answers using the four tier tests instrument.

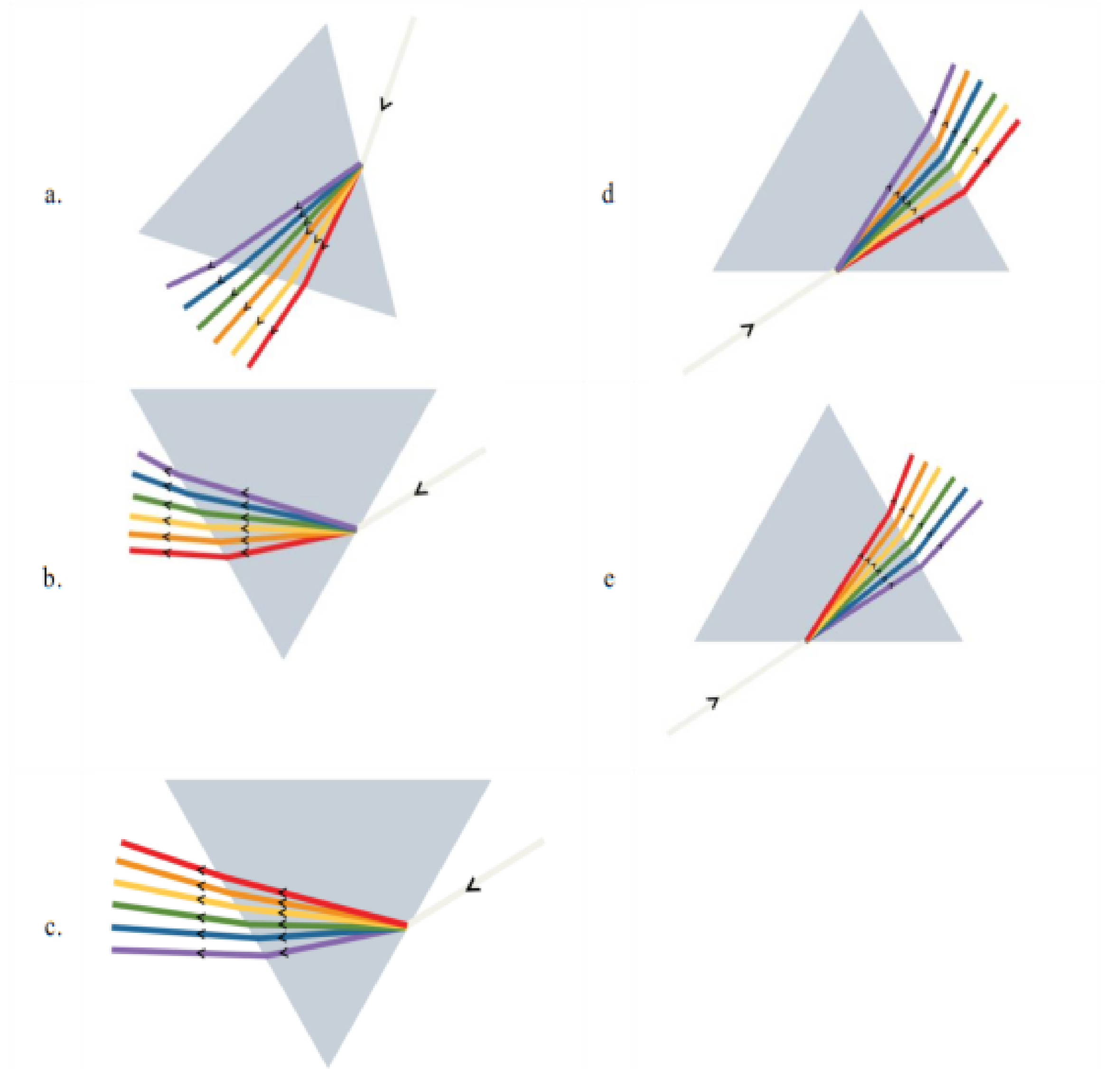
The first level (first tier) on this test instrument is a multiple-choice question that contains four to five answer choices, but there is only one correct answer choice. The second level is the level of confidence that asks students' beliefs about the answers chosen in the first tier.

There are two answer choices at the second level, namely "Sure" and "Not Sure". The third level is the reason for choosing the answer at the first level, the reason consists of multiple choices obtained from mapping students' answers when testing with the form of an instrument in the reason section which is an open-ended question. The fourth level is the level of confidence that asks students' confidence in choosing the reasons that have been chosen in the third tier. The choice of the level of confidence in the fourth tier is the same as the choice in the second tier between "Sure" and "Not sure". An example of the instrument used can be seen in Figure 4.

Figure 4 shows an example of the four-tier questions used. Tier 1 contains questions, Tier 2 contains confidence in the answers to Tier 1, Tier 3 contains explanations for answers to Tier 1, and Tier 4 contains confidence levels in Tier 3. Meanwhile, the distribution of questions can be seen in Table 1.

Tier 1

2.1 If white light (polychromatic) penetrates a triangular prism made of glass at an angle, then the light coming out of the prism is correctly shown in the figure….



Tier 2

2.2 Are you sure about your answer to question 2.1?
A. Sure B. Not Sure

Tier 3

2.3 The reason for the answer to question 2.1 is ….
A. Because after all the rays that come from red are always on top
B. Because light coming from below always produces a purple color at the top
C. Since the colors are ordered according to the direction of the incident light, the topmost color can be red or purple .
D. Because after all the light coming from the purple color is above
E. Because the rays coming from right and left always produce a red color above

Tier 4

2.4 Are you sure about your answer to question 2.3?
A. Sure B. Not Sure

Figure 4. Four-tier Instrument Test

Table 1. Distribution of Problems and Construction of the Four Tiers Test of Light Waves

No	Sub-Concept	Question Number
1	Light Waves (in general), Light Spectrum and Dispersion	1
		2
		3
		4
2	Interference	5
		6
		7
		8
3	Diffraction	9
		1
		10
		11
4	Polarization	13
		14
		15

Data Analysis

Based on the conception of the mental model of students, they can be grouped as shown in Table 2.

Table 2. Category of Student Mental Model

Mental Model Category	Conception Category
Scientific	The conception of students is in the category of understanding concepts according to scientific conceptions
Synthetic	The category of conception in an artificial mental model can be divided into several parts 1. Synthetic I: Understand the concept partially with answers on tier 1 and 2 correct and tier 2 and 4 combinations of sure and not sure. This can be called Partial Positive (PP). 2. Synthetic II Understand the concept partially with answers on tier 1 right and tier 3 wrong and tier 2 and 4 being a combination of sure and not sure. This is also known as Partial Negative 3. Synthetic III Understand the concept partially with answers on tier 1 wrong and tier 3 correct and tier 2 and 4 being a combination of sure and not sure.
Misconception	Misconceptions with answers on tier 1 and 3 wrong and tier 2 and 4 sure.
Initial	The conception of students is in the category of not understanding the concept and no coding

The mental models of students were identified using the four tiers test instrument and then classified and scored based on the scores in Table 3.

Table 3. Mental Model Categories and Scores

Mental Model Category	Symbol	Tier 1	Tier 2	Tier 3	Tier 4	Score
Scientific (SC)		Right	Certain	Right	Certain	5
Synthetic I (SY I)		Right	Uncertain	Right	Certain	4
		Right	Certain	Right	Uncertain	
		Right	Uncertain	Right	Uncertain	
Synthetic II (SY II)		Right	Certain	Wrong	Certain	3
		Right	Uncertain	Wrong	Certain	
		Right	Certain	Wrong	Uncertain	
		Right	Uncertain	Wrong	Uncertain	
Synthetic III (SY III)		Wrong	Certain	Right	Certain	
		Wrong	Uncertain	Right	Certain	
		Wrong	Certain	Right	Uncertain	2
		Wrong	Uncertain	Right	Uncertain	
Misconception (MC)		Wrong	Certain	Wrong	Certain	1
		Wrong	Uncertain	Wrong	Certain	0
		Wrong	Certain	Wrong	Uncertain	
		Wrong	Uncertain	Wrong	Uncertain	
Initial (IN)		If not filling one or more items (level)				(empty)

Based on Table 3, students' mental models on the concept of light waves are characterized by various forms of lasers. This is a representation of the concept of light waves which are identical in relation to lasers. The color of the laser and the laser components characterize the students' conceptions while the color of the laser light represents the level of students' beliefs. The scientific mental model (SC) is depicted with a black laser and a red laser light. This is marked by students being able to explain concepts correctly and confidently. Type I artificial mental model or synthetic I (SY I) is depicted with a black laser and blue laser light. This illustrates that students can explain concepts correctly both at tier 1 and 3 but have a level of confidence which is a combination of "sure" and "not sure" at tier 2 and 4. Artificial mental model type II or synthetic II (SY II) is represented by a black gray laser and blue laser light. This indicates that students are able to determine the answer to a concept correctly but are still wrong on the aspect of reasons and have a level of confidence which is a combination of "sure" and "not sure" at tier 2 and 4. Meanwhile, the artificial mental model is type III or synthetic III. (SY III) is represented by a blue gray laser and blue laser light. This shows that students are not able to answer questions about a concept correctly but can answer the reasons for a question related to a concept, while in terms of the level of confidence students have a level of confidence which is a combination of "sure" and "not sure" at tier 2 and 4. Misconception mental models (MC) are marked with gray lasers and blue laser light. This MC mental model is a mental model that illustrates that participants do not have the right conception of a concept but believe in the inaccurate concept. The initial or initial mental model given the IN symbol is a mental model of students who do not understand the physics concepts presented.

Mental Model Improvement

Improvement of students' mental models can be known by analyzing the pretest and posttest data. Data analysis on improving students' mental models was carried out by analyzing the normalized change (n-change) values. Normalized change (n-changed) is an equation commonly used to measure student improvement in physics education research (Sriyansyah & Azhari, 2017). Normal change can measure all possible student changes as measured by instruments that have been answered, both when the pretest < posttest, pretest = posttest, and pretest > posttest scores. Before the normal change analysis is carried out, scoring is first carried out on the students' mental models for each concept.

Normal change (N-change) is symbolized by the <c> symbol. N-change analysis is carried out by analyzing the pretest and posttest scores obtained by students. N-change can analyze pretest and posttest scores under various conditions, such as when the posttest value is greater than the pretest, when the pretest value is equal to the maximum value, when the pretest value = posttest, and when the pretest value is less than the posttest value. Equation 1, 2, 3, and 4 is the n-change equation used in data analysis (e.g. Marx & Cummings, 2011; Sriyansyah & Azhari, 2017).

$$
\langle c \rangle \begin{cases}
\dfrac{Posttest\ Scores - Pretest\ Scores}{Maximum\ Score - Pretest\ Score} & \rightarrow \text{Posttest > Pretest} & (1) \\[2ex]
Drop & \rightarrow \text{Posttest = Pretest = Maximum Score = 0} & (2) \\[2ex]
0 & \rightarrow \text{Posttest = Pretest} & (3) \\[2ex]
\dfrac{Posttest\ Scores - Pretest\ Scores}{Pretest\ Scores} & \rightarrow \text{Posttest < Pretest} & (4)
\end{cases}
$$

The n-change value obtained is then interpreted and used to identify the role of the treatment given to improving mental models. Table 4 shows the interpretation of the n-change values.

N-Change Value Interpretation

Table 4. N-Change Value Interpretation

N-change	Interpretation
$0,7 < \langle c \rangle \leq 1$	High
$0,3 < \langle c \rangle \leq 0,7$	Moderate
$0 < \langle c \rangle \leq 0,3$	Low
$-1 < \langle c \rangle < 0$	Negative

Mental Model Changes

Furthermore, the identification of changes in the mental model of students is divided into four categories, namely for changes in mental models, namely Acceptable Change (AC), No Positive Change (NCP), No Negative Change (NCN), and Not Acceptable Change (NAC). Mental model Table 5 can show the type of change in the mental model of students.

Table 5. Mental Model Change Type

Mental Model Level		Category	Mental Model Change Direction Symbol
Before	After		
SY I	SC	Acceptable Change (+) (AC)	→
SY II	SY I/ SC		
SY III	SY II/SY I/SC		
MC	SY III/SY II/ SY I/ SC		
IN	MC/ SY III/ SY II/ SY I/ SC		
SC	SC	No Change Positive (NCP)	- - - →
SY I	SY I	No Change Negative (NCN)	→
SY II	SY II		
SY III	SY III		
MC	MC		
IN	IN		
SC	SY I/SY II/SY III/ MC/ IN	Not Acceptable Change (-) (NAC)	- - - →
SY I	SY II/SY III/ MC/ IN		
SY II	SY III/ MC/ IN		
MC	IN		

Based on the types of mental model changes in Table 5, the possible changes in mental models that can be experienced by students after learning can be shown in Figure 5.

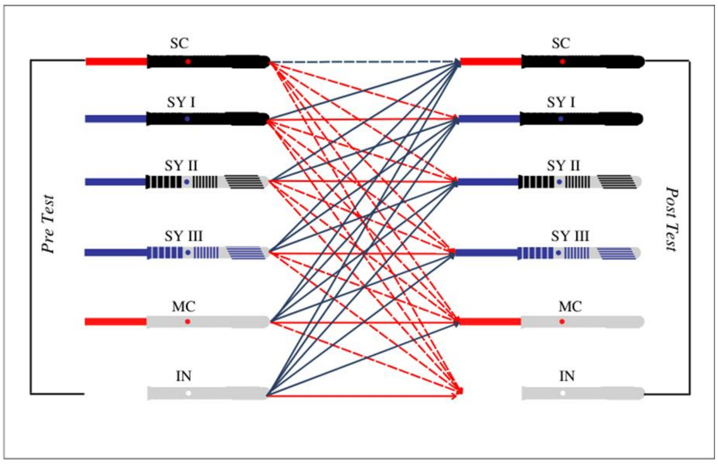


Figure 5. Four-tier Instrument Test

Equation 5 is used to determine the percentage of changes in mental models experienced by students. The following equation can also be used to get a general picture of changes in mental models.

$$\% = \frac{\sum \text{students in a category}}{\sum \text{total students}} \times 100 \quad (5)$$

Result and Discussion

Mental Model Improvement

The effect of the treatment in the form of learning using conceptual change based virtual media (CC-VM) with the POE strategy can be seen from the improvement of students' mental models. An increase in students' mental models was obtained by analyzing the pretest and posttest scores using the n-change value ⟨c⟩. The calculation results for the value of n-change can be seen in Table 6.

Table 6. Recapitulation of Student Mental Model Improvement

No	Students	Pretest	Posttest	N-Change ⟨c⟩	Interpretation
1	PDL 01	29	53	0,52	Moderate
2	PDL 02	35	44	0,23	Low
3	PDL 03	32	36	0,09	Low
4	PDL 04	32	43	0,26	Low
5	PDL 05	23	51	0,54	Moderate
6	PDL 06	27	54	0,56	Moderate
7	PDL 07	22	35	0,25	Low
8	PDL 08	22	39	0,32	Moderate
9	PDP 01	23	72	0,94	High
10	PDP 02	23	39	0,31	Moderate
11	PDP 03	25	43	0,36	Moderate
12	PDP 04	12	51	0,62	Moderate
13	PDP 05	25	40	0,30	Low
14	PDP 06	16	47	0,53	Moderate
15	PDP 07	23	64	0,79	High
16	PDP 08	18	57	0,68	Moderate
17	PDP 09	24	35	0,22	Low
18	PDP 10	24	48	0,47	Moderate
19	PDP 11	23	63	0,77	High
20	PDP 12	27	62	0,73	High
21	PDP 13	22	44	0,42	Moderate
22	PDP 14	26	45	0,39	Moderate
23	PDP 15	19	29	0,18	Low
24	PDP 16	19	55	0,64	Moderate

No	Students	Pretest	Posttest	N-Change ⟨c⟩	Interpretation
25	PDP 17	27	43	0,33	Moderate
26	PDP 18	17	50	0,57	Moderate
27	PDP 19	26	48	0,45	Moderate
28	PDP 20	21	60	0,72	High
29	PDP 21	17	47	0,52	Moderate
30	PDP 22	21	48	0,50	Moderate
31	PDP 23	17	43	0,45	Moderate
32	PDP 24	26	53	0,55	Moderate
33	PDP 25	21	49	0,52	Moderate
34	PDP 26	23	43	0,38	Moderate

Based on the results of normalized change data calculations in Table 6., it can be seen data regarding the number of students for each interpretation of the N-change value. The distribution of n-change values in Table 7 shows that most students have n-change values in the "moderate" category, there are students in the "low" and "high" categories.

Table 7. General Interpretation of n-Change Values

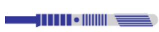
No	Interpretation	Number of Students	%	Average $\langle c \rangle$
1	High	5	15%	0,79
2	Moderate	22	65%	0,48
3	Low	7	21%	0,19

Table 7 shows that 65% of students have an average n-change value of 0.48 with a "moderate" interpretation. Then 15% of students have an average n-change value of 0.79 with the interpretation of "high". While the other 21% of students have an average n-change value of 0.19 with a "low" interpretation. Based on these results it can be seen that most students experienced an increase in mental models after learning using the CC-VM X POE Strategy with moderate interpretation. This is in line with (Samsudin et al., 2021) that the POE strategy can improve students' mental models, even though in this research, the increase occurred in the moderate category. Mental models can be a starting point to facilitate students' initial knowledge to build subsequent new knowledge and achieve a more complete and scientific understanding (Jasdila et al., 2019). Research conducted by Jasdila et al. (2019) also shows that strategy (POE) will lead to greater student participation in learning. Students have the opportunity to issue the information they know. Students finally construct and combine their initial knowledge with the knowledge they have just acquired.

Mental Model Change

The results of this analysis were obtained by comparing the profiles of the mental models of students during the pre-test and post-test as a whole as well as the distribution of students in each type of mental model that was reviewed during the pre-test and post-test. One of the analyzes carried out can be seen in the concept of interference. One of the concepts that students learn is about constructive and destructive interference. The concept of interference and destructiveness is asked in question number 6 (Q6). In question number Q6, students are asked to determine the type of interference and the pattern that results from the image presented in the question. Before learning, most of the students' mental models were in the category of misconceptions (MC). Students believe that the type of interference in question number 6 is constructive interference that will produce a bright pattern on the screen. However, after learning the mental model of students changed. The pattern of changes in the mental model of students on each of these items is shown in detail in Table 8.

Table 8. Categories of Students’ Conceptual Changes

Change Category	Pre	→	Post	Draft (Student Code)	$\langle c \rangle$	f	Examples of Patterns of Changes in Students' Mental Models
Acceptable Change	IN (0)	→	 SC (5)	Constructive and Destructive Interference PDP 02, PDP 04, PDP 06, PDP 11, PDP 18, PDP 21	1.00	6	Before learning PDP 18 had an initial mental model (IN). PDP 18 describes the type of interference in the image is destructive interference that produces a bright pattern on the screen.
		→	 SY II (3)	Constructive and Destructive Interference PDP 12	0,60	1	After doing the learning PDP 18 believes that the type of interference in the image is destructive interference that produces dark patterns on the screen. So that the PDP 18 mental model turns into scientific (SC)
		→	 SY III (3)	Constructive and Destructive Interference PDP 16	0,40	1	PDP 12 in the pretest explains that the type of interference in the image is a type of constructive interference and will produce a bright pattern on the screen. Meanwhile, during the PDP 12 post test, it was explained that the type of interference in the image was destructive interference
		→	MC (1)	Constructive and Destructive Interference PDL 04, PDP 07, PDP 08, PDP 10	0,20	4	The mental model of PDP 16 at the beginning was the initial mental model (IN). PDP 16 selects the type of interference in the image, which is destructive interference and produces a bright pattern because the two sources are in opposite phase to produce a bright pattern. Meanwhile, when the PDP 16 post test was still wrong in determining the type of interference, it was able to correctly explain the reason for the type of interference in the picture.

Change Category	Pre	→	Post	Draft (Student Code)	$\langle c \rangle$	f	Examples of Patterns of Changes in Students' Mental Models
	MC (1)	→	 SC (5)	Constructive and Destructive Interference PDL 03, PDL 08, PDP 01, PDP 15, PDP 17, PDP 20, PDP 22, PDP 25, PDP 26	1,00	9	PDP 10 has an initial mental model (IN) at the pretest and turns into a mental misconception (MC) model at the posttest.
		→	 SY II (3)	Constructive and Destructive Interference PDL 02	0,50	1	PDP 10 describes the type of interference in the image is constructive interference and produces a bright pattern. Meanwhile, when the PDP 10 post test still chose the same answer, only the level of confidence changed from not sure to sure in tiers 1 & 3.
		→	 SY III (3)	Constructive and Destructive Interference PDP 19	0,25	1	PDL 03 at the time of the pretest believed that the answers and reasons were not correct and had a "sure" level of confidence in tiers 1 and 3. At the time of the pretest PDP 03 explained that the type of interference that corresponds to the picture is constructive interference which will produce a bright pattern on the screen. Meanwhile, the PDL 03 post test was able to determine the type of interference and the reason correctly with the level of confidence "sure" in tiers 1 and 3.
	 SY III (3)	→	 SC (5)	Constructive and Destructive Interference PDL 02	01,00	1	PDL 02 at the time of the pretest explained that the type of interference in the image is constructive interference and produces a bright pattern on the screen. Meanwhile, the PDL 02 post test explained that the appropriate interference in the image is destructive interference which will produce a dark pattern on the screen.
		→	 SY II (3)	Constructive and Destructive Interference PDP 13	0,33	1	PDP 19 underwent a mental model change from initial to synthetic type III (SY III). PDP 19 when the pretest could not determine the type of interference in question number 10 and the reason correctly and still did

Change Category	Pre	→	Post	Draft (Student Code)	⟨c⟩	*f*	Examples of Patterns of Changes in Students' Mental Models
							not answer in one of the tiers.
No Change Positive	 SC (5)	→	 SC (5)	Constructive and Destructive Interference PDP 03	0	1	Meanwhile, when the PDP 19 post test was able to answer the reasons but still could not determine the type of interference based on the picture in question number 10.
No Change Negative	 SY III (2)	→	 SY III (2)	Constructive and Destructive Interference PDP 14	0	1	According to PDL 02 at the time of the pretest related to the picture in question number 10, double slits can reinforce each other so as to produce a bright pattern. Meanwhile, when the post test PDL 02 believes that the type of interference in figure 10 is destructive interference that will result in a dark pattern on the screen, because the two sources are in opposite phases, resulting in a dark pattern.
	MC (1)	→	MC (1)	Constructive and Destructive Interference PDL 01, PDL 07, PDP 05, PDP 09, PDP 23	0	5	At the pretest PDP 13 was able to explain the reasons related to question number 10 correctly but could not determine the answer related to the type of interference that corresponded to the picture of question number 10. During the post test PDP 13 was able to determine the type of interference that corresponded to the picture of question number 10 (Q10).
Not Acceptable	 SY III (2)	→	MC (1)	Constructive and Destructive Interference PDL 05	-1	1	PDP 04 explains that the type of interference according to the picture is destructive interference. Because the two sources are in opposite phase, resulting in a dark pattern. After the PDP 04 post test still with the same answer with the same level of confidence.
	 SC (5)	→	 SY III (2)	Constructive and Destructive Interference PDP 24	-0,60	1	The answers and reasons for PDP 14 at the time of the pretest and posttest remained the same. According to PDP 14 the type of interference according the figure is constructive interference.

After doing the learning there is a change in the mental model of the students. After learning the mental model of students is dominated by the scientific mental model (SC). As many as 48% of students were able to determine the type of interference according to the picture in question number 6 (Q6) and were able to determine the reason for the type of interference correctly. The recapitulation of the pattern of changes in the mental model of students in Q6 is shown in Figure 6.

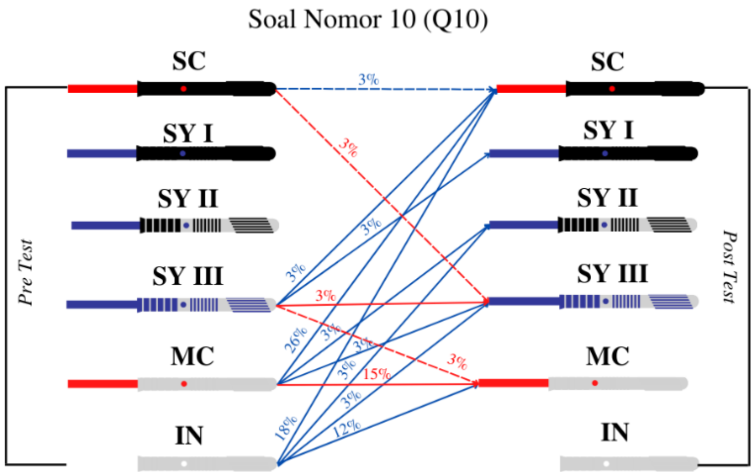


Figure 6. Mental Model Change Patterns on the Concept of Constructive and Destructive Interference

The highest type of change in the concept of constructive and destructive interference is an acceptable change which in Figure 6 is indicated by a full blue arrow. As for the unchanged category with a negative type (no change negative) in Q6 questions of 18%. There are fewer types of mental model changes that are not acceptable, namely 6%. This is because in learning using CC-VM with the POE strategy, students in the predict phase first predict things related to interference as well as constructive and destructive interference. After carrying out the learning process using CC-VM with the POE strategy, students can facilitate students in changing mental models for the better. Table 9 shows the overall mental model of students before and after learning the Interference concept.

Table 9. Learners' Mental Models Before and After Learning on the Concept of Interference

No	Mental Model Type	Pretest		Posttest	
		Total	(%)	Total	(%)
1	Scientific (SC)	4	3	60	44
2	Synthetic Type I (SY I)	0	0	1	1
3	Synthetic Type II (SY II)	11	8	36	26
4	Synthetic Type III (SY III)	27	20	15	11
5	Misconception (MC)	70	51	24	18
6	Initial (IN)	24	18	0	0

Based on the description of each change contained in each number in the concept of interference, it can be seen that the initial mental model of students is mostly in the synthetic type II mental model (SY II). This shows that students have the right initial conception of the concept of interference but have not been able to determine the reason for the answer correctly. The synthetic type II (SY II) mental model is included in partial understanding. Meanwhile, overall mental changes in the concept of interference (Q5, Q6, Q7, and Q8) can be seen in Table 10.

Table 10. Percentage Mental Model Change on Interference Concept

Mental Model Change	Question Number (Q)				Average (%)
	Q5 (%)	Q6 (%)	Q7 (%)	Q8 (%)	
Acceptable Change	79	74	88	82	81
No Change Positive (NCP)	0	3	0	3	1
No Change Negative (NCN)	15	18	12	3	12
Not Acceptable (NA)	6	6	0	12	6

Based on Table 10, it can be seen that most of the mental model changes are in the acceptable category of acceptable change (AC), which is 81%. The mental model changes on the concept of interference are bigger than the concepts of dispersion and diffraction. This is because students have previously studied the general concept of light waves and the concept of diffraction which became the initial concept in the concept of interference, thus making it easier for students to understand. Figure 7 shows the percentage of each type of mental model before and after learning using CC-VM with the POE strategy.

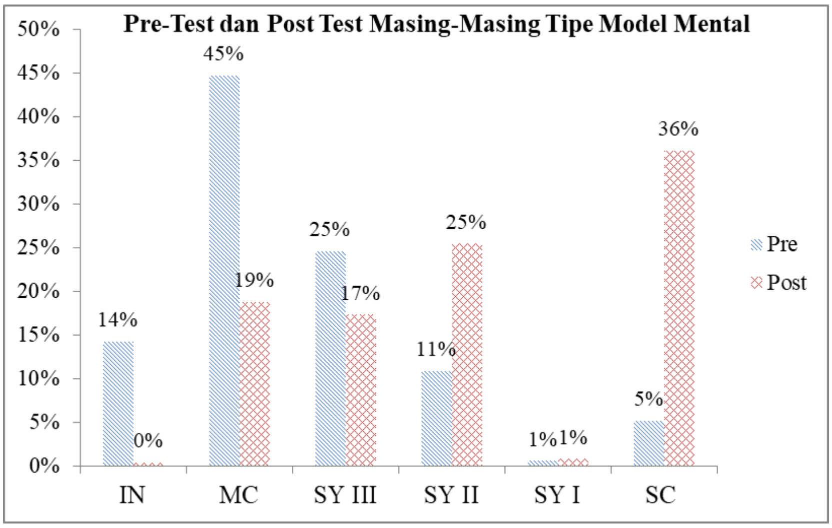


Figure 7. Mental Model Percentage Recapitulation Before and After Learning

Based on Figure 7, it can be seen that there was a change in the mental model before and after learning the light wave material using CC-VM with the POE strategy. Prior to learning, most of the students had mental models in the category of misconception (MC) and type 3 imitation (SY III), namely 45% and 25%. This misconception mental model shows that students have unscientific preconceptions and these students believe in the concepts they have. As for the type III or SY III imitation category, 25% of students know the reason for a phenomenon or concept in light waves presented on the four tiers test question instrument but do not know the actual answer so that the students are categorized in the type III artificial mental model type (SY III). The post test results show that there is an increase in the mental model of light waves by students. The largest type of mental model after learning with CC-VM is a mental model with scientific or scientific (SC) categories, there is a significant increase compared to the results of the pretest. The mental model category with a considerable increase is also type II or synthetic type II (SY II) where in this mental model students know the answers to the light wave phenomenon presented, but these students do not know the reason for the physics concept.

Based on these results, it can be said that there is a change and improvement in the mental model after learning using CC-VM. This shows that meaningful learning and appropriate strategies can change the mental models of students. In addition, other studies also show that learning is a process of changing mental models (e.g. J Vann der Graaf, 2020; Jasdila et al., 2019; Samsudin et al., 2021). The use of CC-VM combined with the POE strategy is able to construct students' mental conceptions and models. The use of CC-VM with the POE strategy can overcome the mental model of the type of misconception that has the largest number and percentage, namely misconceptions. “MC” (e.g. Jasdila et al., 2019; Samsudin et al., 2021).

The pattern of change in the mental model consists of four types, namely acceptable change, no change consists of two types, namely no positive change and negative type no change. No change is a positive type when both pre-test and post-test questions can be answered correctly. The last type of mental model change is a mental model that is not accepted or not acceptable change, namely people who experience a decline during the post test. Figure 98 is a pattern of changes that occur in the mental model of students as a whole.

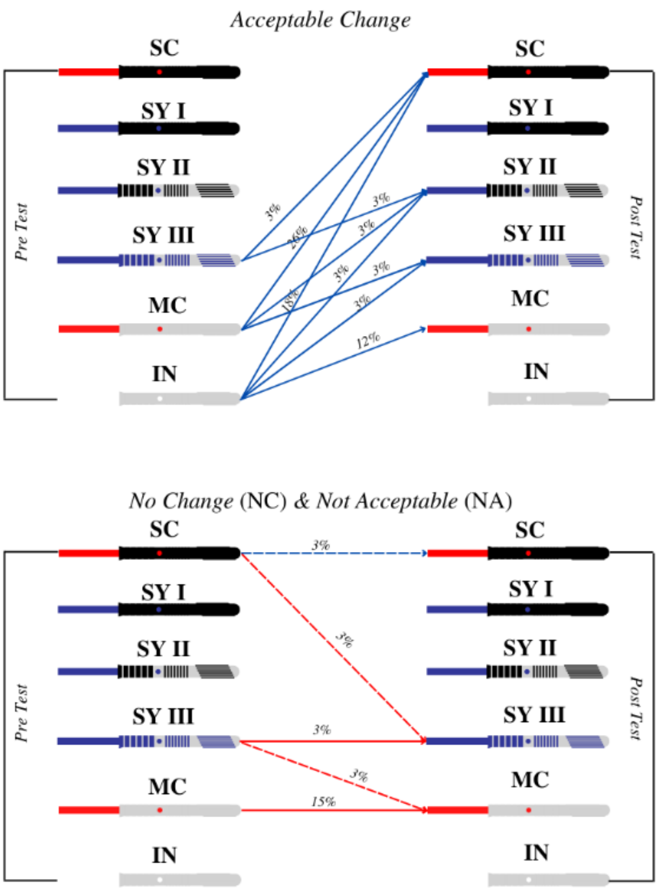


Figure 8. General Light Wave Mental Model Change Pattern

Based on Figure 8, it can be seen that the most dominant change in the mental model of students is the change in the mental model from misconception (MC) to scientific (SC) which is 26%, initial (IN) to scientific (SC) by 18%. Both of these categories are included in acceptable changes. Meanwhile, a large change in mental models occurred from misconceptions (MC) to misconceptions (MC) which was 15% and included in the category of unchanged and not expected (no negative change). As for other changes, there are aspects of changing mental models from initial to synthetic type I (SY I) and synthetic type II (SY II). There are also unacceptable changes, namely when the synthetic type III mental model (SY III) becomes a misconception (MC) and the scientific mental model (SC) becomes synthetic type III (SY III). Meanwhile, an outline comparison for the four categories, Acceptable Change (AC), No Change Positive (NCP), No Change Negative (NCN), and Not Acceptable Change (NAC) can be seen in Figure 9.

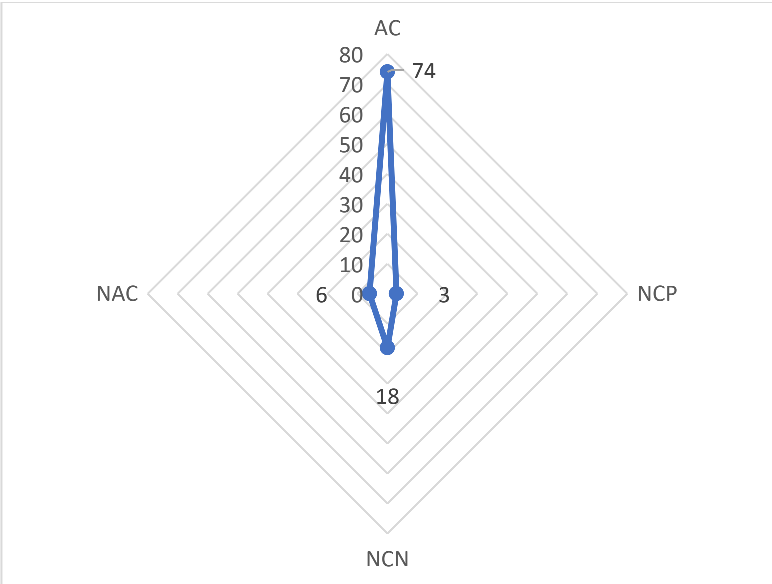


Figure 9. Percentage Distribution of Each Category of Mental Model Change

Based on Figure 9, it can be seen that the mental model changes in the light wave concept are dominated by the Acceptable Change (AC) category with a percentage of 74%. Meanwhile, the smallest mental model change category is in No Change Positive (NCP) of 3%. Thus, it can be said that Conceptual Change based on Virtual Media (CC-VM) X POE strategy can change the mental model of students on light wave concepts.

Conclusion

Research on conceptual change in physics education in schools has been carried out by several researchers. However, in general, existing research has not touched all concepts in physics. Moreover, this research can still be developed so as to bring up new innovations. One of them in this study, we implemented the Conceptual Change based on Virtual Media (CC-VM) x POE strategy to improve and change students' mental models on the concept of light waves. And as a result, it is proven that students' mental models can be improved in the "moderate" category by 65% and the lowest in the "high" category by 21%. Meanwhile, changes in mental models are dominated by the Acceptable Change (AC) category with a percentage of 74%. Meanwhile, the category of the smallest change in mental model is No Change Positive (NCP) of 3%.

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