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Developing Dispersion and Polarization Conceptual Inventory (DiPolCI) to Identify Students' Mental Model

Fini Alfionita Umar[1]*, Achmad Samsudin[2], Hasan Özgür Kapıcı[3], Taufik Ramlan Ramalis[2], Adam Hadiana Aminudin[4], Shobrina Nurul Mufida[5], Jajang Kunaedi[2], Itsna Rona Wahyu Astuti[2], Fanny Herliyana Dewi[2]

[1]Department of Electrical Engineering, Faculty of Engineering, Institut Kesehatan dan Teknologi Graha Medika, Kotamobagu, Indonesia
[2]Department of Physics Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
[3]Department of Mathematics and Science Education, Faculty of Education, Bogazici University, Istanbul, Turkiye
[4]Department of Physics, Faculty of Mathematics and Science, Universitas Kebangsaan Republik Indonesia, Bandung, Indonesia
[5]Department of Science Education, Faculty of Education, Institut Agama Islam Al-Fatimah, Bojonoegoro, Indonesia

*Corresponding author: finialfionitaumar@iktgm.ac.id

ABSTRACT Identifying a student's mental model is important for understanding scientific concepts. Dispersion and polarization are the sub concept of physics that studied in high school on light waves concept. This study aimed to develop dispersion and polarization conceptual inventory (DIPOLCI) to identify students' model mental using Rasch analysis. The research method utilized analyzing, designing, developing, implementing and evaluating (ADDIE) method. The participants involved 34 students (26 female and 8 male) from senior high school in Patokbeusi, West Java, Indonesia and their average 17-18 ages old. DIPOLCI consists of 7 items in the form of one tier and then developed to be four tiers test. DIPOLCI examined through Rasch analysis based on fit statistics, Cronbach Alpha, *item reliability* and *person reliability,* and students' mental model. The results show that DIPOLCI were valid and reliable to identify students' mental model. Students' mental model are mostly in the synthetic (SY) and scientific (SC) mental models were also analyzed in this research. It can be concluded the developed of DIPOLCI was able to analyze students' mental model. Developing this test instrument allows teachers to pinpoint students' comprehension of fundamental light wave concepts, uncover misconceptions, and evaluate the efficacy of teaching methods.

Keywords Students' Mental model, Dispersion, Polarization, Four tier, Conceptual inventory, Rasch analysis

1. INTRODUCTION

Student prior knowledge includes not only formal knowledge acquired at school, but also social and observed information (Fratiwi, et al. 2019; Urey, 2019). Prior knowledge represents an important part of learning information. Students prior knowledge, which contradicts scientific concepts (known as misconceptions or alternative conceptions), is a major problem in learning (Fratiwi, et al. 2019; Samsudin, Fratiwi, & Wibowo, 2017; Buber, 2017). Students need to understand the scientific conception as this is the most basic part of learning physics (Putranta & Pahar, 2019). One of the things related to the formation of a student's conception is the mental model.

Mental models are personal models built by individuals to represent parts of the world and can be represented through actions, speeches, writing, and drawing (Moutinho, Moura, & Vasconcelos, 2016). These models are considered representations of the outside world developed by the human mind and are therefore important for understanding the knowledge-building process (Moutinho, Moura, & Vasconcelos, 2016). Mental models help students distinguish and understand concepts and identify misconceptions (Fratiwi et al., 2019; Stains & Sevian, 2015). Misconceptions or alternative concepts are

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identified through the student's mental model. It is important to identify the student's mental model to understand the knowledge of scientific concepts. Many students struggle to understand physics concepts such as force (Liu & Fang, 2016), simple circuit (Kucukozer & Kocakulah, 2007), refraction and concept of the wave nature of light (Kaewkhong, Mazzolini, Emarat, & Kwan Arayathanitkul, 2010).

Several sub-concepts related to the wave nature of light taught in high school include dispersion and polarization. White light is a mixture of all visible wavelengths. The spreading of white light into the rainbow color (visible spectrum) is called dispersion (Giancoli, 2017). The visible spectrum in the student book does not show all the colors in nature. Many of the colors we see are mixtures of wavelengths (Giancoli, 2017).

Polarization of light is the absorption of part of the direction of light vibrations. Light in which part of the direction of vibration is absorbed is called polarized light. Polarized light can be obtained from unpolarized light by eliminating several vibration directions and only passing one vibration direction. The intensity I_0 of a plane-polarized light beam incident on a Polaroid is reduced to figure 1:

$$I = I_0 cos^2\theta \quad (1)$$

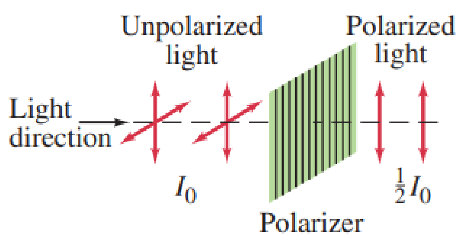


Figure 1 Unpolarized light enter to the polarizer

Based on equation (1) and Figure 1, we can see that unpolarized light has risen to intensity in vertical and horizontal components. After passing through a polarizer, one of these components is disposed of, and the intensity of the light decreases to half.

The nature of the light concepts is abstract, and the characteristics of light (its speed, wavelength, color, etc.) are beyond the perception of student's senses. These things cause difficulties for students and affect students' conceptions (Widiyatmoko & Shimizu, 2018). Teachers need a diagnostic test to get information about students' condition, to analyze students' learning needs in arrange to progress their learning results and to uncover the prior knowledge of students(Cohen, Mason, Singh, & Yerushalmi, 2008; Hadad, Thomas, Kachovska, & Yin, 2020; Van der Nest, Long, & Engelbrecht 2018; Park, 2019). Many researchers develop and use diagnostic tests and concept inventories to identify and measure students' conceptions and mental models. Such as on Newton's concept used MeMoRI, electric and magnetic fields used FCCI, and force used FCI (Fratiwi et al. 2019; Henderson 2014; Samsudin, Suhandi, Rusdiana, Kaniawati, & Costu, 2014). Therefore, the development of the instrument needs to develop in the other topic through different forms. There is much research about developing an instrument in physics. However, no research is related to developing dispersion and polarization instruments to identify students' mental models by using multi-tier and Rasch analysis. Thus, this research aims to develop a dispersion and polarization conception inventory (DiPolCI) to identify students' mental models used in analyzing, designing, developing, implementing, and evaluating (ADDIE) method and examined through Rasch analysis. This instrument is used to identify a student's mental model.

2. METHOD

2.1 Participant

Samples are students who have studied the nature of light material. The study was conducted on 60 students, consisting of 22 male students and 38 female students. Purposive sampling is utilized in this research. Purposive samples are a nonprobability sample "that can be reasonably considered representative of the population" by "using expert understanding of the population to choose a sample of elements in a nonrandom way that reflects a cross section of the population." (Battaglia, 2008; Klar & Leeper, 2019). Purposive sampling: Utilizes sampling methods that depend on the researcher's discretion when choosing individuals. These methods comprise maximum variation sampling, expert sampling, and typical case sampling (Berndt, 2020). These samples came from senior high schools in Subang, West Java, about 97 km from the capital of West Java (Bandung).

2.2 Research Design

This research used the ADDIE (Analyzing, Designing, Developing, Implementing, and Evaluating) model as the research method (Rahman, 2022; Kirk et al., 2015), as displayed in Figure 2. Each stage of this research model is used to develop an instrument for identifying students' mental models.

Analyzing

At this point, a literature analysis is conducted regarding students' mental models and an analysis of the need for tools to identify students' mental models. The literature review was conducted by analyzing various reputable journal sources that discuss identifying students' mental models and developing tools.

Design

At this stage, a tool is designed to identify students' mental models. The design is based on the results of the tool requirements analysis at the first stage, specifically the analysis stage.

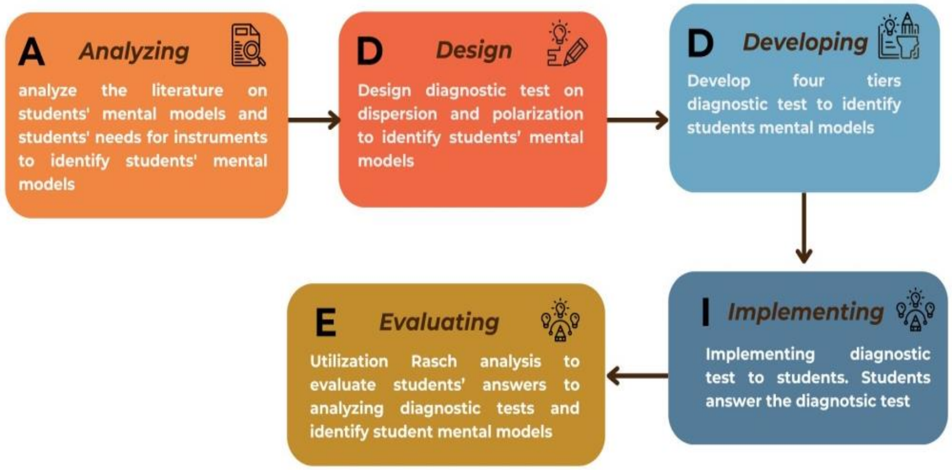


Figure 1 Research design with ADDIE model

Developing

The test instruments that have been designed at the design stage are then developed at the developing stage. This stage is carried out by testing the results of the design and development of the instrument, revising them again if necessary. After that, follow-up is carried out at the following stage.

Implementing

At this stage, the DiPolCI instrument developed in the previous stage is implemented, namely tested in schools that study physics. The implementation phase occurred at a State Senior High School in Subang, West Java. The sample during the implementation phase included 60 students, comprising 22 males and 38 females. The sample was aimed exclusively at students who had learned about light waves.

Evaluation

Evaluation is the final stage, which involves testing the results of the test instrument development carried out in the previous stage. This evaluation process uses the Rasch analysis application to identify students' mental models.

2.3 Data Analysis

In the evaluation phase, the data analysis consisted of three phases. The first phase was the analysis of students' mental models. The second phase was scoring the students' mental models. This score was used to analyze validity (uni-dimensionality), reliability (item reliability), and level of difficulty (variable map) on MINISTEP 4.8.2 software. The mental model's criteria and scoring are shown in Table 1. This research used rating category and conception score develop by Kurnaz & Eksi (2015) and Fratiwi (2019); Kurnaz & Eksi 2015; Fratiwi et al. 2019).

The weakness of the previous mental model classification is the bias between the mental model and conception categories. In addition, the previous mental model categories utilized open-ended questions. So, by using a four-tier test, the category of students' mental models can be developed and categorized more specifically. This research develops and categorizes mental models into five categories, as shown in Table 1.

Table 1 contains scores and mental model indicators when utilizing the four-tier test. Table 2 provides a complete explanation of the differences in scientific (SC), synthetic (SY), misconception (MC), and initial (IN) mental models.

3. RESULT AND DISCUSSION

3.1 ADDIE Model Result

Analyzing

A single step is conducted during the analysis stage, which is the literature analysis phase. A literature examination is conducted with Vos Viewer. The results below stem from a literature review of journals indexed by Scopus, focusing on research themes related to diagnostic tests and the implementation of four-tier tests, particularly in physics education. Figure 3 presents the findings derived from the VoS Viewer analysis.

Table 1 Mental models categorize

Mental Models Categorize	Score	Criteria using Four Tiers Test
Scientific (SC)	3	Tier 1 & 3 correct and the level confident at tier 2 & 4 both are confident
Synthetic (SY)	2	Tier 1 & 3 combination between correct and incorrect and the level confident at tier 2 & 4 are the combination between confident and not
Misconception (MC)	1	Tier 1 and 3 incorrect, and the level confident at tier 2 & 4 both are confident
Initial (IN)	0	Tier 1 and 3 incorrect, and the level confident at tier 2 & 4 are the combination between confident and not

Table 2 Explanation of mental models categorize

Models Mental Category	Explanation
Scientific (SC)	Perceptions or conceptions owned and described by students are in accordance with scientific concepts
Synthetic (SY)	Conceptions claimed by students as it were contain a few concepts that are in accordance with scientific concepts (partially understand).
Misconception (MC)	Students' conceptions incorporate alternative conceptions, and students are sure of their own conceptions
Initial (IN)	Conceptions that students have are in alternative conceptions, do not understand, or do not have a code (do not answer questions)

According to the analysis findings, diagnostic tests, particularly those employing tiered formats (two tiers, three tiers, four tiers, etc.), are more commonly utilized to identify misconceptions. Indeed, employing diagnostic assessments, particularly tiered tests, can help identify students' mental frameworks. Furthermore, a dispersion and polarization material instrument has not yet been created as a diagnostic tool to evaluate students' mental models. This is the reason behind the creation of this diagnostic test. Besides that, the diagnostic test has a fundamental role in in independent curriculum (Kurikulum Merdeka).

In the Independent Curriculum (Kurikulum Merdeka) framework for physics education, diagnostic assessments play a crucial role in determining students' preliminary knowledge and educational requirements before the start of instruction. This assessment aids educators in grasping which physics concepts students have either mastered or find challenging, allowing instruction to be tailored to each learner's abilities and pace. The outcomes of the diagnostic assessment enable educators to offer suitable interventions, whether by modifying teaching methods or supplying extra resources. This aligns with the aim of the Independent Curriculum to enhance student motivation and learning results, as learners engage in a learning process tailored to their skills, particularly in challenging areas like physics. A type of diagnostic test is a four tier test

Four-tier diagnostic tests are valuable for identifying students' mental models more comprehensively than simpler diagnostic methods. Unlike single-tier or two-tier tests, the four-tier test includes multiple layers of assessment that provide deeper insights into a student's understanding and confidence (Caleon & Subramaniam, 2010). Studies indicate that four-tier assessments are especially useful for uncovering the types of alternative conceptions, as they evaluate both the existence of misconceptions and the confidence with which students maintain these beliefs (Caleon & Subramaniam, 2010). These assessments are progressively acknowledged in scholarly studies for their effectiveness. Outcomes from four-tier evaluations tend to be more dependable as they reduce false positives and negatives—frequent problems in less complex tests. This thorough diagnostic method also offers educators more practical insights, facilitating the implementation of teaching strategies that specifically target individual student needs in the learning process (Prabowo, Widodo, & Sukarmin, 2022).

In the analysis phase, we analyzed the student's mental model and its identification. Interviews and open-form questions were most commonly used to identify a student's mental model (Fratiwi et al. 2019; Stains & Sevian, 2015). Figure 4 shows the diagnostic test used in the analysis stage. Tiers 2, 3, and 4 are open-ended questions.

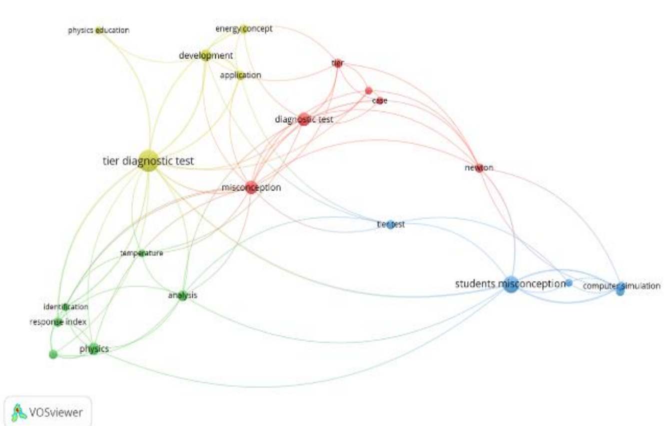


Figure 2 Outcomes of literature review utilizing VoS viewer

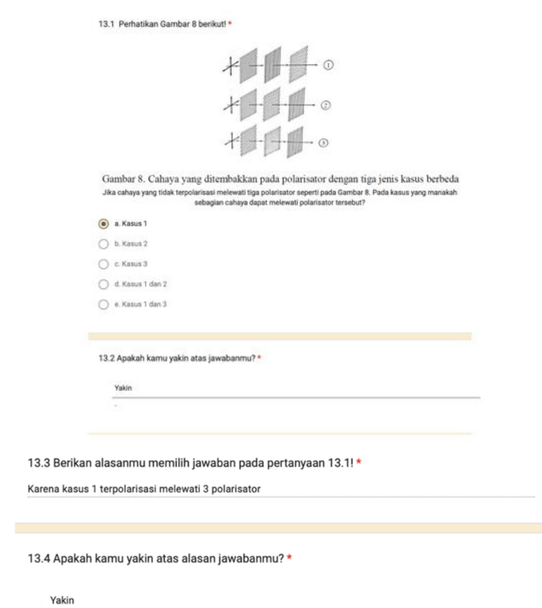


Figure 3 The example of diagnostic test and student respond in analysis phases

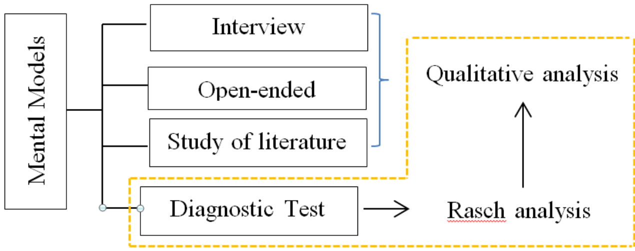


Figure 4 The result of analysis phase

In most cases, the results of interviews and open questions were qualitatively evaluated. Therefore, this research used four-tier tests to identify student mental models through Rasch analysis. Figure 5 shows the results of the analysis phase.

Designing

During the design phase, DiPolCI was designed as a four-tier test, as shown in Figure 6.

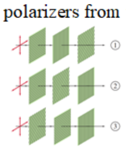
1.1 Question
a. .... d. ....
b. .... e. ....
c. ....
d. ....
1.2 Level of Confident of Answer.
a. Sure b. Not Sure
1.3 Reason
a. .... d. ....
b. .... e. ....
c. ....
d. ....
1.4 Level of Confident of reason
b. Sure b. Not Sure

Figure 6 Designing DiPolCI

Developing

At the development stage, we developed DiPolCI by Design. The questions consist of four questions about dispersion and seven questions about polarization. The example of DiPolCI is shown in Figure 7

1.1 As shown in the figure below, if unpolarized light is incident on the three polarizers from the left, in which case will some light pass through?



a. Case 1 only d. Case 1 and 2
b. Case 2 only e. Case 1 and 3
c. Case 3 only

1.2 Are you sure?
a. Sure b. Not Sure
1.3 Give reasons for choosing the answer to question 13.1!
....
1.4 Are you sure with your reason?
a. Sure b. Not Sure

Figure 7 The example of DiPolCI in developing stage

At this point, validation by experts was performed by 5 specialists. Expert validation was examined with the assistance of the Many Facet application. Figure 8 represents the outcome of expert validation.

The content analysis of this instrument was validated by 5 validators, and the analysis was done using Facet Rasch

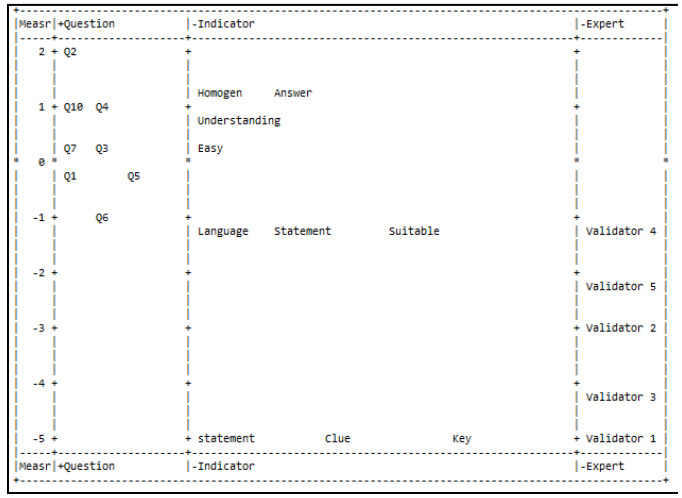


Figure 5 Outcome of expert validation by utilized many **facet**

with Mini Facet software. Based on Figure 8, the right part is the validator, namely V1, V2, V3, V4, V5, V6, and V7 (3 physics education experts, 2 expert practitioners/teachers). The left part contains 7 questions on light wave material, which is coded from Q1 to Q7. The middle part is an indicator of the assessment of the questions, which are coded in the form of words. The question indicators are explained in Table 3.

Based on Figure 8, overall, all questions (7 questions) meet the assessment of 5 validators; Question Q2 is a question that meets all assessment indicators, while some questions need revision based on specific indicators. Questions Q6, Q1, and Q5 need revision for indicators coded easy, understanding, homogeneous, and answerable. Thus, these questions need to be reviewed in terms of question form and answer options. Questions Q7 and Q3 need improvement for indicators coded understanding, homogeneous, and answer. The expert validator 1 suggested that improvements be made to the answer options. While questions Q10 and Q4 only need improvement for indicators coded homogeneous and answer. Validators 3 and 4 asked to revise the reason option. After the questions were improved, the questions were administered to students.

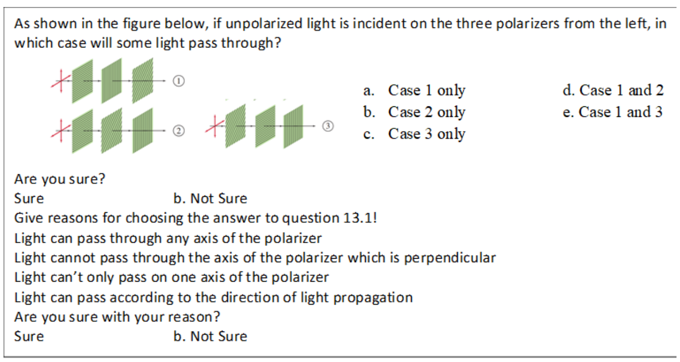
Implementing

At the implementing stage, there are two phases: the first is to get students to reason and make it an option in tier 3, and the second is to analyze students' answers through category conceptions and mental models.

Table 3 question indicators and their codes

Question indicator	Code
Suitability of the concepts in the questions with the concepts put forward by experts	Suitable
Question items made in accordance with question statements	statement
Question items made to determine students' conceptual understanding	Understanding
Use language that is in accordance with Indonesian language rules	Language
Language used is easy for students to understand	Easy
Answer choices and reasons are homogeneous and logical in terms of material	Homogen
There is only one answer key	Key
Questions do not provide clues to the correct answer	Clue
Answer choices do not use the statement "all answers are correct" or "all answers are wrong"	Answer

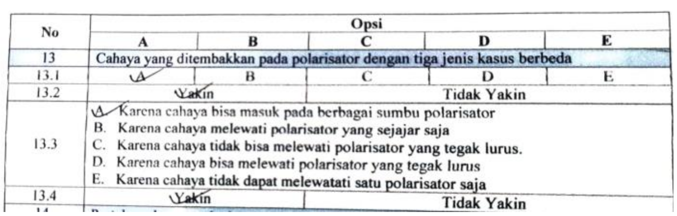
According to the executed implementation, most students possess a synthetic mental model (SY). A synthetic mental model refers to a mental representation in which the learner's understanding includes only a portion of the idea aligned with the scientific concept (incomplete understanding). Figure 10 is a sample response to a question addressed by students.


As shown in the figure below, if unpolarized light is incident on the three polarizers from the left, in which case will some light pass through?

a. Case 1 only
b. Case 2 only
c. Case 3 only
d. Case 1 and 2
e. Case 1 and 3

Are you sure?
Sure b. Not Sure
Give reasons for choosing the answer to question 13.1!
Light can pass through any axis of the polarizer
Light cannot pass through the axis of the polarizer which is perpendicular
Light can't only pass on one axis of the polarizer
Light can pass according to the direction of light propagation
Are you sure with your reason?
Sure b. Not Sure

Figure 9 Example of four tiers test in DiPolCI



No	Opsi				
	A	B	C	D	E
13	Cahaya yang ditembakkan pada polarisator dengan tiga jenis kasus berbeda				
13.1	A	B	C	D	E
13.2	Yakin		Tidak Yakin		
13.3	A. Karena cahaya bisa masuk pada berbagai sumbu polarisator B. Karena cahaya melewati polarisator yang sejajar saja C. Karena cahaya tidak bisa melewati polarisator yang tegak lurus. D. Karena cahaya bisa melewati polarisator yang tegak lurus E. Karena cahaya tidak dapat melewatati satu polarisator saja				
13.4	Yakin		Tidak Yakin		

Figure 8 A sample student respond

The synthetic mental model on the four-tier test instrument emerges when students respond to tiers 1 and 3 with true or false, while their confidence levels in tiers 2 and 4 reflect a mix of certainty and uncertainty. Based on the indicator of students' mental models, the sample student's response to question number 13 (Q13) can be categorized as a synthetic (SY) mental model.

Evaluating

In the evaluation phase, Rasch analysis was used to analyze the validity, reliability, and difficulty of DiPolCI. This phase has done after determining students' mental models of students.

The instrument's construct validity can be seen from the raw variance explained by the measures value. In Table 3, the index was 40.6%, which is more than 40%. So, DiPolCI had appropriated validity measurements. It can be concluded that the instrument is valid. Meanwhile, the reliability of the DiPolCI result is shown in Table 4.

Table 5 shows the value of item reliability and person reliability. Item Reliability pertains to the stability and accuracy of item difficulty assessments in the Rasch model. This measure shows how effectively the test items can differentiate between different levels of the trait being assessed among respondents. Conversely, Person Reliability indicates how dependable the ability estimates are for individuals who are taking the test. It assesses how reliably the test can distinguish between individuals with varying ability levels (Andrich, 1988; Linacre, 2002; Nguyen & Truong, 2023).

Based on Table 5 shows the values of item reliability at .81 and .84. This is an extraordinary category. Meanwhile, the value of person reliability is 0.64 and 0.69, which is a sufficient category. Based on that, results can be categorized as extraordinary for the measure of reliability. The value of Cronbach's Alpha is 0.67. Person reliability and item reliability values from to 1 and can be translated much like Cronbach's alpha, meaning that values closer to 1 show a more steady measure (Aminudin et al., 2019; Boone & Noltemeyer, 2017). So, it can be concluded that the reliability of a DiPolCI instrument is reliable. The level of difficulty shown in Figure 11

Based on Figure 8 we can see a Wright map that schemes the items in an instrument according to their order of difficulty. On the right sideways of the Wright map, the 7 items of the test are offered from easiest (Q1, bottom) to greatest difficult (Q4, top). The items are schemed in positions of item difficulty computed exhausting Winsteps and the Rasch model formula. A "logit" ruler is utilized to definite item difficulty on a linear ruler that spreads from negative infinity to positive infinity (Boone, 2016). For many analyses, item difficulties will range from −1 logits to +1 logits. On the left side is the student distribution and the right side is the question distribution(Van Zile-Tamsen,

Table 4 Result of the validity of DiPolCI

```
INPUT: 34 PERSON  7 ITEM  REPORTED: 34 PERSON  7 ITEM  4 CATS   MINISTEP 4.8.2.0
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = ITEM information units
                                          Eigenvalue   Observed   Expected
Total raw variance in observations     =     11.7894 100.0%         100.0%
  Raw variance explained by measures   =      4.7894  40.6%          40.9%
    Raw variance explained by persons  =      2.3852  20.2%          20.4%
    Raw Variance explained by items    =      2.4042  20.4%          20.5%
  Raw unexplained variance (total)     =      7.0000  59.4% 100.0%   59.1%
    Unexplned variance in 1st contrast =      1.8019  15.3%  25.7%
    Unexplned variance in 2nd contrast =      1.3477  11.4%  19.3%
    Unexplned variance in 3rd contrast =      1.0858   9.2%  15.5%
    Unexplned variance in 4th contrast =      1.0422   8.8%  14.9%
    Unexplned variance in 5th contrast =       .9357   7.9%  13.4%
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Table 5 Result of the reliability of DiPolCI

```
     SUMMARY OF 34 MEASURED PERSON
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      14.7       7.0        1.41     .65       .98    .02    .99    .03 |
|  SEM        .5        .0         .21     .02       .09    .15    .10    .16 |
| P.SD       3.0        .0        1.18     .11       .51    .83    .58    .90 |
| S.SD       3.0        .0        1.20     .11       .51    .85    .59    .91 |
| MAX.      20.0       7.0        4.20    1.09      2.74   2.39   2.95   2.59 |
| MIN.       7.0       7.0       -1.16     .54       .31  -1.58    .31  -1.61 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .71 TRUE SD     .94  SEPARATION  1.34  PERSON RELIABILITY  .64 |
|MODEL RMSE    .66 TRUE SD     .98  SEPARATION  1.48  PERSON RELIABILITY  .69 |
| S.E. OF PERSON MEAN = .21                                                   |
-------------------------------------------------------------------------------
PERSON RAW SCORE-TO-MEASURE CORRELATION = .98
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .67  SEM = 1.72
STANDARDIZED (50 ITEM) RELIABILITY = .94

     SUMMARY OF 7 MEASURED ITEM
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      71.6      34.0         .00     .29      1.05    .06    .99   -.17 |
|  SEM       3.5        .0         .29     .01       .15    .64    .12    .53 |
| P.SD       8.6        .0         .72     .02       .36   1.58    .30   1.31 |
| S.SD       9.3        .0         .78     .02       .39   1.71    .32   1.41 |
| MAX.      86.0      34.0         .91     .33      1.63   2.22   1.36   1.27 |
| MIN.      60.0      34.0       -1.29     .26       .42  -3.09    .45  -2.87 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .32 TRUE SD     .65  SEPARATION  2.04  ITEM   RELIABILITY  .81 |
|MODEL RMSE    .29 TRUE SD     .66  SEPARATION  2.28  ITEM   RELIABILITY  .84 |
| S.E. OF ITEM MEAN = .29                                                     |
-------------------------------------------------------------------------------
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2017). There are nine students who can answer all the questions correctly. Q1 is the easiest of the seven questions, but PDL 07 cannot answer question number 1 correctly (Q1). Q1 ask about characteristic of natural light wave that different with sound wave. Most of students can answer the question correctly. Q4 is the most difficult question for students. The female student (PDP 01) had the best ability. PDP 01 has a synthetic (SY) mental model for dispersion and polarization concept, she has scientific mental models of four question meanwhile three question are synthetic mental models. In addition, PDL 07 (07 male) student had the lowest abilities. From the result above, it can be seen that females (PDP 01) had the best ability and the lowest ability in males (PDL 07), but it can't be generalized because the numbers of females are greater than that of males. This is research support the finding of the research that female students and male students have diverse learning styles. Males appear a greater preference than females for the abstract conceptualization mode of learning (Fratiwi et al., 2019; Sagala, Umam, Thahir, Saregar, & Wardani, 2019; Zhu, 2007; Severiens & Ten Dam, 1994). Male students rational through concepts, logical, and learned thinking forms are skilled to see the reality of reliable information properly, shrewdly achieving investigation through a strategy, and fascination with a decision to offer reactions to complications grounded on proof, concepts, and hypothesis. Female students can solve problems more simply and provide comprehensive measures accepted by others to find novel concepts in learning. Girls preferred to learn physics in a conversational style and collaborative movement and work with concrete objects(Zhu, 2007; Saputra, Setiawan, & Rusdiana, 2019; Fratiwi et al., 2019; Docktor & Heller, 2008).

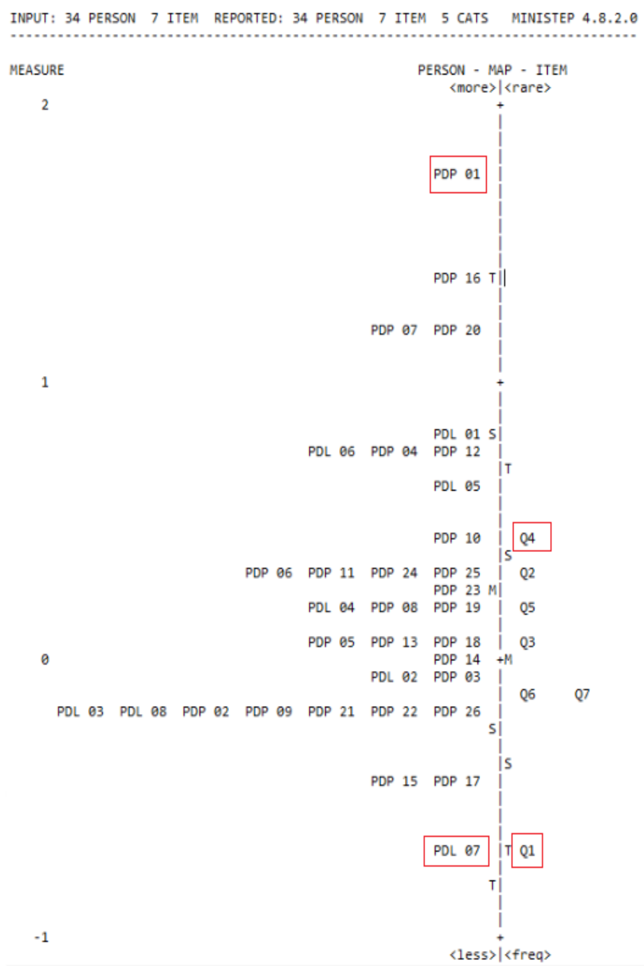

Figure 11 The result of the level of difficulty of DiPolCI

When learning activities accommodate male and female learning styles, students' mental models can be improved. Moreover, when the number of female students is greater than that of male students, the chances of the mental models of female students being better than those of male students are greater because the ratio of the number of male students is unequal. So, one of the things that affects the improvement of students' mental models is how learning physics in class takes place, especially on the concepts of dispersion and polarization.

3.2 Identify Students' Mental Models Using DiPolCI

Identified students mental models, appear by the percentage of students' mental models shown in Figure 12

The research sample is 34 students, with 8 male students and 26 female students in 11th grade. The female students greater than male students around 24% are male students, meanwhile 76% are female students from Figure 7. Around 33% of students have scientific (SC) mental models (7% male and 26% female). 33% students can answer the question correctly. Then 48% students that have synthetic (SY). Most of female students have synthetic mental models. More over male students have initial (IN), synthetic type II (SYN II) and scientific (SC) mental models. We can see that most of students have synthetic

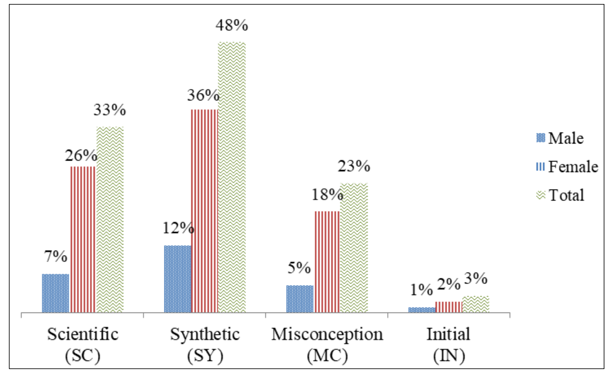

Figure 10 The percentage of student's mental models on dispersion and polarization

mental models around 12% male and 36% female students. It is support the finding of Kurnaz & Eksi (2015) and Fratiwi (2019) that the majority of students did not have scientific mental models, majority students have synthetic mental models that included a few scientific perceptions. It can be illustrated that they have acquired relevant scientific information. Students in lower grades (10th grade) had more beginning (IN) mental models, with a decrease in this model appearing within the eleventh grade. Whereas the proportion of synthetic and scientific mental models increases within the 11th grade, the ratio of scientific mental models increments in the 12th. Since the students have studied almost numerous concreate and abstract concept (Fratiwi et al. 2019;Sciences 2016).

Mental models need to be known first on because they can encouragement the learning process. The identification of students` mental models is important for being able to recognize their understanding of scientific concepts (Fratiwi et al. 2019). Students may have various experiences and interpretations about concepts linked to science in their situation and may start their education with the attainments they have (Fratiwi et al. 2019; Urey, 2019). Also, teachers need design learning processes that are following students` mental models, both learning models, approaches or strategies, instructional media, and textbooks. The students` mental models in natural light concepts especially dispersion and polarization need to be identified to make it easier for students to learn further physics concepts. This is because concepts such as dispersion and polarization are abstract concepts. Also, the phenomenon of scattering and polarization is common in students' daily lives.

The advantages of this study are: The diagnostic assessment created is suitable for educators or researchers interested in understanding students' mental models, particularly regarding dispersion and polarization concepts. The diagnostic assessment created employs a four-tier evaluation that examines not only the student's understanding but also their level of confidence. Results from four-tier assessments are generally more reliable since they minimize false positives and negatives—common issues in simpler tests. This comprehensive diagnostic approach also provides educators with more actionable insights, aiding in the adoption of teaching strategies that directly address the unique needs of each student in the learning journey. The drawbacks of this research include that the diagnostic test created in this study is confined to dispersion and polarization materials, which require further development for other physics materials.

4. CONCLUSION

Students' mental models are mostly in synthetic that analyzed in this research. It can be conclude the developed of DIPOLCI was able to analyze students' mental models in dispersion and polarization concept. Beside of that the findings indicate that the created diagnostic assessment, referred to as the dispersion and polarization conception inventory (DiPolCI), is both valid and reliable for recognizing students' mental models. This diagnostic assessment can be applied in physics education, particularly in the topics of dispersion and polarization. The benefits of this study theoretically are to provide a contribution of thought for the renewal of diagnostic tests used to determine students' mental models on dispersion and polarization materials. While practically, it can be used to find out students' mental models on dispersion and polarization materials so that teachers can design appropriate learning.

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