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# Development of Three-Dimensional Light Wave Test Based on Three-Dimensional Learning Framework

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**Abstract:** The three-dimensional learning framework as a current science learning standard to facilitate the development of students' knowledge that is coherent and interconnected so that it can be used in various situations of daily life, is only possible if the assessment is oriented towards the science learning standards in question. The focus of this research is to develop a Three-Dimensional light wave test based on the Three-Dimensional Learning Framework. Development was carried out through quantitative research methods with construction design and validation, involving physics lecturers, physics teachers and high school students. Construction and validation were carried out using document analysis sheets, cognitive questionnaires, content validation sheets and student responses. Analysis was carried out through descriptive analysis, V-Aiken content validation, and Item Response Theory (IRT) using eIRT software. The construction and validation results show that the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework has differentiating power in the good category, five items are very high, three items are high, eight items are medium and five items are low; the level of difficulty is in the medium category, two questions are very difficult, seven questions are difficult, eight questions are medium and four questions are easy; the pseudo guessing factor overall functions well; and reliable for measuring the level of ability of students with low to very high abilities. The Three-Dimensional test of light waves based on the Three-Dimentional Learning Framework can be used by educational practitioners as an assessment tool to explore students' coherent understanding of disciplinary core ideas (DCI), scientific practices (SP), and crosscutting concepts (CC) in wave material light.

**Keywords:** Three-dimensional test; Light waves; Three-dimensional learning framework.

## Introduction

Research reveals that students need to be guided in developing coherent and interconnected knowledge so that it can be used in various situations of everyday life (Bain et al., 2020; Cooper & Stowe, 2018; Singer, S.R., Nielsen, N.R., and Schweingruber, 2012). The direction of change in question is stated in A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (National Research Council, 2012) and Next Generation Science Standards: For States, By States (National Research Council, 2013) in the form of a three-dimensional learning framework as a standard for today's science learning.

Three-dimensional learning involves the dimensions of scientific practices, cross-cutting concepts, and disciplinary core ideas in building students' knowledge (National Research Council, 2012, 2013). This is different from the general science learning approach which builds conceptual knowledge and scientific practice separately (National Research Council, 1996; Wyner & Doherty, 2017).

Changes in the science learning framework in the context of three-dimensional learning must be accompanied by appropriate learning and assessment designs to align with new learning objectives. Therefore, integration of the *Next Generation Science Standard* (NGSS) framework in learning and assessment must be

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carried out. NGSS brings changes in learning for the better (Lee et al., 2013). However, creating learning to produce students who achieve the NGSS framework is a challenge for educators (Pellien T. & Rothenburger L, 2014).

This research is focused on developing tests that are in accordance with the three-dimensional learning framework on the topic of light waves. Although the development of three-dimensional learning-oriented assessments has been carried out by previous researchers, very few researchers have reported the development of tests based on this framework, generally in the field of physics, especially on the topic of light waves. The concept of light is a basic, meaningful concept in physics. Most students are unable to explain light-related phenomena in scientific language, even though they have knowledge about it (Uzun et al., 2013).

## Method

This research uses a construction and validation design (Crocker & Algina, 2008), as presented in Figure 1. This research involved several participants, namely four expert lecturers and two High School (SMA) Physics teachers as content, construction and grammar validators, and 279 class XII high school students from high schools in districts/cities in Java West, who had studied light wave material, were divided into two groups, namely 29 students participating in the limited trial process and 250 students who participated as respondents in the extensive trial of the Three-Dimentional light wave prototype test based on the Three-Dimentional Learning Framework.

Students as broad trial participants are determined using convenience sampling, which is a type of non-random sampling technique where members of the target population meet certain practical criteria, such as easy accessibility, availability at a certain time, or willingness to participate in certain research (Fraenkel & Wallen, 2009). Apart from that, participants were also determined according to the willingness of the teachers and students to take part in this research. These participants have the following characteristics: 1) Students aged between 15-18 years; 2) have studied light wave material; and 3) Have the same cognitive achievement based on input from the teacher.

This research uses three types of instruments, namely document analysis sheets, cognitive questionnaires, and content validation sheets for Three-Dimentional light wave test based on the Three-Dimentional Learning Framework.

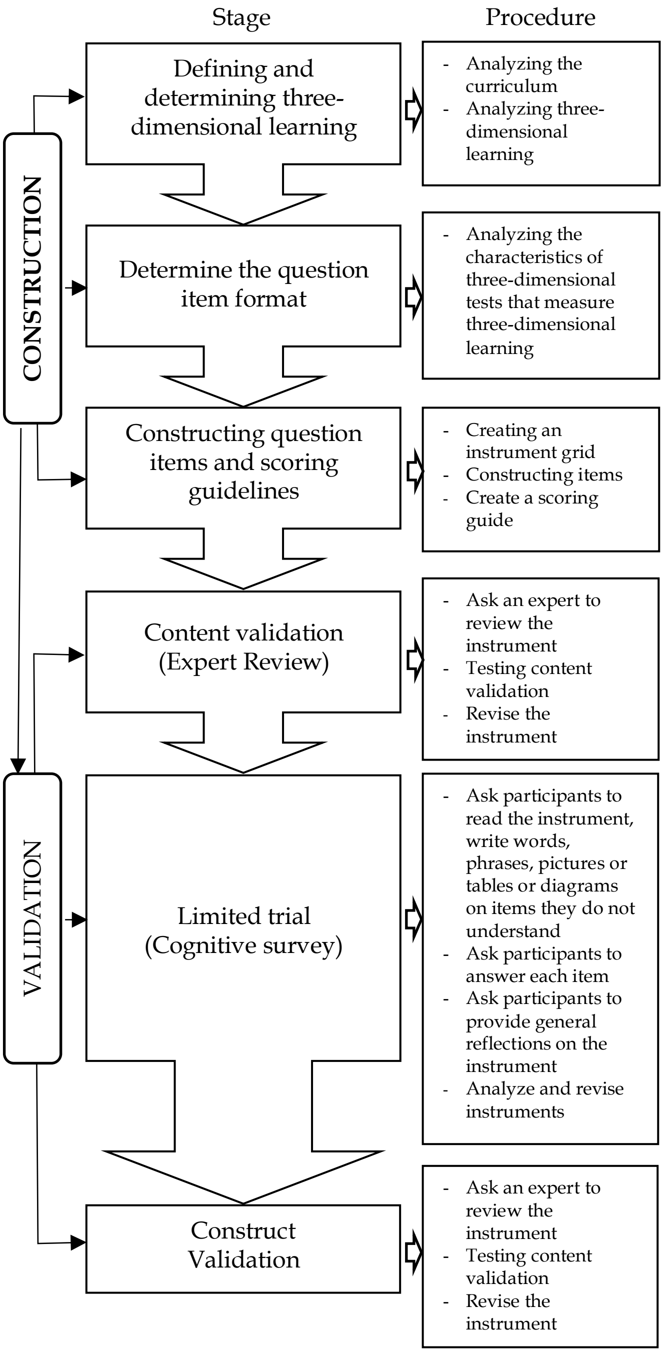


**Figure 1.** Research Design

The role of the three research instruments in developing a three-dimensional light wave test based on the Three-Dimentional Learning Framework can be explained as follows.

*Document Analysis Sheet*

This sheet contains a list and explanation regarding the mapping of Basic Competencies (KD) of the applicable curriculum, performance expectations (PE) and learning objectives (LO), disciplinary core ideas (DCI), scientific practices (SP), as well as cross-cutting concepts (CC) in the topic learning (Cooper et al., 2017).

This is done because there are differences between the preparation of KD in the National Curriculum RBT and the performance expectations (PE) and learning objectives (LO) used in the three-dimensional learning framework.

*Cognitive Questionnaire*

The cognitive questionnaire aims to see the readability, understanding and answers of respondents to the questions on the Three-Dimentional light wave prototype test based on the Three-Dimentional Learning Framework which was developed and is part of the suggestions for improvement. Through this cognitive questionnaire, respondents are asked to read each question item, then write down words, phrases, images, graphs, tables and statements that they do not understand, answer each question item by selecting the correct answer option, and provide a general reflection on the difficulty of the question item. understood and/or answered with arguments.

*Content Validation Sheet*

The content validation sheet aims to assess the extent to which the Three-Dimensional light wave test based on the Three-Dimentional Learning Framework developed is in accordance with the rules of content, construction and grammar. This validation sheet covers the quality of the content (accuracy of the question items measuring learning objectives, scientific concepts of physics content in the question items, homogeneity and logic of answer choices, accuracy of answer keys in the question items), construction (clarity and logic of the stem/main formulation of the questions, clarity and functionality stimulus for question items (pictures, graphs, tables, diagrams, and the like), option arrangement (answer choices), and grammar (language rules in question items).

## Result and Discussion

In the national curriculum for high school Physics subjects, the subject of Light Waves is several basic competencies which are a reference and need to be obtained by students. In Minister of Education and Culture Regulation Number 37 of 2018, basic competencies related to light waves are stated as follows.

3.10. Applying the concepts and principles of sound and light waves in technology.

4.10. Carrying out experiments on sound and/or light waves, along with a presentation of the experimental results and their physical meaning, for example sonometers and diffraction gratings.

The basic competencies above are stated according to the formulation of learning objectives in the Revised Bloom Taxonomy (RBT). Referring to this taxonomy, learning objectives contain two components, namely verbs (verbs) which express the dimensions of the cognitive process, and nouns (nouns) which mean the dimensions of knowledge that students must have. (Anderson et al., 2001). As in Basic Competency 3.10, the verb used is "apply" so that at least the dimensions of the cognitive process at level C3 (applying) need to be experienced and mastered by students. Then, there is the noun "concepts and principles" which means that students at least need to reach the dimension of knowledge in the conceptual realm as a result of learning Cahaya. So KD 3.10 is in the Conceptual C3 realm in the Revised Bloom Taxonomy (RBT) which has two dimensions of learning, namely cognitive and knowledge.

The concepts and principles in Basic Competency 3.10 consist of sound and light waves in technology. So, in this Light Waves chapter it is hoped that learning can make students have sufficient knowledge regarding the concepts and principles of light to their application in technology, not only in the case of simple physics. Apart from that, from KD 4.10 students also need to acquire procedural knowledge to be able to carry out experiments and present the results.

To prepare a Three-Dimensional light wave test based on the Three-Dimentional Learning Framework related to the basic competencies (KD) of the applicable curriculum, a remapping was carried out on disciplinary core ideas (DCI), scientific practices (SP), and crosscutting concepts (CC) in learning topics. (Cooper et al., 2017). This is done because there are differences between the preparation of KD in the National Curriculum RBT with performance expectations (PE) and learning objectives used in the three-dimensional learning framework. So, adjustments to performance expectations (PE) and learning objectives are needed to bridge these differences. Based on document analysis of the three-dimensional learning framework (National Research Council, 2012, 2013), performance expectation (PE) related to light waves is found in the Physical Science 4 (PS4) domain, namely "Waves and their Application in Technology for Information Transfer". Then PE on PS4 was adapted and adapted to Basic Competencies 3.10 and 4.10 in the National Curriculum, with a focus on light waves. The performance expectations (PE) and learning objectives (LO) that have been prepared are then used as references in preparing the Three-Dimensional Light Wave test prototype based on the Three-Dimensional Learning Framework.

1. *Construction of Three-Dimensional test of light waves based on the Three-Dimensional Learning Framework*

The Three-Dimensional light wave test based on the Three-Dimensional Learning Framework is constructed based on Performance Expectation (PE) which has been analyzed in Table 1.

**Table 1.** Construction of the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework

| Learning objective | 3 Dimensional Aspect | | |
|---|---|---|---|
| | Discipline Core Idea | Scientific Practices | Crosscutting Concepts |
| Ask questions regarding the structure and function of objects that cause light wave interference. | Light wave interference | Asking question | The structure and function of objects |
| Developing a model of light wave interference in the form of light and dark pattern images on the screen. | Light wave interference. Light and dark pattern. | Develop and use models | Image pattern |
| Plan an investigation into the causes of light wave interference. | Interference of light waves | Planning an investigation | Cause and effect |
| Analyzing data in the form of a table of wavelength measurements from light and dark patterns resulting from interference in the double slit. | Wavelength Light and dark patterns Double slit interference | Analyze and interpret data | Table pattern |
| Computational thinking regarding the relationship between double slit distance and the distance between light and dark patterns in light wave interference. | Double slit. Light and dark patterns. Interference of light waves | Computational thinking | The relationship between scale, proportion and quantity |
| Build explanations and engage in arguments from evidence that interference can cause differences in the intensity of light waves on a screen. | Interference Wave nature of light. | Construct explanations and engage in arguments from evidence | Systems and System Models: wave model. |
| Evaluate information related to the application of light wave interference in the design of television station studio lighting systems. | Light wave interference | Evaluate information | Systems and System Models: television station studio lighting planning. |
| Ask questions related to the structure and function of objects that cause diffraction of light waves. | Diffraction of light waves | Asking question | Structure and function of objects. |
| Developing a diffraction model of light waves in the form of light and dark pattern images on the screen. | Diffraction of light waves. Light and dark pattern. | Develop and use models | Image pattern |
| Plan an investigation into the causes of light wave diffraction. | Diffraction of light waves | Planning an investigation | Cause and effect |
| Analyzing data in the form of a table of wavelength measurements from light and dark patterns resulting from diffraction at a single slit. | Wave length Light and dark pattern Difraction Grid | Analyze and interpret data | Table pattern |
| Computational thinking regarding the relationship between the width of a single slit and the distance between light and dark patterns in light wave diffraction | Single gap Light and dark pattern. Diffraction of light waves. | Computational thinking | Relationship of scale, proportion and quantity |
| Develop a scientific argument that the phenomenon of diffraction does not cause changes in the frequency of light waves. | Light waves Diffraction Wave frequency | Construct explanations and engage in arguments from evidence | Stability and change |
| Evaluate information related to the application of light wave diffraction in the design of television station studio lighting systems. | Diffraction of light waves | Evaluate information | Systems and System Models: Television station studio lighting planning. |
| Asking questions related to the structure and function of objects that cause the polarization of light waves. | Polarization Light Waves | Asking question | Structure and Function of objects |
| Ask questions related to the structure and function of objects that cause the polarization of light waves. | Polarization of light waves | Develop and use models | Image pattern |
| Plan an investigation into the causes of the polarization of light waves. | Polarization Light Waves | Planning an investigation | Cause-effect |

| Learning objective | 3 Dimensional Aspect | | |
|---|---|---|---|
| | Discipline Core Idea | Scientific Practices | Crosscutting Concepts |
| Analyze data in the form of a table of polarization angle measurements with the intensity of polarized light waves | Polarization angle<br>Intensity<br>Light Waves | Analyze and interpret data | Table pattern |
| Computational thinking is related to the relationship between polarization angle and the intensity of polarized light waves | Polarization angle<br>Intensity<br>Light Waves | Computational thinking | Relationship between scale, proportion and quantity |
| Develop a scientific argument that polarization can be explained through the properties of light as a transverse wave model. | Polarization<br>Light<br>Transverse waves | Construct explanations and engage in arguments from evidence | Systems and System Models: transverse wave model. |
| Evaluate information related to the application of light wave polarization in the design of television station studio lighting systems. | Polarization<br>Wave length | Evaluate information | Systems and System Models: Design of a television station studio lighting system |

An example of one of the questions for one of the learning objectives is shown in Figure 2.

**Learning objective** : Ask questions related to the structure and function of objects that cause the polarization of light waves
***Discipline Core Idea*** : Polarization of Light Waves
***Scientific Practices*** : Asking question
***Crosscutting Concepts*** : Structure and Function of objects
**Question item:**
A physics teacher shows two polarizing filters stacked parallel (a) and perpendicular (b). Then he arranged the Polaroid glasses perpendicularly and parallel (c).

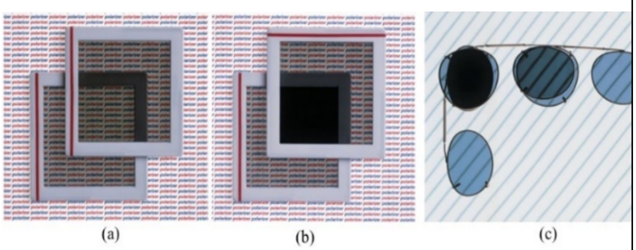


Figure 1. Example of *Three-Dimentional Assessment* on Light Waves material based on *Framework Three-Dimentional Learning*
After observing this phenomenon, there were several questions asked by students as follows.
1) Is it true that angle could affects the intensity of polarized light?
2) Is it possible to use polarizing filters to observe the sun as an alternative to polarized glasses?
3) Are polarizing filters cheaper than polaroid glasses?
4) Could the polaroid glasses make by using same material as same as polarizing filters?

Questions that reveal students' suspicions regarding the structure and function of the two objects above are: ….
A. 1, 2, dan 3
B. 1 dan 3
C. 2 dan 4
D. 4
E. 1, 2, 3 dan 4

**Figure 2.** Example of Three-Dimensional Light Wave Test Items Based on the Three-Dimensional Learning Framework

2. Quality of Three-Dimensional light wave tests based on the Three-Dimensional Learning Framework

2.1 Content Validity of the Three-Dimensional light wave test based on the Three-Dimentional Learning Framework

Content validation involved six validators (n = 6), namely four physics education lecturers and two high school physics teachers and five scales for each assessment aspect (c = 5) so that the V coefficient value was the minimum for an aspect to be considered valid according to the V index table (Aiken Lewis R., 1985) with an error of 5% is 0.78. Complete content validation results are presented in Table 2.

**Table 2.** Content Validity of the Three-Dimensional Light Wave Test Based on the Three-Dimentional Learning Framework

| Items | Validator | | | | | | | | | | | | S | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | | |
| | r | s | r | s | r | s | r | s | r | s | r | s | | |
| 1 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 19 | 0.95 |
| 2 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 3 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 20 | 1.00 |
| 4 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 19 | 0.95 |
| 5 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 6 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 7 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 8 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 4 | 3 | 19 | 0.95 |
| 9 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 10 | 5 | 4 | 4 | 3 | 4 | 3 | 4 | 3 | 5 | 4 | 4 | 3 | 16 | 0.80 |
| 11 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 19 | 0.95 |
| 12 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 13 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 14 | 4 | 3 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 17 | 0.85 |
| 15 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 20 | 1.00 |
| 16 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 19 | 0.95 |
| 17 | 5 | 4 | 5 | 4 | 3 | 2 | 5 | 4 | 5 | 4 | 4 | 3 | 17 | 0.85 |
| 18 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 20 | 1.00 |
| 19 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 20 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | 18 | 0.90 |
| 21 | 5 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | 5 | 4 | 5 | 4 | 18 | 0.90 |

Note: Number of validators (n) = 6; $r$ = Score that the validator assigns to the item; s = score that stated by the validator – 1; $S = \sum n_r(r - l_o)$; $n_r$ = number of validators who voted on the scale value $r$; *Vitem* = Koefisien V Aiken on each item = $\frac{S}{[n \times (c-1)]}$.

The results of content validation in Table 2 show that each item in the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework based on the Aiken V index is rated as valid. Therefore, there is no need for fundamental revisions and the general view of the validators generally states that the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework is good and can be used for research, it is found that each question item conforms to the Three-Dimentional Learning Framework which includes Practices , Crosscutting Concepts, and Core Ideas. The content meets learning objectives, scientific conceptions, and logical answer choices. The question construction is formulated clearly and the question item stimulus functions well. The questions used are communicative and meet the rules of good and correct Indonesian. This test emphasizes concepts, context and facts that are relevant to the material being studied so it is very good for use in evaluating student learning outcomes.

There are several notes submitted by the validator, including checking again aspects of the Disciplinary Core Ideas in Performance Expectation (PE) which have not been listed, the structure of the Learning Objective (LO) can be in the form of materials, geometry or the composition of objects, what is meant by interference patterns needs to be clarified, needs to be clarified what is meant by an experimental scheme, revising or deleting several words/phrases that were written incorrectly in the stem/option, avoiding repetition of words/phrases in the option, providing information on the image.

### 2.2 *Preliminary Testing*

After content validation, the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework was then tested on 29 students at one of the State High Schools in Bandung. The results of preliminary trials show that of the 21 Three-Dimentional light wave test items based on the Three-Dimentional Learning Framework, in general they have clarity, but there are several words or phrases or images in some items that participants think they don't understand, even though the words/phrases are concepts. -key concepts in the physics material being tested. Of the 21 Three-Dimentional test items on light waves based on the Three-Dimentional Learning Framework, in general they had readability above 87% (two to four participants) who thought there were several items that were not clear to them. The preliminary test results of the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework were then revised by revising words or phrases that were ambiguous or difficult to understand, pictures or tables that were unclear, and summarizing statements that were too long.

### 2.3 *Construct Validity of the Three-Dimentional Light Wave Test Based on the Three-Dimentional Learning Framework*

The construct validity of the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework was carried out on 250 public high school students from several high schools in West Java. In general, the item parameters can be expected to be relatively stable for a sample of 200 participants. Referring to the rule of thumb, the sample size is determined to be five to ten times the number of questions (Crocker & Algina, 2008).

The results of the empirical trials were then analyzed using item response theory. A summary of the construct validation results is explained as follows.

#### 2.3.1 Selection of Logistic Parameter Models

To find out the appropriate logistic parameter model for estimating the Three-Dimentional test characteristics of light waves based on the Three-Dimentional Learning Framework, the empirical test data obtained was analyzed based on statistical model suitability based on a comparison of the calculated chi-square value with the chi-square table with degrees. certain freedom. An item is said to fit a model if the calculated chi-square value does not exceed the table chi-square value. Suitability can also be determined from the probability value (P-value). If the P-value <<α (0.05), then the item is said to not fit the model. Item Suitability Three-Dimentional light wave test prototype based on the Three-Dimentional Learning Framework based on Item Response Theory Models 1, 2, and 3 Parameters are presented in Table 3.

**Table 3.** Suitability of Three-Dimensional Light Wave Test Items Based on Three-Dimentional Learning Framework Based on Model Item Response Theory 1, 2, and 3 Parameters

| Items | 1PL | | 2PL | | 3PL | |
|---|---|---|---|---|---|---|
| | $\chi^2$ | P-Value | $\chi^2$ | P-Value | $\chi^2$ | P-Value |
| 1 | 3.157 | 0.977 | 0.269 | 1.000 | 0.248 | 1.000 |
| 2 | 1.546 | 0.999 | 1.700 | 0.998 | 2.621 | 0.989 |
| 3 | 1.990 | 0.996 | 0.302 | 1.000 | 0.355 | 1.000 |
| 4 | 5.025 | 0.890 | 1.896 | 0.997 | 2.942 | 0.983 |
| 5 | 1.390 | 0.999 | 0.782 | 1.000 | 1.146 | 1.000 |
| 6 | 1.965 | 0.997 | 0.498 | 1.000 | 0.436 | 1.000 |
| 7 | 1.267 | 0.999 | 0.132 | 1.000 | 0.227 | 1.000 |
| 8 | 4.009 | 0.947 | 2.300 | 0.993 | 2.131 | 0.995 |
| 9 | 16.341 | 0.090 | 3.751 | 0.958 | 2.890 | 0.984 |
| 10 | 2.642 | 0.989 | 2.158 | 0.995 | 2.226 | 0.994 |
| 11 | 2.184 | 0.995 | 0.845 | 1.000 | 0.328 | 1.000 |
| 12 | 1.395 | 0.999 | 0.153 | 1.000 | 0.331 | 1.000 |
| 13 | 1.038 | 1.000 | 0.135 | 1.000 | 0.195 | 1.000 |
| 14 | 8.785 | 0.553 | 1.536 | 0.999 | 1.176 | 1.000 |
| 15 | 0.785 | 1.000 | 0.556 | 1.000 | 0.517 | 1.000 |
| 16 | 2.651 | 0.988 | 0.923 | 1.000 | 1.811 | 0.998 |
| 17 | 2.034 | 0.996 | 1.897 | 0.997 | 1.224 | 1.000 |
| 18 | 1.638 | 0.998 | 0.926 | 1.000 | 1.086 | 1.000 |
| 19 | 2.090 | 0.996 | 0.460 | 1.000 | 0.512 | 1.000 |
| 20 | 9.742 | 0.463 | 6.711 | 0.752 | 7.448 | 0.683 |
| 21 | 8.455 | 0.585 | 1.083 | 1.000 | 1.187 | 1.000 |

Note: 1PL = 1 logistic parameter, 2PL = 2 logistic parameters, 3PL = 3 logistic parameters, $\chi^2_{tabel}$ at degrees of freedom (df) 10 at a significance level of 0.05 = 18.307

Table 3 shows that in terms of both the comparison of the calculated chi-square value with the chi-square table with certain degrees of freedom (df = 10) and based on the probability value (P-value) the three models are suitable for analyzing Three-Dimensional light wave test items. based on the Three-Dimensional Learning

Framework. A question item is said to match a model if the calculated chi-square value does not exceed the table chi-square value. Suitability can also be determined from the probability value (significance, sig). If the sig value <α, then the item is said to not fit the model (Retnawati, 2014). Therefore, there is no doubt in choosing one of the three to be used as an item analysis model. However, in this analysis a 3 parameter model was used to analyze the Three-Dimentional light wave prototype test items based on the Three-Dimentional Learning Framework. This consideration is based on the fact that the 3 parameter model provides more information regarding the item parameters of the Three-Dimentional light wave test prototype based on the Three-Dimentional Learning Framework.

2.3.2 *Characteristics of Three-Dimensional Light Wave Test Items Based on the Three-Dimentional Learning Framework*

Characteristics of Three-Dimentional test items Light wave material based on the Three-Dimentional Learning Framework using item response theory with 3 logistic parameters containing distinguishing power (parameter a), level of difficulty (parameter b) and pseudo-guess factor (parameter c) which are presented in Table 4.

**Table 4.** Parameters of Three-Dimentional Light Wave Test Items Based on the Three-Dimentional Learning Framework

| Item | Differentiating power (a) | Degree of difficulty (b) | *Factor Guessing* (c) |
|---|---|---|---|
| 1 | 1.872 | -1.042 | 0.153 |
| 2 | 1.195 | -0.031 | 0.112 |
| 3 | 1.744 | -0.783 | 0.152 |
| 4 | 1.729 | -0.259 | 0.096 |
| 5 | 0.895 | 1.997 | 0.166 |
| 6 | 0.925 | -0.317 | 0.160 |
| 7 | 1.327 | 0.960 | 0.134 |
| 8 | 0.917 | -1.522 | 0.171 |
| 9 | 1.864 | 2.687 | 0.192 |
| 10 | 0.556 | 1.878 | 0.158 |
| 11 | 1.441 | 1.140 | 0.177 |
| 12 | 1.583 | 1.916 | 0.095 |
| 13 | 1.826 | 0.466 | 0.129 |
| 14 | 0.398 | -0.977 | 0.165 |
| 15 | 1.191 | -0.461 | 0.166 |
| 16 | 0.448 | 0.377 | 0.163 |
| 17 | 0.938 | 0.593 | 0.203 |
| 18 | 0.813 | 1.383 | 0.175 |
| 19 | 0.921 | 0.498 | 0.172 |
| 20 | 0.434 | -1.832 | 0.160 |
| 21 | 0.548 | 3.710 | 0.183 |

Based on the results of the slope value analysis which states the differentiating power parameter (a), all the questions on the Three-Dimentional light wave prototype test based on the Three-Dimentional Learning Framework are in the range 0-2. This shows that all the prototype questions on the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework are categorized as having good differentiating power (Baker Frank B., 2001; Hambleton et al., 1991).

An item is said to be good if its difficulty level (b) is in the range -2 to +2 (Hambelton et al., 1991). The usual range in practice is -2.80 to +2.80 (Baker Frank B., 2001). The estimated level of difficulty for item (b) as shown in table 4 is in the range -1,832 to +3,710, which means that all Three-Dimentional light wave test items based on the Three-Dimentional Learning Framework have varying levels of difficulty from easy to very difficult (Baker Frank B., 2001; Hambleton et al., 1991).

*Factor guessing (c) has a theoretical range of 0 < = c < = 1.0, but in practice, values above 0.35 are considered unacceptable* (Baker Frank B., 2001). The estimated guessing factor (c) data as shown in table 4 shows that all Three-Dimentional light wave test items based on the Three-Dimentional Learning Framework have a guessing factor (c) value of less than 1, so it can be concluded that almost all the inquiry ability test items have good pseudo-guess factor (Baker Frank B., 2001; Hambleton et al., 1991).

2.4 *Estimation of Test Parameters*

Based on the analysis of item response theory, the overall characteristics of the test can be determined through the total characteristic curve (TCC). This curve shows the estimation results for each test parameter obtained by participants from completing 21 questions. The total characteristic curve of the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework with the 3 PL model item response theory is presented in Figure 3.

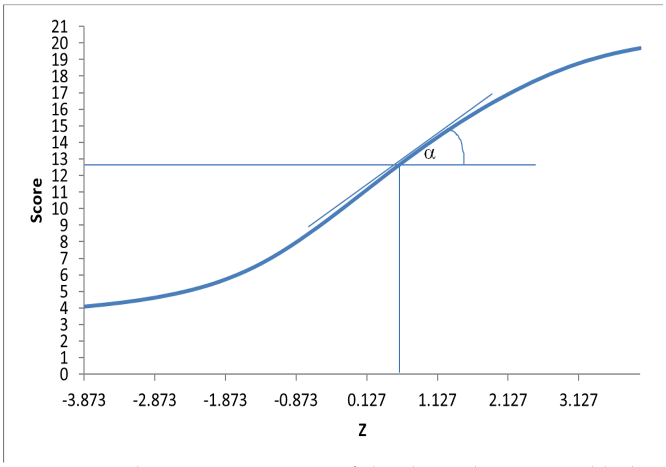


**Figure 3.** Characteristic curve of the three-dimensional light wave test based on the three-dimensional learning framework

Based on the curve in Figure 3, participants who have ability (z) -3.783 (very low) will get a score of 4.087 out of a total ideal score of 21, which means a probability of 0 is at a score of 4.087. Participants who have an ability of +4 (very high) will get a score of 19.698 out of a total ideal score of 21, which means a probability of 1 is a score of 19.698. So then it can be seen that the probability of 0.5 is at 12.544 on the total characteristic curve.

The value of parameter b can be found by drawing a horizontal line at the probability value of 0.5 (score 2,544) up to the curve and then drawing a vertical line from the curve to the X axis right at its intersection. The value shown on the x-axis is the value of parameter b from the characteristic curve which is located at 0.547 or is included in the medium difficulty level category. The parameter value c is the asymptote of the total characteristic curve which is located at a score of 4.087 so the probability is 0.195, which means it is in the good category because the value is no more than 0.25 or 1/k. This parameter c represents the assumed pseudo-guessing factor from participants which is less than 19.50%. Meanwhile, the value of parameter a is obtained from the slope of the curve (slope) or can be known by tan α, which on the total characteristic curve, the value of tan α=1.86. This means that the distinguishing power (parameter a) of the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework has a value of 1.86 or is included in the good category because it is in the range 0 to 2 (Baker Frank B., 2001; Hambleton et al., 1991).

2.5 *Test Realiability*

The item parameter values and participants' abilities in the Three-Dimentional light wave test based on the Three-Dimentional Learning Framework are estimation results, so their truth is probability and cannot be separated from measurement error. In item response theory, standard error measurement or SEM is closely related to the information function. Both are used to measure the estimated reliability of a test using item response theory. The graph of the information function and SEM test of Three-Dimentional light waves based on the Three-Dimentional Learning Framework is presented in Figure 4.

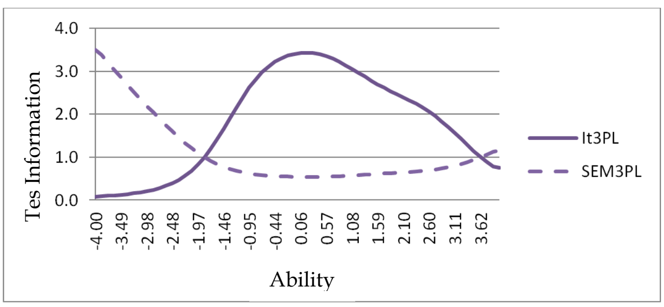


**Figure 4.** Graph of the Information Function (FI) and Standard Error Measurement (SEM) Three-Dimentional Light Wave Test based on the Three-Dimentional Learning Framework

The peak of total information is at 3.433 with an estimation error (SEM) of 0.539. Based on the curve in Figure 4, it shows that the test is reliable when given to students with a medium level of ability. The intersection between the two curves also shows that the test items will be suitable if used to measure ability levels in the range -1.84 to 3.62, namely participants who have low ability to very high ability (Hambleton et al., 1991).

## Conclusion

Referring to the results and discussion, the following conclusions can be drawn. First, to prepare a Three-Dimentional test based on the Three-Dimentional Learning Framework related to the basic competencies of the applicable curriculum, a remapping of disciplinary core ideas (DCI), scientific practices (SP), and cross-cutting concepts (CC) is needed in learning topics. This was done because there are differences between the preparation of basic competencies in the National Curriculum and the Performance Expectations (PE) and Learning Objectives (LO) used in the three-dimensional learning framework. Adjustment of Performance Expectation (PE) and Learning Objective (LO) is based on analysis of three-dimensional learning framework documents related to physics material contained in the Physical Science 4 (PS4) domain, then Performance Expectation (PE) in Physical Science 4 (PS4) is adapted and adapted to basic competencies 3 and 4 in the National Curriculum. The Three-Dimensional light wave test based on the Three-Dimentional Learning Framework is constructed by mapping disciplinary core ideas (DCI), scientific practices (SP), and crosscutting concepts (CC) referring to Performance Expectation (PE) and Learning Objective (LO). Based on this mapping, multiple choice questions with five options were created to measure LO, so that PE achievement could be measured by paying attention to aspects of content, construction and good grammar.

Second, based on analysis using 3-parameter logistic (PL) item response theory, it shows that the Three-Dimentional test of light waves based on the Three-Dimentional Learning Framework has a test discrimination power (parameter a/slope) in the good category, with details of five questions. very high, three items high, eight items medium and five items low. The test difficulty level (parameter b value or threshold) is in the medium category, with details of two very difficult questions, seven difficult questions, eight medium questions and four easy questions. The pseudo guessing factor indicated by parameter c, overall functions well. Referring to the information function and Standard Error Measurement (SEM) to measure test reliability estimates, it shows that the Three-Dimentional light wave test based on the Three-Dimentional Learning

Framework is reliable for measuring the ability level of participants in the low to very high ability categories.

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**Conflicts of Interest**
The authors declare no conflict of interest

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