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Development of Five-Step Diagnostic Test on Light Wave Concepts to Analyze Students' Understanding Map on The Concepts

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Abstract

During the Physics learning processes, students often have difficulty in understanding the concepts so that misconceptions occur. This is what was found in the Light Wave concepts when the Authors did the pre-research at one high school in Nganjuk. For example in Light Diffraction, students assumed that light diffraction be able to bending when it passes through all slit size, does not produce interference, and new waves. The truth is, diffraction in Light Wave occurs when light bends through a small slit and is characterized by interference and a new wave pattern. The misconceptions that occur in the Light Wave have the potential to hinder students' understanding of the following concepts, so they must be detected immediately. This article intends to report the results of writing the five-step conception diagnostic test on the Light Wave concepts, examine its feasibility, and then use it to map students' understanding concepts, as well as to identify the most dominant internal factors that lead students' misconceptions. Based on the feasibility test results, ten valid and reliable questions were selected so they can be used to test students' conceptions. The details are: the internal validity 96% (very valid), the external content validity consists of Correct Fake and Incorrect Fake scores are 3.3% and 4.5% (<10%) respectively, the construct external validity (rxy)=0.416>rtable=0.2638, and the reliability (r11)=0.796 (very reliable). Of the 19 students that were mapped using this feasible diagnostic test, 61.05% of them experienced a lack of knowledge.

Keywords: *Five-step conception diagnostic test, Light wave, Validity and reliability test, Students' understanding map*

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1. Introduction

Physics is a branch of Natural Sciences that is fundamental and forms the basis of the science and technology, also applied in everyday life [1]. The main key that students must learn in Physics is mastery of the concepts [2]. However, often during the learning processes, students experience difficulties in digesting the material well so what happens is that students experience misunderstandings about the concepts in the material presented by the teacher [3]. One of the Physics concepts that are taught and have the potential to causes conceptual misunderstandings is Light Wave.

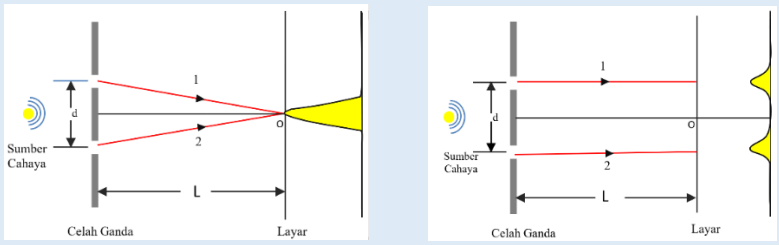
Based on the pre-research activities that had been done by the Authors at a high school in Nganjuk, it was found that there was a possibility of misunderstandings among students regarding the Light Wave concepts. One example is in the light diffraction sub-concept. When students were asked the question: "If a light is passed through a single slit and then the light is scattered out of the slit, then what happens to the light? Will light bend as it passes through all sizes of slits? Or does light produce

interference patterns and form new Light Wave?" Students assumed that diffraction on all waves has the same properties, namely bending when passing through a small slit regardless of the size of the slit, does not produce interference (dark-bright patterns), and does not produce new waves. Meanwhile, the correct answer is that the diffraction of Light Wave shows the bending of light when it passes through a small slit (the width of the slit is equal to or narrower than the wavelength), and interference (dark-bright patterns) will occur, and it forms a new wave [4].

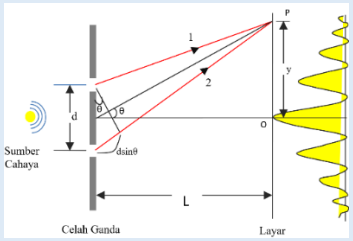
Misconceptions that occur in the Light Wave concepts mentioned above have the potential to hinder students' understanding of the following concepts [5]. For this reason, these misconceptions must be detected immediately [6]. Several methods were reported to be used to detect these misconceptions, such as interviews, concept maps or open answers and multiple-choice tests [7]. According to Salsabila and Ermawati [8], multiple-choice tests are the more efficient method to detecting misconceptions than interview tests and concept maps. The multiple-choice test that has been widely reported to the date is a four-step diagnostic test [9][10][11][12][13][14][15][16][17] which consists of first to the fourth steps questions. The first step consists of the question and answer selection. The second step of the question test is in the form of the students' self-confidence asking when choosing the correct answer from the first step questions preliminary. The third step consists of choosing the reason for answering the question in the first step. The fourth step is in the form of the students' self-confidence who are asked to select the correct answer on the reason from the third step question. Table 1 shows an example of a five-step conception diagnostic test consisting of questions from the first step to the fifth step written by the Authors of this work. The diagnostic test for the four-step conception mentioned above is the question in Table 1 below from the first to the fifth steps, not including the question for the fifth step.

Table 1. One of the ten questions on the Light Wave concepts that had been written by the Authors and declared feasible to be used

Step	Questions
1	Look at Figure 1 below



(a) (b)



(c)

Figure 1. Light Wave (Source: Personal Document)

	Based on Figure 1 above, when two lights with a fixed phase difference and the same amplitude are combined, thus the complete properties of the light produced on the screen are shown in Figure… A. All is correct B. Figures (a) and (b) C. Figures (a) and (c) D. Figure (a) only E. Figure (c) only (√)
2	Choice of confidence in choosing the answer: A. Confident B. Unconfident
3	The reasons for choosing the answer: A. The light that is passed through a slit will only be bright in the part that is close to the slit B. The light that is passed through a slit will produce a dark shadow pattern C. The light that is passed through a slit will be bright in the part that is far from the slit D. The shadows formation on the screen is not affected by the phase difference and the amplitude of the Light Wave E. The combination of two Light Waves will always produce the same pattern of shadows F. The light sources with the same frequency and wavelength will cause a certain superposition of interference patterns (√)
4	Choice of confidence in choosing the reasons answer: A. Confident B. Unconfident
5	Draw (with the descriptions) the process of combining two coherent Light Waves with a constant phase difference and the same amplitude!

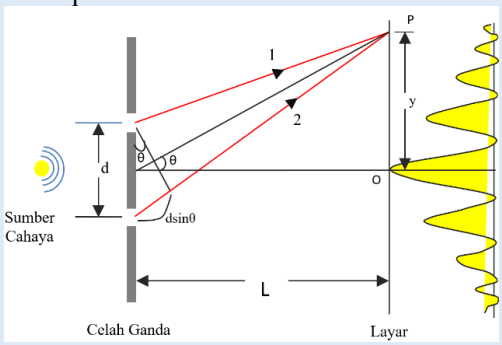


Figure 2. The combination of two coherent waves (constant phase difference and the same amplitude) will cause light interference. Source: [4]

As shown in Table 1, the questions from the first step to the fourth step are in the form of multiple-choice questions, and students have the opportunity to choose only one answer that they consider correct. According to the researchers [9-17], this diagnostic method can already be used to detect the step of students' conceptions. However, the examiner still does not have confidence whether the answers of students from the first to the fourth steps are correct or just guesses. It is therefore necessary to add another question that seems to provide the required confidence. In this case, the additional question required is an open-ended question in the fifth step of Table 1.

The method for assessing students' work results are using a four-step conception diagnostic test, especially in the first, second, third and fourth step columns as shown in Table 2. For the four-step conception, when combination of student's answers from step one to four is E-C-E-C, which means exact-confident-exact and confident, then student can be concluded as understanding the concepts, and so on. The Correct Fake (CF) means that even though the student's answer to the question is correct

and the student believes it, but he/she cannot clearly state the reason, or in other words, the answer is dubious or false, it is called a Correct Fake [18]. Thus, the combination of student answers is classified as CF when the student's answer from the first to the fourth steps are E-C-IE-C as shown in the sixth row (red font) of Table 2. Likewise in Incorrect Fake (IF), a student's answer is indeed wrong and the student believes that the answer is wrong but the student can show arguments/reasons for answering like that, meaning that a student's answer looks wrong but it turns out that the student can correctly state the reason so it is called as Incorrect Fake [18]. Thus, the combination of student answers is classified as IF when the student's answers from the first to the fourth steps are IE-C-E-C as shown in the ninth row (red font) Table 2.

Meanwhile, the assessment of answers for the five-step conception diagnostic test is similar to the assessment on the four-step conception diagnostic test but is added to the assessment question in the fifth step column of Table 2. The combination of student answers to the question from the first to the fourth steps and combined with the answers in the fifth step will produce the student step conception. When the student's answers from the first to the fourth steps are correct (E) and confident (C), then it is still possible for the student to experience Scientific Conception (ScC), Almost Scientific Conception (AScC), Lack of Knowledge (LKn) or Uncode (UnCd). Students can be categorized as Scientific Conception (ScC) when the combination of their answers from the first step to the fourth step is correct (E)-confident (C) and the answer at the fifth step is correct (ScU). Meanwhile, when the student's answers from the first to the fourth steps are correct (E) and confident (C) but the step five answer is still partially wrong (PrU), it is classified as having an Almost Scientific Conception (AScC) as shown in Table 2. The step of conception experienced by students is divided into six categories, namely Scientific Conception (ScC), Almost Scientific Conception (AScC), Lack of Knowledge (LKn), No Understanding on Concept (NUC), Misconception (Mc), and Uncode (UnCd).

Table 2. Assessment and criteria of students' step of conception on the five-step diagnostic test [19][20][21]

No.	Combination of Student Answers					Conception Step
	1st step	2nd step	3rd step	4th step	5th step	
1	E	C	E	C	ScU PrU McU UnU NoU	ScC AScC LKn UnCd
2	E	C	E	UC		
3	E	UC	E	C		
4	E	UC	E	UC		
5	E	C	IE	UC	(PrU) or	
6	E	C	IE	C	(UnU) or	
7	E	UC	IE	C	(McU)	LKn
8	E	UC	IE	UC		
9	IE	C	E	C		
10	IE	C	E	UC		
11	IE	UC	E	C		
12	IE	UC	E	UC		
13	IE	C	IE	UC	(PrU) or	
14	IE	UC	IE	UC	(UnU) or	NUC
15	IE	UC	IE	UC	(McU)	
16	IE	UC	IE	C	(PrU) or (UnU) or (McU)	Mc
17	If one "step" is not answered or has more than one answer					UnCd

Note:
E = Exact, IE = Inexact, C = Confident, UC = Unconfident, ScU = Scientific Understanding, PrU = Partial Understanding, McU = Misconception Understanding, UnU = Undefinied Understanding, NoU = No Understanding ScC = Scientific Conception, AscC = Almost Scientific Conception, LKn = Lack of Knowledge, NUC = No Understanding on Concept, Mc = Misconception, UnCd = Uncode.

As shown in Table 2, considering that the question from the first to the fourth steps are multiple-choice, there are only two possible answers, namely true or false. Meanwhile, for the fifth step that is an open-ended question, student answers may be grouped into one of five categories as shown in Table 3 below. When a student answers the fifth step question correctly and according to the Physics concepts, then this student is categorized as Scientific Understanding (ScU) and gets a 100% score, and so on as shown in Table 3.

Table 3. Category rubrics and scores at the fifth step [22]

No.	Category	Description	Score (%)
1	ScU	When students provide the correct answer according to the Physics concepts (completely correct)	100
2	PrU	When students provide an answer that is partially correct to the Physics concepts that asked in the question (partially correct)	70 - 99
3	McU	When students provide an answer incorrectly and do not match the Physics concepts (misconception)	40 - 69
4	UnU	When students provide an answer that is difficult to define or do not match with the Physics concepts (wrong)	1 - 39
5	NoU	When students do not answer the questions (no answer)	0

Until the end of 2021, it was reported that several studies had used the five-step conception diagnostic test in diagnosing students' step conception, such as the concepts of Changes of Matters [23], Heat Transfer [24], Sound Waves [1], Vectors [19], Elasticity [8], Kinetic Theory of Gases [7], Simple Harmonic Vibration [21], Straight Motion [20], and Uniform Circular Motion [6] but nothing has been reported for the Light Wave concepts. Based on the above explanation, this article intends to report the results of writing the five-step conception diagnostic test on the Light Wave concepts, examine its feasibility (validity and reliability), and then use it to map students' understanding on the Light Wave concepts, as well as to identify the most dominant internal factors that lead students' misconceptions.

2. Method

Considering that so far there is no standardized conception step diagnostic test, it means that someone who wants to detect or test the potential misconceptions of his students have to write the instrument first and then test its feasibility (valid and reliable) and it takes too much time so not everyone can do it. For this reason, a step called "Research and Development (R&D)" is needed [21]. "Research" of this work means that the Authors conducted a literature study on Young and Freedman's book entitled "University Physics with Modern Physics" (Pages 1080-1190) and Arthur Beiser's book entitled "Concepts of Modern Physics" (Pages 53- 67), especially on the Light Wave concepts. Next, the writer examines and details the potential misconceptions that students will experience through the pre-

research activities. Table 4 below shows some of the potential misconceptions found in the Light Wave concepts.

Table 4. Some potential misconceptions found in the Light Wave concepts

Sub-concepts	The Correct Concepts	Potential Misconceptions
Medium of light propagation	Light can propagate either there is a medium or there is no medium so that light is an electromagnetic wave [4].	Students assumed that light can only propagate when there is an intermediary medium such as sunlight to our homes through the medium of air.
Light Interference	Light interference is the combination of two or more Light Waves into one new wave. Conditions for interference are the light must be coherent and have the same amplitude [4].	Students assumed that interference is a combination of two or more combinations of light without certain conditions for example without going through the same phase difference and the amplitude between waves is different because all Light Waves have the same frequency and amplitude.
Light Polarization	Polarization is the process of partially absorbing the direction of the vibrating plane of the wave. The phenomenon of polarization can only be experienced by transverse waves. In general, Light Wave have many directions of vibration. A light that has many directions of vibration is called unpolarized light while light whose vibration direction is reduced is called polarized light [4].	Students assumed that Light Wave that is passed through a polarizer does not reduce the incoming vibration direction (the direction of vibration remains the same) because light has diffraction properties that bend when passed through a slit.

Furthermore, the meaning of "Development" here is that the Authors write the first draft of the diagnostic test question for the Light Wave concepts (consisting of ten questions) based on the results of the literature study and the pre-research that had been done [20]. The first draft that had been written then would be checked for its internal validity by two Physics lecturers who were selected as validators. Aspects of this internal validity assessment consist of content, construct, and language. The results of the internal validity will then be calculated using Equation (1) [25] and interpreted according to Table 5 to produce the second Draft as follows [26].

$$R = \frac{T_S}{H \times N \times R} \times 100\% \quad (1)$$

where: R = the results of the internal validity, T_S= the total score of validators, H = the highest score of the questionnaire, N = the number of questionnaire questions, R = the number of respondents

Table 5. Internal Validity Results Criteria [27]

%	Criteria
0-20	Very weak
21-40	Weak
41-60	Enough
61-80	Strong
81-100	Very strong

Then, the Authors examined the second draft of the internal validity results to 40 numbers of twelfth-grade students who had previously taught Light Wave concepts when taking eleventh-grade, based on Table 5. This second trial did when the Authors were doing the Introduction to the School Field (PLP) II at one of Sidoarjo's secondary schools. The purpose of this first trial is to determine the step of external validity and reliability of the Draft II instrument. The external validity itself consists of the content empirical validity and the construct empirical validity. The content empirical validity will be fulfilled if the % CF and %IF scores < 10% by using Equations (2) and (3) [6]. The explanation for the combination of the CF and IF answers has been mentioned in the Introduction above.

$$\%CF = \frac{\sum CF}{\sum items \times \sum S} \times 100\% \quad (2)$$

$$\%IF = \frac{\sum IF}{\sum items \times \sum S} \times 100\% \quad (3)$$

Note: $\sum CF$ = the results of the CF, $\sum IF$ = the results of the IF, $\sum items$ = the number of questions, $\sum S$= the number of students

Then the empirical validity of the construct is fulfilled when $r_{xy} > r_{tabel}$, and following the Pearson Product Moment correlation criteria as shown in Table 6 [25]. The number of construct empirical validity can be calculated by Equation (4) [26] Pearson Product Moment correlation as follows

$$r_{ab} = \frac{\sum ab}{\sqrt{(\sum a^2)+(\sum b^2)}} \quad (4)$$

Where: r_{ab} = the correlation of variables a and b, a = the difference between the correct answers in the step one and step three with the average correct answers for all questions, b = the difference between the correct answers in the step two and step four with the average correct answers for all questions.

Table 6. Criteria for the Pearson Product Moment correlation coefficient [25]

Correlation Coefficient Interval (r_{xy})	Criteria
0,000 – 0,199	Very weak
0,200 – 0,399	Weak
0,400 – 0,599	Enough
0,600 – 0,799	Strong
0,800 – 1,000	Very strong

The reliability is calculated by Equation (5) Cronbach's Alpha [26] and the calculation results are categorized according to the criteria in Table 7 below [25].

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\sum {\sigma_1}^2}{{\sigma_t}^2}\right) \quad (5)$$

where: r_{11}= the results of reliability, k = the number of questions, $\sum {\sigma_1}^2$= total variants per question, ${\sigma_t}^2$ = total all variance

Table 7. Reliability criteria based on Cronbach's Alpha calculations [25]

Reliability Range (r)	Criteria
-1,000 - 0,199	Very weak
0,200 - 0,399	Weak
0,400 - 0,599	Enough
0,600 - 0,799	Strong
0,800 - 1,000	Very strong

The external validity and reliability test above resulted in the Final Draft of a five-step diagnostic test with a total of ten questions. The Final Draft that had been declared valid and reliable then be used to test and map the conception step of the 19 students who had never seen/done the diagnostic test on the Light Wave concepts before.

3. Result and Discussion

3.1. Writing of five-step diagnostic test

Previously, many diagnostic tests have been developed for the concept of light waves, but there are no multilevel diagnostic test instruments for light waves concepts, especially up to five steps as far as the Authors know. As mentioned earlier, ten questions for the five-step conception diagnostic test were successfully written and declared valid and reliable. One of the ten questions referred to is as given in Table 1. Note: the answer marked with a tick (√) is the correct answer.

3.2. Validity and reliability results

Table 8 , Table 9, Table 10, and Table 11 below shows the recapitulation results of the internal validity, the content and construct external validity and the reliability in the Final Draft. Meanwhile, Figure 3 shows the r_{table} score with the 40 students being the respondents and a significance of 5% and is marked with a red box.

Table 8. Results of the internal validity

No.	Aspects	Indicators	Validator		%	Criteria
			1	2		
1.	Content	(a)	4	4	94	Very strong
		(b)	3	4		
		(c)	4	4		
		(d)	3	4		
2.	Construct	(a)	4	4	94	
		(b)	4	3		
		(c)	3	4		
		(d)	4	4		
		(e)	3	4		
		(f)	4	4		
3.	Language	(a)	4	4	100	
		(b)	4	4		
		(c)	4	4		
Average					96	Very strong

Indicators of the content aspect: (a) the compatibility between the question and the concept, (b) the compatibility between the questions and the indicators, (c) the compatibility between the problem and the concepts sequence, (d) providing the clear boundaries for the questions, answers, and reasons. Indicators of the construct aspect: (a) the test procedure is completely written, (b) questions criteria according to the Bloom's Taxonomy and basic competency, (c) each question can reveal the students' conception step, (d) the choices reason (third step) can reveal the causes of students' misconceptions, (e) distractors at the third step are logical and according to the answers to the first step, (f) additional information according to the provided questions.
Indicators of language aspect: (a) standard use of Indonesian, (b) the questions used do not lead to ambiguity, (c) the sentences used are clear and communicative.
The results of the internal validity scores were calculated using Equation (1) and the categories are according to Table 1.

Table 9. Results of the empirical external validity content

No.	ΣS	ΣCF	ΣIF
1	40	0	7
2		0	1
3		5	0
4		1	3
5		1	3
6		0	1
7		3	0
8		0	0
9		3	2
10		0	1
	%	3,25%	4,5%

Note: % CF and IF are calculated using Equations (2) and (3). Based on Table 9 above, it was found that % CF <10% and % IF <10% so that the question test can be declared empirically valid in its contents.

Table 10. The results of the empirical external validity construct

No.	r_{xy}	r_{tabel}	Validity
1	0,4205	0,2638	All valid
2	0,6376		
3	0,5156		
4	0,3793		
5	0,3079		
6	0,4041		
7	0,4327		
8	0,3386		
9	0,4548		
10	0,2688		

df = (N-2)	Tingkat signifikansi untuk uji satu arah				
	0.05	0.025	0.01	0.005	0.0005
	Tingkat signifikansi untuk uji dua arah				
	0.1	0.05	0.02	0.01	0.001
38	0.2638	0.3120	0.3665	0.4026	0.5007
39	0.2605	0.3081	0.3621	0.3978	0.4950
40	0.2573	0.3044	0.3578	0.3932	0.4896

Figure 3. Screenshot of the r_{table} on 40 respondents with a significance step of 0.05 [28]

Table 10 above shows that the ten questions in Draft 2 were declared empirically valid constructs ($r_{xy} > r_{tabel}$) so that the ten questions can be used to test students' conceptions of the Light Wave concepts. Figure 3 above is a screenshot of the table for the construct empirical validity test. Because the number of students tested was 40, the number of *df* obtained was 38 and with a significance step of 0.05, the total $r_{table} = 0.2638$.

Table 11. Results of the reliability

r_{11}	r_{tabel}	Criteria
0,796	0,2638	High

Note: Reliability was calculated using Equation 5 and categorized according to the Table 6. Table 11 above shows that the second Draft (final draft) was reliable with the high criteria so that it can be used to test students' conceptions on the students understanding map test.

3.3. The results of mapping students understanding

Table 12 provides the mapping of 19 test students and their answers to ten questions consisting of 7 sub-concepts. In Table 12 the cells that are given a red box show examples of students work as shown in Figure 4 below.

Table 12. The recapitulation understanding map results of the 19 students twelfth graders in a senior high school in the Sidoarjo area

Students	SUB-CONCEPTS										Description of the most dominant conception step per student
	a	b	c	d		e		f		g	
	QUESTION NUMBER										
	1	2	3	4	5	6	7	8	9	10	
1	ScC	AScC	AScC	LKn	LKn	LKn	UnCd	LKn	UnCd	LKn	LKn (50%)
2	ScC	UnCd	AScC	LKn	UnCd (NoC)	LKn	LKn	LKn	LKn	LKn (WR)	LKn (60%)
3	LKn (AT)	LKn	LKn (AT)	NUC (WI)	LKn	LKn	LKn	LKn	LKn	LKn (WR)	LKn (90%)
4	Mc (HT)	LKn	Mc (AT)	Mc (WI)	LKn	LKn	LKn	LKn	LKn	LKn (WR)	LKn (70%)
5	Mc (HT)	LKn	LKn (P)	LKn (WR)	LKn	LKn	NUC (P)	LKn (AT)	LKn	LKn	LKn (80%)
6	Mc (HT)	UnCd (NoC)	Mc (AT)	LKn (HT)	LKn	LKn	Mc (AT)	LKn	NUC (AT)	LKn	LKn (50%)
7	ScC	AScC	AScC	LKn	LKn (P)	LKn (WR)	LKn	LKn	LKn	LKn	LKn (70%)

8	Mc (HT)	LKn	AScC	Mc (WI)	LKn	LKn	LKn	LKn	LKn	LKn	LKn (70%)
9	Mc (HT)	LKn	LKn (AT)	NUC (WI)	LKn	LKn	LKn	LKn	LKn	LKn (WR)	LKn (80%)
10	LKn	LKn	Mc (AT)	UnCd (WI)	LKn	AScC	UnCd	LKn	UnCd	UnCd (NoC)	LKn (40%) dan UnCd (40%)
11	Mc (HT)	NUC	NUC (AT)	NUC (WI)	LKn	LKn	LKn	LKn	LKn	LKn	LKn (60%)
12	LKn	LKn	Mc (AT)	UnCd (WI)	LKn	LKn	UnCd	LKn	UnCd	UnCd (NoC)	LKn (50%)
13	AScC	AScC	LKn (AT)	UnCd (WI)	AScC	LKn	LKn	LKn	UnCd (NoD)	LKn (NoC)	LKn (50%)
14	AScC	AScC	LKn (AT)	Mc (WI)	AScC	LKn	LKn	LKn	LKn	LKn (WR)	LKn (60%)
15	Mc (HT)	LKn	Mc (AT)	NUC (WI)	LKn	AScC	LKn	LKn	LKn	AScC	LKn (50%)
16	LKn	LKn	Mc (AT)	UnCd (WI)	LKn	AScC	UnCd	LKn	UnCd	AScC	LKn (40%)
17	Mc (HT)	LKn	LKn (AT)	Mc (WI)	LKn	LKn	LKn	LKn	LKn	UnCd (NoC)	LKn (70%)
18	LKn	LKn	LKn (AT)	UnCd (NoD)	AScC	LKn	LKn	UnCd (NoD)	UnCd (NoD)	LKn (WR)	LKn (60%)
19	Mc (HT)	AScC	LKn (AT)	NUC (P)	AScC	LKn	LKn	LKn	LKn	LKn (WR)	LKn (60%)

The description of the conception step in Table 12 is the same as the description of the conception step in Table 2.

Description of the causes of misconceptions; HT=Humanistic Thinking, AT=Associative Thinking, WI=Wrong Intuition, P=Praconception, WR= Wrong Reasoning, NoC/D= No Conception/Drawing.

Sub-concept: (a)= medium of light propagation, (b) = wave nature of light, (c) = light dispersion/color spectrum, (d) = Light Wave interference, (e) = thin film interference, (f) = the light diffraction, (g) = the light polarization.

The concept map in Table 12 shows that student 1 most dominant conception step was Lack of Knowledge (50%) and he had difficulty in sub-concepts (d), (f), and (g). It was probably because this problem required an in-depth understanding of the description and properties of interference, diffraction, and polarization of light precisely where students did not memorize the concepts and only remember the formulas. The most dominant step conception of Student 2 was Lack of Knowledge (60%) and he had difficulty in sub-concepts (d), (e), (f), and (g). It was probably because this question required clear statements and descriptions at the fifth step, while students did not know how to describe the processes of dispersion, interference, diffraction, and polarization.

The most dominant step conception of student 3 was Lack of Knowledge (90%) which means that the student still lack of knowledge in all Light Wave concepts. The most dominant step conception of Student 4 was Lack of Knowledge (70%) and he had difficulty in sub-concepts (b), (d), (e), (f), and (g), it happened because a student was unconfident in answer questions at step two or step four. The most dominant step conception of Student 4 was Lack of Knowledge (80%) in sub-concepts (b), (c), (d), (f), and (g), It had happened probably because the majority of students answered unconfident in the second and fourth step.

The most dominant step conception of student 6 was Lack of Knowledge (50%) in sub-concepts (d), (e), (f), and (g). It was happened probably because this problem required an understanding of the Light Wave concepts and the student did not remember the properties and pictures of the interference, diffraction, and polarization. The most dominant step conception of Student 7 was Lack of Knowledge (70%) and he had difficulty in sub-concepts (d), (e), (f), and (g). It was probably because this problem required an overview of the interference, diffraction, and polarization process, while the student did not remember the concept of the Light Wave. The most dominant step conception of Student 8 is Lack of Knowledge (70%) and he had difficulty in sub-concepts (b), (d), (e), (f), and (g).

It was probably because this problem required an understanding of the nature of Light Wave concepts and the properties of interference, diffraction, and polarization, but a student cannot distinguish concepts between sub-concepts. The most dominant step conception of Student 9 was Lack of Knowledge (80%) in sub-concepts (b), (c), (d), (e), (f), (g), it was probably because in the second and fourth step questions student answer unconfident. The most dominant step conception of Student 10 is Lack of Knowledge (40%) and Uncode (40%) in sub-concepts (a), (b), (d), (e), (f), and (g). It was probably because this question required an understanding of the nature of Light Wave concepts and their descriptions correctly, but unfortunately a student cannot answer questions at the fifth step.

The most dominant step conception of Student 11 was Lack of Knowledge (60%) in sub-concepts (d), (e), (f), and (g). It probably happened because this problem required an understanding of the Light Wave concepts and the student did not remember properties and pictures of the interference, diffraction, and polarization of light. The most dominant step conception of Student 12 was Lack of Knowledge (50%) in sub-concepts (a), (b), (d), It probably because this question required an understanding concept of the Light Wave nature and descriptions correctly but unfortunately student cannot answer the questions about the figure or conclusion at the fifth step. The most dominant step conception of Student 13 was Lack of Knowledge (50%) in sub-concepts (c), (d), (e), and (g), It probably because this question required an explanation of the understanding concepts of dispersion, interference, diffraction, and polarization that was unknown by the student. The most dominant step conception of Student 14 was Lack of Knowledge (60%) in sub-concepts (c), (d), (e), (f), and (g), It probably because this question required an explanation of understanding the concepts of dispersion, interference, thin layer interference, diffraction and polarization that was unknown by the student. The most dominant step conception of Student 15 was Lack of Knowledge (50%) in sub-concepts (b), (d), (e), (f), It probably because this question required an explanation of concept understanding and description of properties, dispersion, interference, thin layer interference, light diffraction that was unknown by the student.

The most dominant step conception of Student 16 was Lack of Knowledge (40%) in sub-concepts (a), (b), (d), (f). It had happened probably because the answer choices on this question are deceptive. The most dominant step conception of Student 17 is Lack of Knowledge (70%) and he had difficulty in sub-concepts (b), (c), (d), (e), (f). It was probably because this problem required understanding concepts of the Light Wave nature and the properties of interference, diffraction, and polarization, but the student cannot distinguish concepts between sub-concepts. The most dominant step conception of Student 18 was Lack of Knowledge (60%) and he had difficulty in sub-concepts (a), (b), (c), (d), (e), (g). It was probably because this problem required understanding concepts of the Light Wave nature and the properties of dispersion, interference, diffraction, and polarization, but the student cannot distinguish concepts between sub-concepts. The most dominant conception step of Student 19 is Lack of Knowledge (60%) in sub-concepts (c), (d), (e), (f), (g). It was probably because this problem required understanding concepts of the dispersion properties, interference, thin layer interference, diffraction, and light polarization, but students did not understand the concepts.

Table 12 above shows that the majority conception step of twelfth-grade students was Lack of Knowledge with a total of 61.053% from the Light Wave concepts. Furthermore, the percentages obtained by the students at the step of Scientific Conception, Almost Scientific Conception, No Understanding on Concept, Misconception, and Uncode were 1.579%, 10%, 5.263%, 10%, and 11.58%, respectively. From the understanding map of the 19 students, it turned out that there were no students who experienced Scientific Conception in question numbers 2-10, students only experienced the step conception of Scientific Conception in question number 1. That means that from some of the Light Wave sub-concepts that had been taught, students only experience understanding concepts on the light propagation sub-concept. The most common misconceptions experienced by students were in question number 1, the sub-concept of the medium of light propagation. In question number one, only 3 students (test students 1, 2, 7) reached the Scientific Conception step while 9 other students experienced misconceptions (test students 4, 5, 6, 8, 9, 11, 15, 17, 19).

The most dominant internal factor that causes misunderstanding of concepts in students are Associative Thinking (AT) with a total of 27.27%, then the next number of internal factors are Wrong Intuition (18.18%), Humanistic Thinking (16.67%), Wrong Reasoning (15.15%), Preconception (7.58%). Figure 4 below shows an example of students work that becomes the dominant step of conception for the student concerned. The red stamp shows the step of conception experienced by the students.

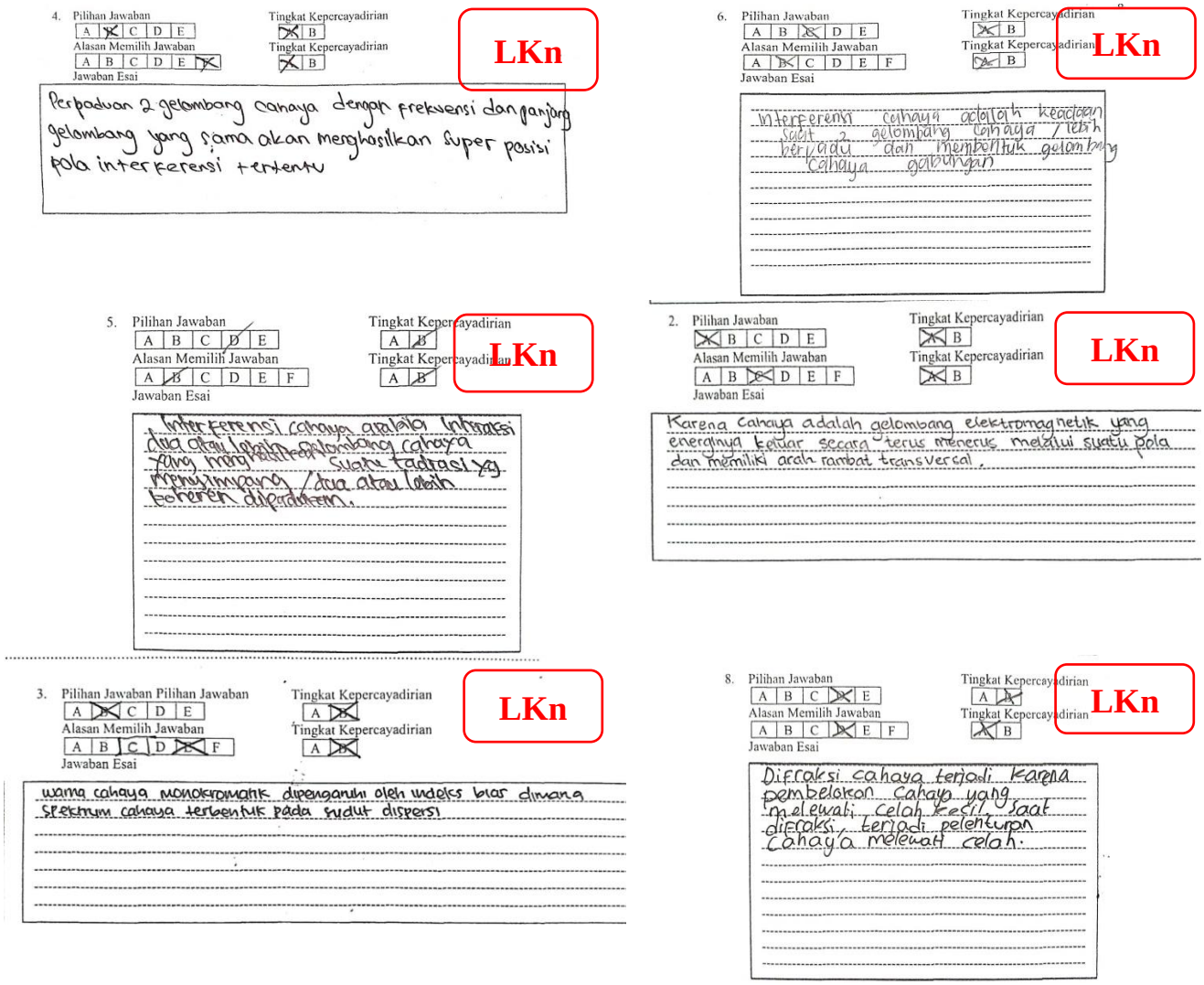


Figure 4. The students' answer to the questions and marked as lack of knowledge

Figure 5 below shows examples of different student conception based on the combination of answers in question number 4 (look back at the Table 1 above). Question number 4 is one of the sub-concepts of light wave interference, where students are shown several examples of figures of light passing through a double slit and given a question if two lights with a fixed phase difference and the same amplitude are combined, the complete properties of the resulting light on the screen are shown which figures? It can be seen from the students' answers in the fifth step of Figure 10, the first student who experienced Lack of Knowledge (LKn) answered that "the combination of two light waves with the same frequency and wavelength will produce a superposition of certain interference patterns". The third student who experienced No Understanding Concept (NUC) answered with the wrong figure. The fourth student who experienced the Misconception (Mc) also answered with the wrong figure. And the tenth student did not answer the question in the fifth step (UnCd).

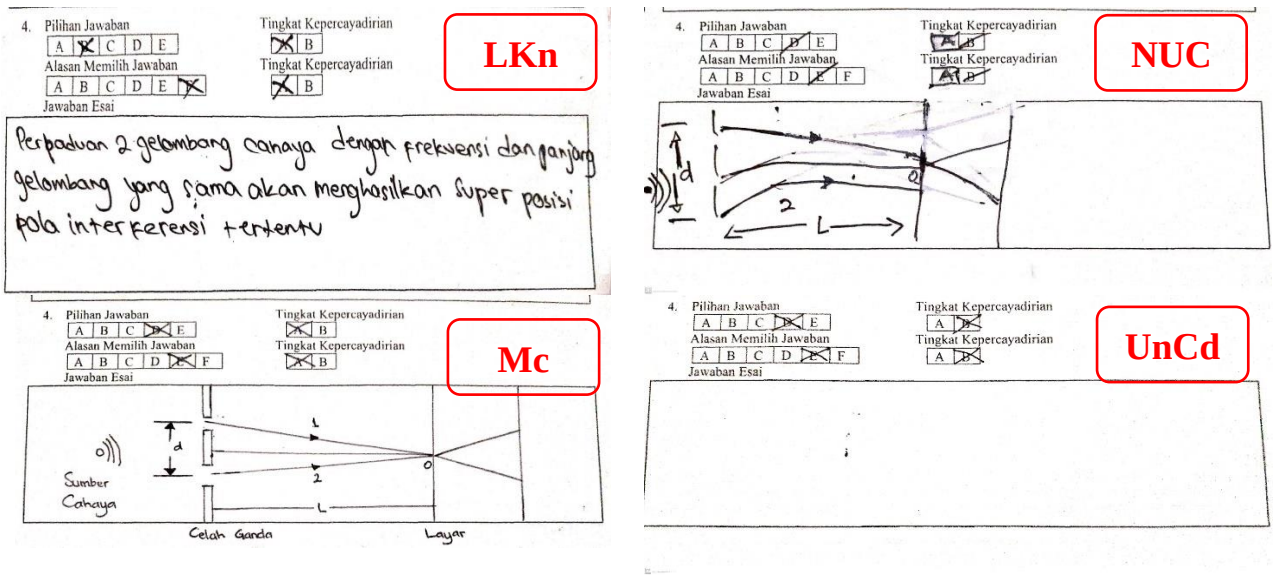


Figure 5. Some combinations of student responses in question number 4

Meanwhile, according to the concept of physics, interference in the double slit see Figure 6 and Figure 7 occurs because of the phase difference (d sin θ) of the light that passes through the two slits. When a light source with exactly the same frequency (f) and wavelength (λ) passes through two slits (distance d) (and with almost the same amplitude) to a point (P), there will be a superposition which causes bright (T0, T1, T2, T3) streaks to appearand dark (G1, G2, G3) on the screen (L Distance). (Freedman and Young 13th, 2012, Pages 1164 and 1165) [4].

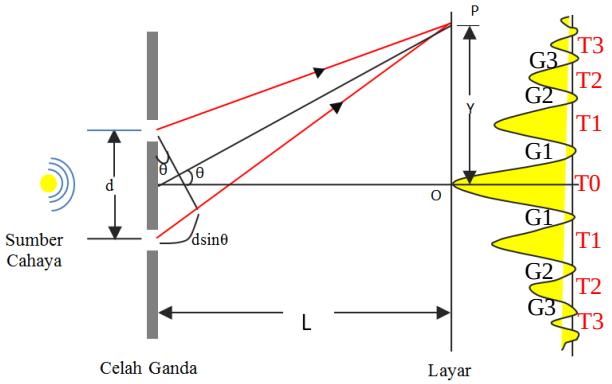


Figure 6. The combination of two coherent waves (fixed phase difference and same amplitude) will cause light wave interference.

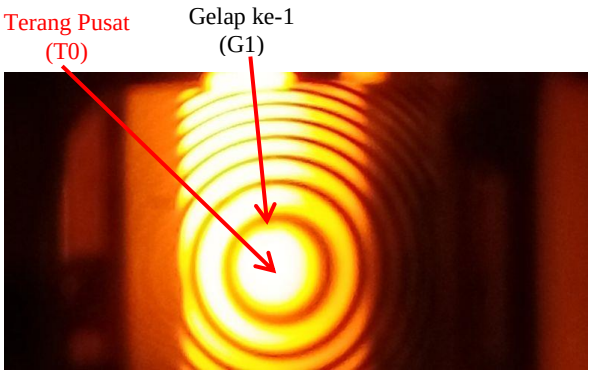


Figure 7. Light interference showing the presence of dark and light patterns when two lights are combined

Information:

O	= Midpoint between the two slits	T0	= Central bright spot
L	= Distance between double slit and screen	T1	= 1st Light
P	= Resultant of the intensity of light coming from the two slits	T2	= 2nd Light
d	= distance between the two slits	T3	= 3rd Light
d sin θ	= Difference in path of the two rays	G1	= 1st Dark
y	= distance from the center of the bright band to the th band	G2	= 2nd Dark
n	= Order	G3	= 3rd Dark
λ	= Wavelength	G4	= 4th Dark

A similar study was conducted by Wafi Lutfia & Ngurah Made Darma Putra [29] that also identified the student's understanding of the concept of Light Wave Interference, namely in an article entitled "Profile Analysis of Understanding Concepts and Mental Models of Students at SMA Kesatrian 2 Semarang on Light Interference and Diffraction Materials". Data collection techniques carried out in this study were observation techniques, written tests and interview technique with three tiers multiple choice instrument, sheet validation questions and interview sheets. According to the findings of this study, the indicator of the condition of light interference shows that 65 percent of students still have misconceptions. Concept understanding of class XI MIPA 2 SMA Kesatrian 2 Semarang on light interference and diffraction material is included in the category of understanding concepts by 30%, misconceptions 48% and not understanding concepts 22%

4. Conclusion

The work to compose a five-step diagnostic test for the Light Wave concept and test it out on a group of students to understand it against the concept, as well as to identify the most dominant internal factors causing misconceptions has been completed. It was found that most of the students still experienced Lack of Knowledge on the concept of Light Waves with the most dominating internal factor being Associative Thinking (AT). Thus this five-level conception diagnostic test can be used practically and effectively to test or diagnose students' conceptual abilities and can be a guide for teachers or researchers who want to test and determine the best learning method in guiding students, provided that the examiner must understand the concepts and methods of determining validity and reliability well.

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