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Identifying Students' Conceptions on Sound Wave via the Sound Wave Four Tier (SOFT) Diagnostic Test

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Abstract

This paper aimed to assess the validity of the Sound Wave Four Tier (SOFT) Diagnostic Test that can be used to identify students' conception profiles. Using the Four Design (The participants were 42 students aged 15-17 years old in one of the public high schools in Bandung City. The participants were 42 students aged 15-17 in one of the public high schools in Bandung City. The data's validity, the instrument's reliability, and the distribution of students' conceptions were analyzed using the Rasch model with the MINISTEP 4.5.3.0 program. The dimensional-based validity of the items used was valid. Accuracy based on Cronbach Alpha (α) was in the high category, the item reliability score was in the good category, and the reliability of personnel was in the low category. The conception profile of the students categorized as. Sound Understanding (SU), Partial Positive (PP), Partial Neutral (PNt), Partial Negative (PNg), Misconception (MC), No Understanding (NU), and No Coding (NC). The highest category of conception found was MC. There were a lot of misconceptions found in the sound wave material. Students' Misconceptions are still commonly found in sound waves. A 4D model can be developed using Rasch modeling analysis to identify students' profiles. Utilizing the SOFT instrument enables students to gain a broader understanding of the concept, including verbal statements and various representations of images and mathematical symbols.

Keywords: Four-tier instrument diagnostic test; Rasch model analysis; Sound wave

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INTRODUCTION

Physics learning, which contains many concepts, should lead students to have a complete understanding of phenomena that occur in everyday life. The facts are that students don't get the all the time during the learning process the physics concepts, or they experience

misconceptions and discrepancies in the concepts that students understand, or Most of the misconceptions in physics arise from the students themselves, causing the expected physics learning outcomes to be difficult to achieve. (Syahrul, 2015; Suparno, 2013; Pratiwi,



2015). Misconceptions are ideas or beliefs that do not correspond to students' scientific understanding, and misconceptions are expressed as inaccuracies and improper links between students' concepts and experts' concepts (Suparno, 2013). Misconceptions experienced by students can hinder the process of acquiring new knowledge and allow them to continue making mistakes in their learning process (Eviyani, 2017). If misconceptions persist, this can impact student learning outcomes and allow them to carry these wrong conceptions when they continue their studies to a

higher level (Olaoluwa & Olufunke, 2015; Alias & Ibrahim, 2016).

In physics learning, misconceptions occur on various discussion topics (Gurel et al., 2015). According to the findings in a study conducted by Hrepic, et al. (2010) and Elfani (2013), sound waves are one of the physics learning materials in which students still experience misconceptions. For instance, previous research found misconceptions about topic sound waves experienced by students, as demonstrated in Figure 1 (Nofriati et al., 2016; Widiastuti et al. 2019; Setyarini et al. 2021).

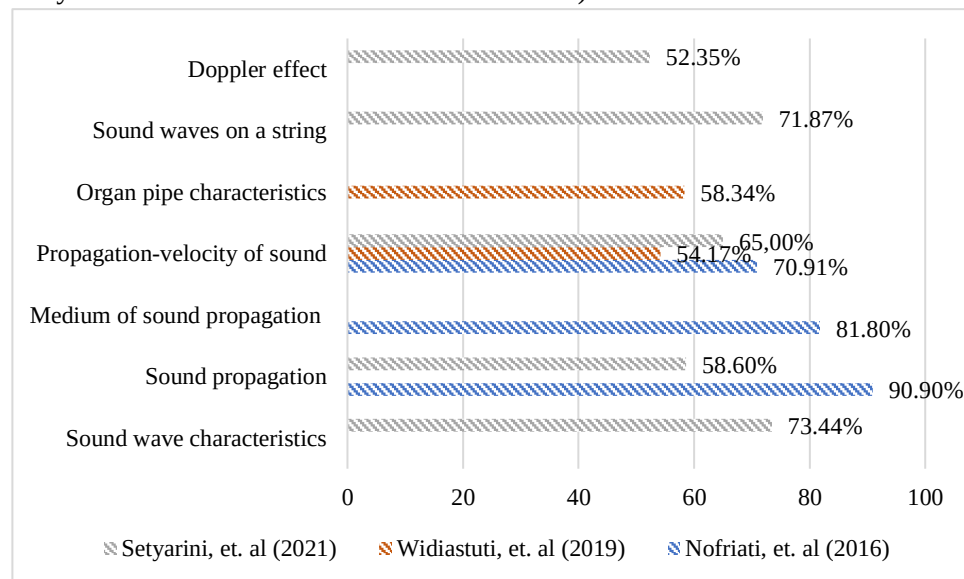


Figure 1 Percentage of misconceptions in sound waves

Figure 1 shows that the concepts of sound propagation and medium of sound propagation have the mean percentage of the highest misconceptions, compared to the Doppler effect, resulting in the lowest mean percentage of misconceptions. When this occurs, student misconceptions should not be dismissed because, according to Suparno (2013) and Lassonde et al. (2016), student misconceptions can persist for a long time, are resistant to change, are universal, and impede further learning. In addition, misconceptions tend to be stable and not easily transformed into more scientific concepts, making them resistant to change. This resistance is generated by students' belief in their initial concepts for understanding a

problem or phenomenon, and they do not easily adopt new ways of thinking (Dahar, 2006; Suparno, 2013). Based on this, it is crucial to identify student conceptions so that teachers can appropriately treat students in learning to reduce misconceptions.

Identification of students' conceptions can be done using a diagnostic test instrument. The diagnostic test is an evaluation tool based on student learning problems or unresolved problems in the learning process (Gurel et al., 2015). Teachers can use diagnostic tests to find out students' initial conceptions and students' difficulties in learning so that appropriate learning methods can be selected to overcome these difficulties (Ayar et al., 2015; Gurel et al., 2015;

Kaltaçki & Didiş, 2007). This study developed a diagnostic instrument called the Sound Wave Four Tier Diagnostic Test (SOFT) to identify students' conceptions of sound waves. The instrument in this study was evaluated for feasibility before it was distributed. The construct validity of the SOFT instrument was assessed using Rasch modeling.

METHOD

This research was conducted using the 4D model developed by Thiagarajan et al. (1974). The 4D model has four stages: define, design, develop, and disseminate, to identify conceptions about sound waves. The SOFT instruments in this study were evaluated for eligibility before being disseminated. The

construction validity of the SOFT instrument was assessed using Rasch modeling. These analyses involve testing student parameters (Boone & Neltemeyer, 2017; Chan et al., 2014; Makransky et al., 2015; Othman et al., 2014; Rasch, 1960; Suryana et al., 2020). Here, the Findings from this study can be used to identify students' conceptual profiles of sound waves (Boone & Neltemeyer, 2017; Suryana et al., 2020). The result of this study can be used to identify students' conceptual profiles about sound waves. The method used in this research is the 4D model developed by Thiagarajan et al (1974). There are four stages of the 4D model: define, design, develop, and disseminate. The development stage of the worksheet using the 4D model is shown in Figure 2.

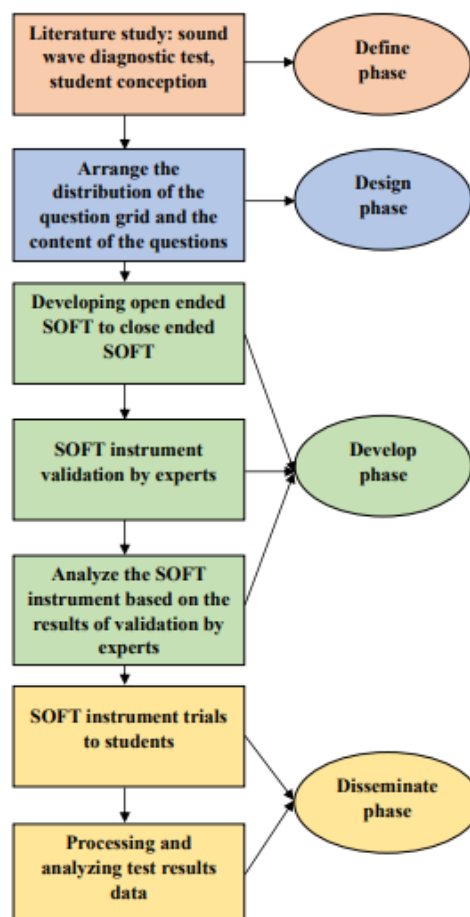


Figure 2 SOFT preparation stage with 4D models

Participants

This research involved 42 students of class XI MIPA at a senior high school in Bandung, West Java. Participants in this study included 13 male students and 29 female students ranging in age from 15 to 17 years. Participants were taken from one of the classes that had not studied sound waves. The location of the school where the research was conducted is shown in Figure 3.



Figure 3 Map of the school

Instruments

The SOFT instrument consists of 12 questions covering the concepts of sound wave characteristics, sound wave

velocity, organ pipe characteristics, string vibration, and the Doppler effect concept. The SOFT instrument consists of four levels. The first consists of multiple-choice questions, the second contains the first level of belief, the third consists of the first level of reasoning, and the fourth consists of the third level of belief.

Data Analysis

The SOFT instrument was used to identify students' conception profiles based on their conception categories. There are seven categories of conceptions developed by Kaltacki-Gurel et al. (2017), Aminudin et al. (2019), and Samsudin et al. (2020), as shown in Table 1. In addition to the conception categories, there is a conception score for each category which was adapted from research conducted by Samsudin et al. (2016), Amalia et al. (2019), and Aminudin et al. (2019).

Conception Category	Symbol	Tier-1	Tier-2	Tier-3	Tier-4	Score
Sound Understanding (SU)		C	S	C	S	5
Partial Positive (PP)		C	S	C	NS	4
		C	NS	C	S	
		C	NS	C	NS	
Partial Netral (PNt)		C	S	IC	S	3
		C	S	IC	NS	
		C	NS	IC	S	
Partial Negative (PNg)		C	NS	IC	NS	2
		IC	S	C	S	
		IC	S	C	NS	
		IC	NS	C	S	
Misconception (MC)		IC	NS	C	NS	1
		IC	S	IC	S	
No Understanding (NU)		IC	S	IC	NS	0
		IC	NS	IC	NS	
No Coding (NC)		If the tier is empty				-

Description: C (Correct), IC (Incorrect), S (Sure), NS (Not Sure)

Figure 4 Categories, symbols, and conception scores

Based on Figure 4, the Sound Understanding (SU) category is given to students who fully understand the concept, the Partial Positive (PP) category is given to students who understand some concepts because they have doubts in choosing answers, the

category is given to students who understand some concepts for choosing the correct answer but choose the wrong reason; the Partial Negative (PNg) category is given to students who understand some of the concepts for choosing the wrong answer but choosing the right reason. Whereas the Misconception (MC) category is

given to students who are sure of the wrong answers and reasons, No Understanding (NU) is given to students who choose the wrong answers. Reasons without being sure, and No Coding (NC) is given to students who give multiple answers or do not provide an answer at a certain tier.

Student responses to the SOFT instrument were categorized and scored. The students' responses were compared based on the seven levels of conception provided in Figure 4. Subsequently, students' responses were used for further analysis with Rasch modeling using

MINISTEP 5.4.3.0. These results are based on the dimensionality of items, Cronbach's alpha, object reliability, and personal reliability. Wherein an instrument is valid if 1) the raw variance predicted by the measure is more than 20%, and 2) an unexplained variance at first contrast for Eigenvalues of less than three and observable values less than 15 (Fisher, 2007; Sumintono & Widhiarso, 2015; Adams et al., 2018). An interpretation of the item and person reliability values and Cronbach's alpha is shown in Table 1.

Table 1 Interpretation of item and person reliability and Cronbach's alpha

Summary statistic	Index value	Interpretation
Item and person reliability	$r > 0.94$	Special
	$0.90 < r \leq 0.94$	Very good
	$0.80 < r \leq 0.90$	Good
	$0.67 < r \leq 0.80$	Moderate
	$r \leq 0.67$	Low
Cronbach's alpha (KR-20)	$KR-20 \geq 0.80$	Very high
	$0.70 \leq KR-20 < 0.80$	High
	$0.60 \leq KR-20 < 0.70$	Good
	$0.50 \leq KR-20 < 0.60$	Moderate
	$KR-20 < 0.50$	Low

(Sumintono & Widhiarso, 2015)

RESULTS AND DISCUSSION

The results of the research and discussion include the stages of instrument development using the 4D model and the identification results of students' conception profiles based on student responses to the SOFT instrument.

Define phase

In this stage, a literature review is required to determine the diagnostic test instruments previously used in sound wave research. The researcher also conducted a literature study to determine the misconception indicators for preparing the SOFT instrument.

Design Phase

In the second phase, a grid distribution of questions is made. The distribution of the problem grid consists of the distribution of misconceptions, scientific conceptions, and problem construction. Misconception indicators are made based on the results of a literature study that has

been conducted. Then, arrange the content of the questions according to the distribution of the grid that has been made.

Develop Phase

An open-ended Sound Wave Four Tier Diagnostic Test (SOFT) was developed at the development stage to become a close-ended SOFT, as shown in Figure 5. This development was made based on adapting students' reasoning responses in the third tier. Expert validation by three lecturers and two physics teachers was also carried out at this stage.

Disseminate phase

At this dissemination phase, the SOFT instruments are developed and declared fit for use for field trials by the validator, and they are distributed and tested on students. Data obtained from student responses were analyzed to obtain profiles of students' conceptions of sound waves and further analyzed using

MINISTEP 5.4.3.0. The validity and reliability results of the items are explained in Figure 6.

SOFT Open-ended	SOFT Close-ended
1.1 Andi conducted an experiment by placing a sounding alarm into a glass tube as shown in Figure 1.  Figure 1. The experiment placed an alarm on a glass tube At first Andi placed the alarm in a glass tube which was tightly closed. When the glass tube is tightly closed, an alarm sounds loudly. Then the air in the glass tube was completely pumped out by Andi. How does the alarm sound after the air in the glass tube is completely pumped? A. The sound of the alarm remains as before. B. The sound of the alarm is getting louder. C. The sound of the alarm is getting weaker. D. The sound of the alarm sounds loud for a moment then weakens. E. The sound of the alarm is not heard at all. 1.2 Are you sure about the answer to question 1.1? A. Sure B. Not sure 1.3 Reasons for answering question 1.1: 1.4 Are you sure about the answer to question 1.3? A. Sure B. Not sure	1.1 Andi conducted an experiment by placing a sounding alarm into a glass tube as shown in Figure 1.  Figure 1. The experiment placed an alarm on a glass tube At first Andi placed the alarm in a glass tube which was tightly closed. When the glass tube is tightly closed, an alarm sounds loudly. Then the air in the glass tube was completely pumped out by Andi. How does the alarm sound after the air in the glass tube is completely pumped? A. The sound of the alarm remains as before. B. The sound of the alarm is getting louder. C. The sound of the alarm is getting weaker. D. The sound of the alarm sounds loud for a moment then weakens. E. The sound of the alarm is not heard at all. 1.2 Are you sure about the answer to question 1.1? A. Sure B. Not sure 1.3 Reasons for answering question 1.1: A. The glass tube blocks the sound from escaping so the sound of the alarm sounds progressively weaker. B. Sound cannot travel in a vacuum, so the alarm sound is not heard at all. C. Sound can penetrate the glass tube so that the sound of the alarm can be heard louder. D. Air does not affect the propagation of sound so that the sound of the alarm still sounds as before. E. The absence of air makes sound travel faster so that the frequency of the sound increases beyond the limits of human hearing and causes the alarm sound to become inaudible. 1.4 Are you sure about the answer to question 1.3? A. Sure B. Not sure

Figure 5 SOFT instrument development

Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = Item information units			
	Eigenvalue	Observed	Expected
Total raw variance in observations =	18.5994	100.0%	100.0%
Raw variance explained by measures =	6.5994	35.5%	34.4%
Raw variance explained by persons =	4.1058	22.1%	21.4%
Raw Variance explained by items =	2.4936	13.4%	13.0%
Raw unexplained variance (total) =	12.0000	64.5%	65.6%
Unexpln variance in 1st contrast =	2.2458	12.1%	18.7%
Unexpln variance in 2nd contrast =	2.0568	11.1%	17.1%
Unexpln variance in 3rd contrast =	1.7580	9.5%	14.6%
Unexpln variance in 4th contrast =	1.3737	7.4%	11.4%
Unexpln variance in 5th contrast =	1.0635	5.7%	8.9%

Figure 6 SOFT instrument validity results

Figure 6 illustrates states that the variance explained by the raw measuring instrument is 35,50%. Sumintono & Widhiarso (2015) state that if the variance explained by the measuring instrument is more than 20%. The instrument can measure one variable without being influenced by other variables. In the case of variance, which cannot be explained, an eigenvalue of the first contrast is 2,24 (less than 3), and the observed value is 12,1% (less than 15%). The instruments were, therefore, declared valid. The corresponding

Cronbach's alpha coefficient, item reliability, and person reliability are shown in Figure 7.

SUMMARY OF 42 MEASURED Person									
	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	
MEAN	20.6	12.0	-.29	.25	1.09	.01	1.08	.02	
SEM	1.3	.0	.07	.01	.10	.18	.11	.18	
P.SD	8.3	.0	.46	.05	.67	1.15	.70	1.17	
S.SD	8.4	.0	.46	.05	.67	1.17	.71	1.18	
MAX.	45.0	12.0	.78	.42	3.15	2.55	3.05	2.52	
MIN.	7.0	12.0	-1.45	.19	.27	-1.90	.23	-1.94	
REAL RMSE	.31	TRUE SD	.34	SEPARATION	1.11	Person RELIABILITY		.55	
MODEL RMSE	.25	TRUE SD	.38	SEPARATION	1.50	Person RELIABILITY		.69	
S.E. of Person MEAN = .07									
Person RAW SCORE-TO-MEASURE CORRELATION = .96									
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .71 SEM = 4.46									
STANDARDIZED (50 ITEM) RELIABILITY = .90									
SUMMARY OF 12 MEASURED Item									
	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	
MEAN	72.0	42.0	.00	.13	.97	-.12	1.08	.29	
SEM	6.6	.0	.09	.00	.08	.35	.10	.35	
P.SD	21.7	.0	.31	.01	.27	1.15	.33	1.15	
S.SD	22.7	.0	.32	.01	.28	1.20	.34	1.21	
MAX.	128.0	42.0	.32	.15	1.51	2.19	1.81	2.42	
MIN.	52.0	42.0	-.74	.11	.58	-1.73	.62	-1.40	
REAL RMSE	.14	TRUE SD	.28	SEPARATION	2.06	Item RELIABILITY		.81	
MODEL RMSE	.13	TRUE SD	.28	SEPARATION	2.18	Item RELIABILITY		.83	
S.E. of Item MEAN = .09									

Figure 7 Results from Cronbach's alpha, item reliability, and person reliability of the SOFT instrument

Based on Figure 7, it can be seen that person reliability is 0,55 with a "low" interpretation. According to Sumintono & Widhiarso (2015), low interpretation results may indicate that there may not be many samples and items because obtaining a high personal reliability coefficient requires a sample with a large range of abilities and/or an

instrument with a large number of items. As for the item reliability value of 0,81 with the interpretation of "good". The results of this interpretation indicate that the SOFT instrument is stated to be consistent in the weight of the questions and the choice of answers. Then, for the Cronbach's alpha (KR-20) value of 0,71 with the interpretation of "high". This

shows that the SOFT instrument has good quality because it can identify the relationship between students (person reliability) and item items (item reliability). Based on the results of this analysis, it can be concluded that the Sound Wave Four Tier Diagnostic Test (SOFT) instrument is reliable for diagnostic testing.

Identification of Student Conception Profiles

Conception profiles of students based on diagnostic tests that have been carried out using the SOFT instrument are processed into percentages for each conception category, as shown in Figure 8.

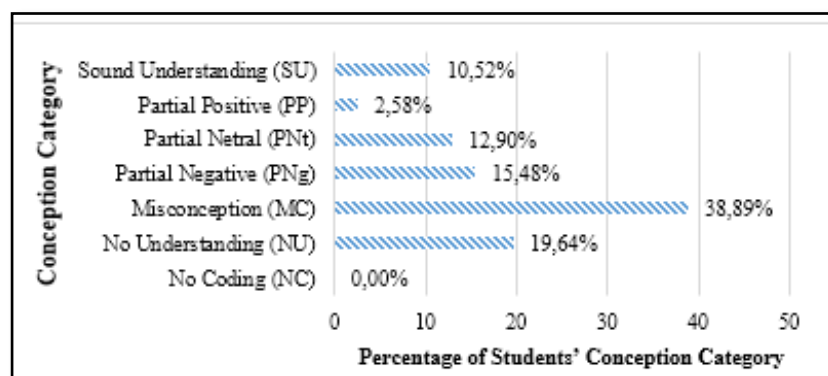


Figure 8 Student Conception Profile

Figure 8 provides information on students' conception profiles for each conception category. The Sound Understanding (SU) category obtained a percentage of 10,52%. This category shows that students understand the concept completely. This category is given to students if they feel confident answering questions and correctly giving reasons. Partial Positive (PP) category is 2,58%. This category shows students answered questions and gave reasons correctly at Tier 1 and Tier 3 but had doubts and lacked confidence in one of the tiers, Tier 2 or Tier 4. Partial Neutral (PNt) was 12,90%, which shows that students understand some of the concepts with the criteria that students can answer questions correctly at tier 1 and answer

questions incorrectly at tier 3 and feel unsure about the options for tier 2 and tier 4.

Meanwhile, the Partial Negative (PNg) category shows a percentage of 15,48%. This shows that students who understand some of the concepts with the criteria that students can answer questions correctly in tier 3, but answer incorrectly in tier 1. They also feel unsure about the choice of tier 2 and tier 4. The misconception (MC) category, with a percentage of 38,89%, shows that students are confident in the wrong answers and reasons. So, the conceptions that students have are not following scientific conceptions. For the No Understanding (NU) category, 19,64% was given to students who did not

understand the concept of sound waves. Students answer questions incorrectly and give reasons without being sure to indicate this lack of understanding. The last category, namely No Coding (NC) of 0%, indicates that no students gave multiple answers or did not provide answers from the answer tier, reasons, or level of confidence.

The highest percentage was obtained for the Misconception (MC) category of 38,89%, which indicated that some students still had misconceptions about sound waves. The findings of misconceptions about sound waves are provided in Table 2.

Table 2 Findings of misconceptions about sound waves

Concept	Misconception
Characteristics of sound waves	Sound can travel in a vacuum. During its propagation, sound can push or move other objects. Sound is a particle that moves transversely.
Propagation velocity of sound waves	Sound does not require a medium for its propagation, and a medium composed of loose particles will facilitate the movement of sound when it passes through this medium. The speed of sound is always constant for every situation. Sound will be heard faster when the position of the sound source is right in front of the listener compared to when the position of the sound source is facing away from the listener, even though the distance between the listener and the sound source is the same.
Characteristics of organ pipe	The fundamental note on an open organ pipe has one wavelength (λ). The frequency on closed and open organ pipes is the same, or the frequency on closed organ pipes is greater than on open organ pipes.
String vibration	The longer the strings or strings on an acoustic musical instrument, the higher the sound pitch produced. The basic note on a plucked guitar string has one wavelength (λ).
Doppler effect	The frequency that the listener will receive is the same as long as the distance from the listener to the sound source changes, regardless of the relative motion of the listener or the sound source.

Table 2 shows that misconceptions about sound waves still occur in sound wave characteristics, sound wave velocity, organ pipe characteristics, string vibration, and the Doppler effect. Tumanggor et al. (2020) state that misconceptions that persist in students are generated by students who are less focused when studying and learning, which does not place them in a position of cognitive conflict for an extended period. Setiawan & Jaelani (2021) also state that misconceptions persist because students associate these concepts with

everyday situations based on their own experiences.

The results of this research and discussion suggest that teachers can use the Sound Wave Four Tier (SOFT) Diagnostic Test to identify students' conceptions of sound waves before and after learning activities. Furthermore, teachers can also carry out learning and provide treatment for students who still experience misconceptions. Tanggira et al. (2022) stated that it is very important in the learning process if the teacher actively asks questions to students

regarding the ideas and concepts they understand.

During teaching, the teachers must provide opportunities for each student to share their understanding of the studied physics material. The lesson activities can use strategies, approaches, or learning models in which there are cognitive conflict activities and the development of teaching materials such as the student worksheet and teaching materials that contain the text of concept change. It can also be conducted in different areas with a larger sample.

CONCLUSION

The conclusion of the research indicated the validity and reliability of the Sound Wave Four Tier (SOFT) Diagnostic Test using the 4D model. The analysis of Rasch modeling showed that the SOFT instrument is valid and reliable with a reliability of person value of 0.55 in the "low" category, reliability of an item of 0.81 in the "good" category, and Cronbach's alpha (KR-20) value of 0.71 with "high" category. SOFT instruments are used to identify students' abilities and conception profiles, and the findings revealed that students still had misconceptions about sound waves.

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