KnE Social Sciences
ICMScE
International Conference On Mathematics And Science Education
Volume 2024

Research Article

Developing Multitier Open-ended Transverse Wave Instrument (MOTWI): How to Assess Students' Misconceptions?

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Published: 26 April 2024

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICMScE Conference Committee.

Abstract.

At school, students have studied the characteristics of waves and the relationship between period, frequency, wavelength, and the speed of propagation of transverse waves. However, students often experience misconceptions based on intuitive thinking and the phenomena they encountered. Thus, the research aims to describe the instrument validation of developing a multitier open-ended transverse wave instrument (MOTWI), which is useful in deeply assessing the misconceptions of high school students. The 4D (defining, designing, developing, and disseminating) model has been utilized as the method for developing the instrument. The participants were 67 high school students aged between 16 and 18 years (21 males namely “Mas” and 46 females namely “Mba”). The validity and reliability of MOTWI were analyzed using Rasch Model with MINISTEP 4.7.0.0 software. MOTWI validity from item dimensionality was valid. Cronbach Alpha (α) value was 0.75 (good category), and item reliability was a very good category. The construct validation results of MOTWI were valid and reliable for seven items. The students’ conceptions and misconceptions were analyzed with Wright maps. The conceptions of students were categorized as sound understanding (SU), partial understanding positive (PUP), partial understanding negative (PUN), no understanding (NU), misconception (MC), and no oding (NC). The misconceptions were mostly found in the characteristics and the factors that affect the speed of propagation of transverse waves. In conclusion, developing MOTWI can be used to assess and identify conceptions and misconceptions of students.

Keywords: Multitier Open-ended Transverse Wave Instrument, students’ misconceptions

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1. INTRODUCTION

Concepts are the basic things that must be owned by students [1–3]. In school students have obtained material related to transverse waves. However, often students find conceptions based on intuitive thoughts and phenomena they see. Many of these conceptions are incompatible with scientific conceptions. This is called misconception, alternative conception, misunderstanding, etc [4].

In some physics topics, students have experienced misconceptions [4]. One of them is transverse waves, for example, the concept of a relationship between magnitude in transverse waves [5–8]. Students who have misconceptions about wave material will have an impact on the acceptance of new related concepts [9]. One of the causes of students having difficulty or not understanding the relationship between wave propagation, frequency, wavelength, period, and amplitude [6–8, 10, 11]. Such as the demonstration event in Figure 1, when the tension force of the rope and the mass per unit length of the rope are constant, if the frequency is changed more, the faster the wave propagation of the rope will be.

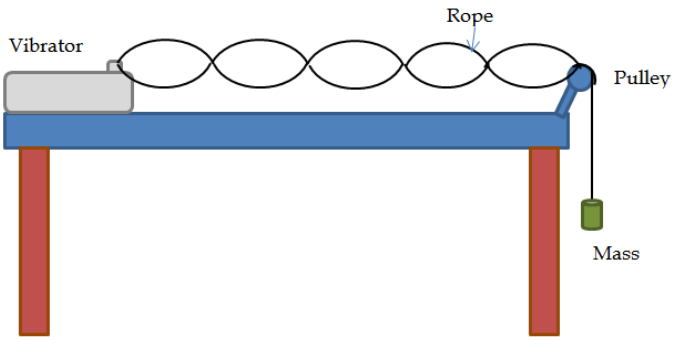


Figure 1: Rope wave experiment.

Even many students are trapped because of the following mathematical equations (1).

$$v = l.f \tag{1}$$

Based on that, in learning, assessment is needed, especially regarding the development of transverse wave diagnostic test instruments. Diagnostic tests can be in the form of two-tier, three-tier, and four-tier. The four-tier diagnostic test is a development of the lack of two-tier and three-tier forms [12]. In the four-tier test, the level of confidence at tiers two and fourth is added. The level of confidence makes it perfect to diagnose students' misconceptions [4]. Several studies have developed diagnostic tests in the

form of two-tier, three-tier, and four-tier on the topic of waves [5–8, 10, 11, 13–15]. However, multiple-choice tests have several disadvantages because they do not provide an explanation of students' ideas on the topic under investigation [13, 16]. On the other hand for this research needs, a diagnostic test is needed that can assess students' conceptions and misconceptions more deeply. So, in this research to find out the depth of the concept that students have, it is used an open-ended test too. Several studies developed multi-tier open-ended diagnostic instruments, such as MOWEI [16], MOLWI [13], MOMI [17]. However, the topic of transverse waves has not yet been developed. Therefore, the diagnostic test instrument has been developed, which is called Multitier Open-Ended Transverse Wave Instrument (MOTWI). At the first tier, it is a multiple-choice test with questions. While at the third tier it is an open-ended test, which is the reasons answered by students. At the second and fourth tiers is the student's level of confidence. Thus, the research aims to describe the instrument validation of developing MOTWI which is useful in assessing misconceptions of high school students.

2. RESEARCH METHOD

The 4D (Defining, Designing, Developing, and Disseminating) model is used as the method in this research. At the defining stage, namely conducting literature studies, field studies, and determining the topic content of the concept of transverse waves. At the designing stage, designing a form of diagnostic test will be used in MOTWI. The form of the diagnostic instrument is multitier open-ended. Then at the developing stage, namely developing questions in seven questions. In the final stage, implementing it in schools to assess students' conceptions and misconceptions, as well as obtain data on the validity and reliability of instruments.

The sample consists of 67 high school students aged 16-18 years (21 males namely "Mas" and 46 females namely "Mba") in Tuban, East Java, Indonesia. All samples that have received transverse wave topics are selected by cluster random sampling. Tuban Regency is located on the north coast of Java, where students encounter many wave phenomena. The map of Tuban regency is shown in Figure 2.

The instrument used Multitier Open-Ended Transverse Wave Instrument (MOTWI), which consisted of 7 items. MOTWI consists of the topic of transverse waves, namely the characteristics of transverse waves and the relationships of magnitudes transverse waves, such as amplitude, wavelength, wave propagation, frequency, and period. MOTWI and the assessment of misconceptions were analyzed using Rasch Model with MINISTEP 4.7.0.0 software based on Wright map, validity from item dimensionality,

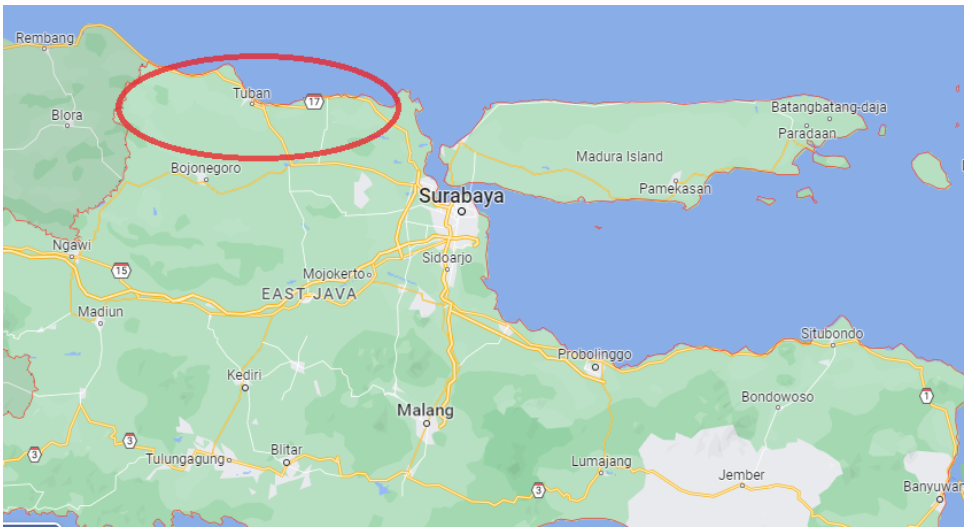


Figure 2: Map of Tuban regency, East Java, Indonesia (souce:https://www.google.com/maps/place/East+Java).

Cronbach alpha, and item reliability. The students' conceptions and the scores are adapted from Aminudin [13], which are shown in Table 1.

TABLE 1: Categories of students' conceptions.

Tier	Categories of Students' Conception																
	SU	PUP			PUN								NU			MC	NC
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 (Option)	C	C	C	C	C	C	C	C	IC	IC	IC	IC	IC	IC	IC	IC	IA
2 (Level Confidence)	S	S	NS	NS	S	S	NS	NS	S	S	NS	NS	S	NS	NS	S	
3 (Reason)	C	C	C	C	IC	IC	IC	IC	C	C	C	C	IC	IC	IC	IC	
4 (Level Confidence)	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	NS	S	NS	S	

Note: Sound Understanding (SU), Partial Understanding Positive (PUP), Partial Understanding Negative (PUN), No Understanding (NC), Misconception (MC), and No Coding (NC). Correct (C), Incorret (IC), Sure (S), Not Sure (NS), and Incomplete Answer (IA)

The scores of students' conceptions and misconceptions can be presented in Table 2.

3. RESULTS AND DISCUSSION

Based on the data, the development diagnostic test of a Multitier Open-Ended Transverse Wave Instrument (MOTWI) was analyzed using the 4D (Defining, Designing, Developing, and Disseminating) model. The results of the development are described as follows.

Table 2: Conception and misconception score.

Category	Score	
	Conception	Misconception
Sound Understanding (SU)	4	0
Partial Understanding Positive (PUP)	3	0
Partial Understanding Negative (PUN)	1	1
No Understanding (NC)	0	3
Misconception (MC)	0	4
No Coding (NC)	(empty)	(empty)

3.1. Defining

At this stage conducts a literature study of the student's conception of transverse waves. This literature study is adjusted to the topics that students have received in school. Determination of topics wave content is in the form of magnitud relationships in transverse waves, such as amplitude, wavelength, wave propagation, frequency, and period. Based on the identification of some literature, many students have not understood the concept as a [6–8, 10, 11]. Students are still complacent with mathematical equations [10]. Students do not understand wave charts and there are still many students who have difficulty reading charts [6, 10]. There are still many students who experience misconceptions or express alternative conceptions based on intuition or natural events in everyday life [18].

3.2. Designing

After conducting a literature review and field studies, this stage designs the form of diagnostic test instruments. The development of diagnostic tests is useful for assessing students' concepts and misconceptions about transverse wave topics. MOTWI design flow is shown in Figure 3. The first tier is a multiple-choice test and the third tier is an open-ended test. The open-ended test is designed to know deeper students' conceptions through the explanations of conceptions they provide. So that at the third tier, students are asked to write their ideas. The second and fourth-tier questions are a form of confidence level in the form of "sure" or "not sure". Therefore, this diagnostic instrument is called Multitier Open-Ended Transverse Wave Instrument (MOTWI).

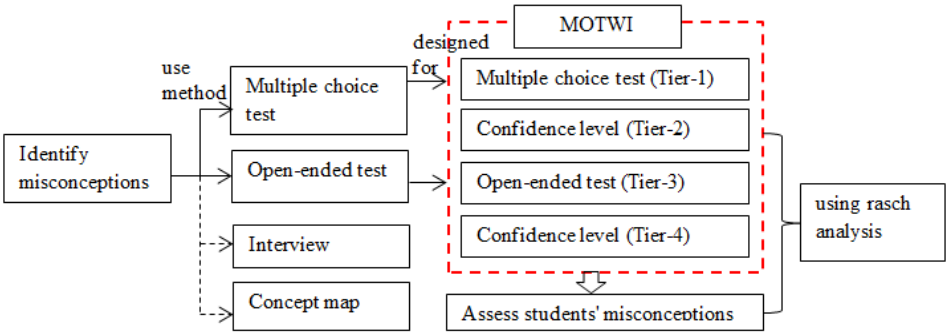


Figure 3: MOTWI design .

3.3. Developing

The form of the MOTWI development is shown in Figure 4. The total number of MOTWI is 7 items. The example question in Figure 4 is an adaptation of Caleon's instrument [15]. Meanwhile, the novelty of this research is to develop instruments in the first tier, namely by comparing the representation of two graphs and the answer in the form of a mathematical symbol representation. In the first tier, graphical representations and mathematical symbols are presented. Students determine the wave magnitude in the form of mathematical symbols, not statements. Then at the third tier, students write down the reasons according to the answers chosen.

1.1 Figures 1(a) and 1(b) show wave graphs.

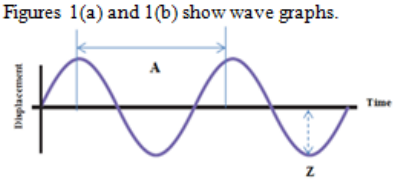


Figure 1(a) The graph of the relationship of displacement and time.

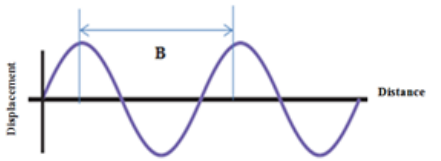


Figure 1(b) The graph of the relationship of displacement and distance.

The signs A, Z, and B in Figures 2(a) and 2(b) indicate...

	A	Z	B
A.	T	f	λ
B.	λ	A	λ
C.	λ	A	T
D.	v	λ	T
E.	T	A	λ

1.2 Are you sure of the answer to question 1.1?
A. Sure
B. Not sure
1.3 The reason for answering the question 1.1:
.....
.....
1.4 Are you sure of the answer to question 1.3? (Tier 4)
A. Sure
B. Not sure

Figure 4: The example of MOTWI in representation graph and mathematic symbol.

3.4. Disseminating

In the last stage, MOTWI diagnostic test was implemented for students to assess students' conceptions and misconceptions about the transverse wave topic. Students' conceptions can be categorized based on Table 1, namely Sound Understanding (SU), Partial Understanding Positive (PUP), Partial Understanding Negative (PUN), No Understanding (NU), Misconception (MC), and No Coding (NC) [13]. In addition, information about validity, Cronbach Alpha, and item reliability can be obtained from MOTWI. The analysis in assessing the conception and determining the validity and reliability of the items used the Rasch model with the MINISTEP 4.7.0.0 software. The results of students' conceptions, validity, Cronbach alpha, and item reliability are explained as follows.

3.4.1. The Result of Validity, Cronbach Alpha, and Item Reliability MOTWI

Before assessing students' conceptions and misconceptions, MOTWI was analyzed using Rasch Model with MINISTEP 4.7.0.0 software to determine validity from item dimensionality, Cronbach Alpha, and item reliability. The validity results of MOTWI are shown in Figure 5.

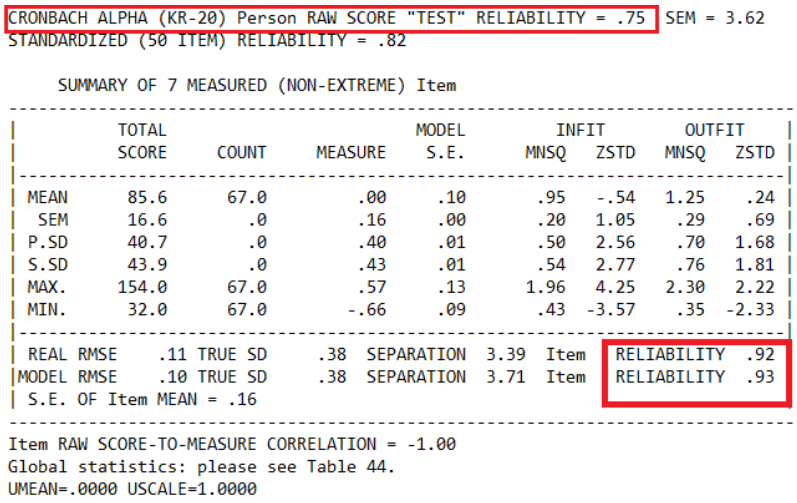
```
INPUT: 67 Person  7 Item  REPORTED: 67 Person  7 Item  5 CATS   MINISTEP 4.7.0.0
-------------------------------------------------------------------------------

    Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = Item information units
                                      Eigenvalue   Observed   Expected
Total raw variance in observations  =    15.0049 100.0%        100.0%
  Raw variance explained by measures =     8.0049  53.3%         50.0%
    Raw variance explained by persons =    1.9276  12.8%         12.0%
    Raw Variance explained by items   =    6.0774  40.5%         38.0%
  Raw unexplained variance (total)    =    7.0000  46.7% 100.0%   50.0%
    Unexplned variance in 1st contrast =    2.1373  14.2%  30.5%
    Unexplned variance in 2nd contrast =    1.7846  11.9%  25.5%
    Unexplned variance in 3rd contrast =    1.0468   7.0%  15.0%
    Unexplned variance in 4th contrast =     .8537   5.7%  12.2%
    Unexplned variance in 5th contrast =     .6873   4.6%   9.8%
```

Figure 5: Validity result of MOTWI.

In Figure 5, the value of the raw variance explained by measures is 53.3%. The index value is more than the minimum validity limit, which is more than 20%. So MOTWI is an appropriate or valid instrument. MOTWI reliability results in terms of Cronbach Alpha and Item Reliability are shown in Figure 6.

The Cronbach Alpha value shows the relationship between item reliability and person reliability. In Figure 6, the Cronbach Alpha (α) value of MOTWI is 0.75. Based on these



```
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .75 SEM = 3.62
STANDARDIZED (50 ITEM) RELIABILITY = .82

     SUMMARY OF 7 MEASURED (NON-EXTREME) Item
-------------------------------------------------------------------------------
|          TOTAL                        MODEL         INFIT        OUTFIT     |
|          SCORE     COUNT     MEASURE    S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      85.6      67.0         .00     .10       .95   -.54   1.25    .24 |
|  SEM      16.6        .0         .16     .00       .20   1.05    .29    .69 |
| P.SD      40.7        .0         .40     .01       .50   2.56    .70   1.68 |
| S.SD      43.9        .0         .43     .01       .54   2.77    .76   1.81 |
| MAX.     154.0      67.0         .57     .13      1.96   4.25   2.30   2.22 |
| MIN.      32.0      67.0        -.66     .09       .43  -3.57    .35  -2.33 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .11 TRUE SD     .38  SEPARATION  3.39  Item   RELIABILITY  .92 |
|MODEL RMSE    .10 TRUE SD     .38  SEPARATION  3.71  Item   RELIABILITY  .93 |
| S.E. OF Item MEAN = .16                                                     |
-------------------------------------------------------------------------------
Item RAW SCORE-TO-MEASURE CORRELATION = -1.00
Global statistics: please see Table 44.
UMEAN=.0000 USCALE=1.0000
```

Figure 6: Reliability result of MOTWI.

results, it can be interpreted that MOTWI is an instrument with a “good” category. In addition, the value of item reliability is 0.92 and 0.93, which MOTWI is a “very good” instrument. So, it can be said that MOTWI is a stable instrument. Based on the analysis using the Rasch Model, it can be said that the development of MOTWI is a valid and reliable diagnostic test for all items.

3.4.2. The Result of Assessing Students' Conception and Misconception

Assessing students’ conceptions and misconceptions used Wright maps in Figure 7 and Figure 8. Based on Figure 8 and Figure ??, Q3 questions are the highest level of difficulty, meaning that very few students can answer the questions. The more difficult the questions, the fewer students can answer. Question Q7 is the easiest question, meaning that many students can answer the question. While the questions Q2 and Q6 have a level of difficulty that is not much different. Students’ conceptions can be seen from the variable (Wright) Maps in Figure 7, while students’ misconceptions can be seen from the variable (Wright) Maps in Figure 8.

Based on Figure 7, the students who have the potential to have good concepts are students 15P, 48P, 49P, 52P, and 65P (Mba/female student), because they can almost answer all easy, medium, and difficult questions. This is following Wright maps in Figure 8, the five students have the lowest potential for experiencing misconceptions. Students 1 Mba/female (04P) and 5 Mas/male students (07L, 08P, 39L, 47L, 63L) have low concepts, because they cannot answer all questions. However, the 5 students were not said to have experienced misconceptions, because the six students were categorized in No Coding (NC). Meanwhile, 2 Mas (20L and 23L) and 6 Mba (21P, 22P, 24L, 25P, 26P,

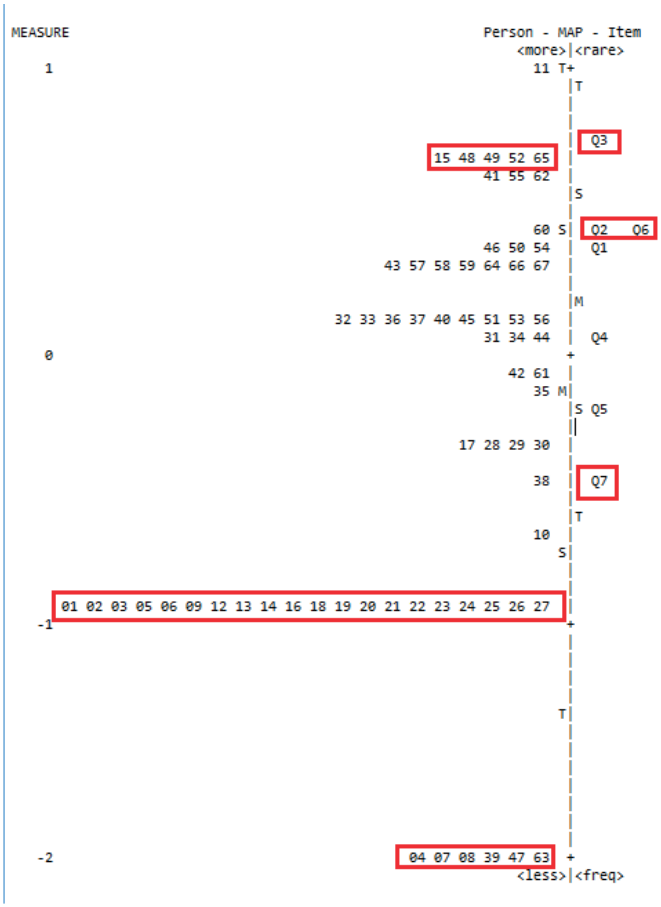


Figure 7: Score conceptions based on Wright maps.

and 27P) can be categorized as having low concept potential. In Figure 8, 4 Mas (19L, 20L, 23L, 24L) and 14 Mba (01P, 02P, 09P, 12P, 13P, 14P, 16P, 18P, 21P, 22P, 25P, 26P, 27P) have the highest potential for misconceptions. Based on this, students who have low concepts and experience the highest misconceptions are 8 students, namely 2 Mas (20L and 23L) and 6 Mba (21P, 22P, 24L, 25P, 26P, 27P).

The most common misconceptions are in question Q3, that is, if the deviation of the rope is changed to a greater extent, then the wavelength, frequency, period, and wave propagation will be larger. Though the deviation only affects the amplitude. In addition, many students experience misconceptions on question Q2. Students assume that the graph of the relationship of deviation with time is a wavelength, but it is a period. Question Q6 also diagnoses many misconceptions. Students think that if the frequency is changed but the nature of the string is constant, the speed of the wave will change as well. Whereas the speed of wave propagation depends on the nature of the rope (string tension force and mass per unit length of the rope). Misconceptions are caused by several factors, such as strategies, learning models and instructions given by teachers, book texts, language in books, learning media, and even the circumstances

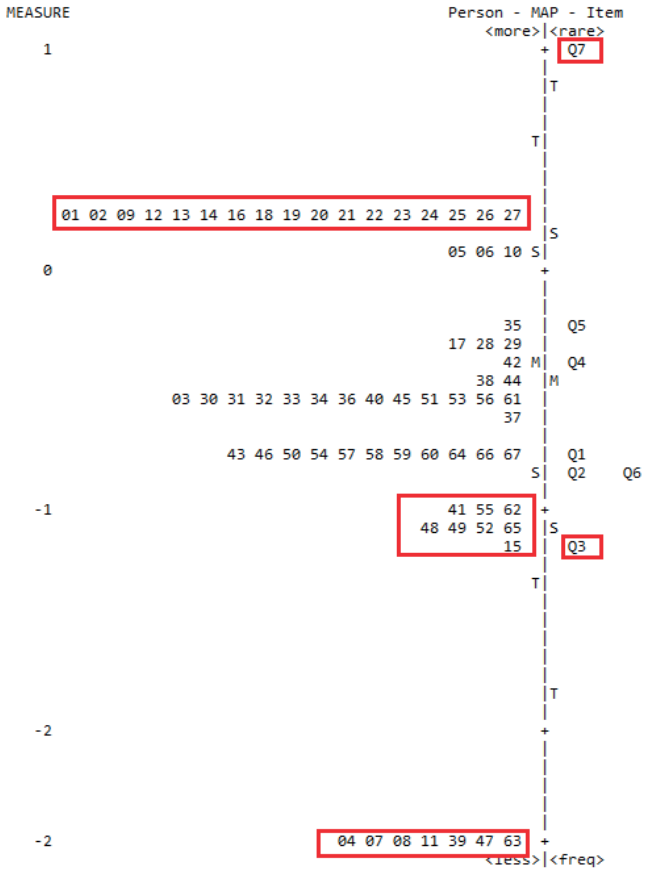


Figure 8: Score misconceptions based on Wright maps.

of the students themselves [18, 19]. In addition, students have difficulty understanding the concept of transverse waves in abstract parts [5, 10]. Students do not explore concepts in-depth, understanding is incomplete and only relies on rote plug-chug [6]. The concept of low impact students in connecting between transverse wave magnitudes [5–8, 11]. While a complete understanding of the concept will be able to reduce students' misconceptions. Therefore, learning activities are needed in building scientific concepts. Students who have experienced misconceptions need to be given learning that contains cognitive conflicts and fulfills four conditions, namely dissatisfaction, intelligibility, plausibility, and fruitfulness [20] . In addition, learning must also include activities to change conceptions, such as approaches, strategies, learning models based on conceptual change, utilizing visual multimedia, refutation texts, conceptual change text material learning, or conceptual change laboratory activities [2, 9, 19].

4. CONCLUSION

Diagnostic test in the form of Multitier Open-Ended Transverse Wave Instrument (MOTWI) is accurate in assessing students' conceptions and misconceptions. The design of the multitier instrument is a multiple-choice test at the first tier and an open-ended test at the third tier, while at the second and fourth-tiers it is a level of student confidence in answering the questions. In the development stage, MOTWI is made in seven questions. In the disseminating stage, MOTWI is implemented for students to determine students conceptions. The validity of MOTWI diagnostic test in terms of item dimensionality is valid. The Cronbach Alpha (α) value from MOTWI is 0.75 (good category) and the value of item reliability is 0.92 and 0.93 (very good category). The construct validation results of MOTWI are valid and reliable for 7 items. The findings of the most misconceptions are about the characteristics of transverse waves and the relationship between the magnitudes of the waves. The recommendation for further research is to assess students' conceptions and misconceptions of the transverse wave using MOTWI in other locations or other countries.

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