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Jurnal Riset Pendidikan Matematika 11 (1), 2024, 64-76

Construction of three-tier diagnostic test for identifying student misconceptions in exponential properties

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ARTICLE INFO

Article history
Received: 23 May 2024
Revised: 24 May 2024
Accepted: 31 May 2024

Keywords
Design Task, Three-Tier Diagnostic Test, Misconceptions, Exponential.

ABSTRACT

Misconceptions are considered the most detrimental errors. A mathematics topic that students commonly experience misconceptions is in understanding exponential properties. This study aims to develop a three-tier diagnostic test. The development methodology follows a 3D model, Define, Design, and Develop. The resulting test comprises both essay and multiple-choice questions. Expert validation indicates that the essay questions are deemed suitable for use, with an 84.24% validation rate and a total of 20 questions. For the multiple-choice format, 9 questions meet moderate validity criteria, while 11 questions achieve high validity. Subsequent limited trial analysis, considering validity, reliability, difficulty, and discriminant power, identifies 8 questions as suitable for identifying student misconceptions in exponential properties. The construction of these questions consist of four types of misconceptions, generalisation, notation, spesialisation, and language. Reffering to exponential properties, the test item was developed asking students to apply the properties on real numbers.

Miskonsepsi dianggap sebagai kesalahan yang paling merugikan. Salah satu topik matematika yang sering mengalami miskonsepsi adalah dalam memahami sifat-sifat eksponen. Penelitian ini bertujuan untuk mengembangkan tes diagnostik tiga tingkat. Metodologi pengembangan mengikuti model 3D, yaitu Define, Design, dan Develop. Tes yang dihasilkan terdiri dari soal esai dan pilihan ganda. Validasi ahli menunjukkan bahwa soal esai dianggap layak untuk digunakan, dengan tingkat validasi 84,24% dan jumlah soal sebanyak 20 soal. Untuk format pilihan ganda, 9 soal memenuhi kriteria validitas sedang, sementara 11 soal mencapai validitas tinggi. Analisis uji coba terbatas selanjutnya, dengan mempertimbangkan validitas, reliabilitas, tingkat kesukaran, dan daya pembeda, mengidentifikasi 8 soal yang sesuai untuk mengidentifikasi miskonsepsi siswa pada materi sifat-sifat eksponen. Konstruksi pertanyaan-pertanyaan ini terdiri dari empat jenis miskonsepsi, yaitu generalisasi, notasi, spesialisasi, dan bahasa. Berkaitan dengan sifat eksponensial, soal yang dikembangkan meminta siswa untuk mengaplikasikan sifat-sifat tersebut pada bilangan riil.

https://doi.org/10.21831/jrpm.v11i1.73561 jrpm.ppsuny@uny.ac.id

How to Cite: Pramasdyahsari, A. S., Viviana, D., Sugiyanti, S., Pant, B. P., Ratnayake, I (2024). Construction of three-tier diagnostic test for identifying student misconception in exponential properties. *Jurnal Riset Pendidikan Matematika, 11*(1) 64-76. https://doi.org/10.21831/jrpm.v11i1.73561

INTRODUCTION

Comprehending mathematical concepts plays a pivotal role in the process of learning mathematics. As noted by Hiebert & Carpenter (1992), the notion that understanding involves forging connections between ideas, facts, or procedures is not novel. This underscores the significance of grasping concepts, as emphasized by the NCTM (2000), which asserts that the ability to comprehend mathematics is fundamental to the principles of mathematical learning. Conceptual understanding serves as a crucial asset in problem-solving endeavours, as a robust understanding of underlying concepts is essential for devising effective problem-solving strategies (Agustina, 2016). Such conceptual understanding aids students in tackling existing problems, empowering them to leverage their comprehension of mathematical concepts to navigate and resolve challenges. Consequently, conceptual understanding can be viewed as a prerequisite for grasping subsequent concepts (Karim, 2011).

Despite the acknowledged importance of conceptual understanding, the actual quality of students' conceptual understanding abilities often falls short (Diana, Marethi & Pamungkas, 2020). Handayani (2016) observes that students' current mathematical comprehension often diverges from the expected levels. One contributing factor to students' struggles in solving mathematical problems is their difficulty in grasping concepts and their tendency to overlook reasoning when tackling problems (Mutmainna, et al., 2018). These factors collectively contribute to a diminished understanding of mathematical concepts.

Improving students' grasp of concepts in mathematics is not a straightforward task, as each student's understanding of mathematical concepts is highly individual (Melisari, et al., 2020). Every student possesses unique abilities. Hence, instilling a solid conceptual understanding is crucial for their learning success, preventing difficulties in comprehending and assimilating new material at higher levels. Consequently, teachers need to avoid errors when conveying fundamental concepts, as these could lead to serious repercussions when students encounter subsequent concept-related challenges (Oktavianingtyas, 2015).

Students often struggle with mastering mathematical concepts, and they may even misinterpret them (Rohana, et al., 2009). Errors or misinterpretations in understanding a concept are commonly termed misconceptions. According to Özkan (2011), a misconception refers to a false concept or understanding that an individual perceives as correct and adopts as habitual. This notion corresponds with Sarlina's (2015) perspective that concept errors or misconceptions involve concepts that diverge from the scientific understanding accepted by experts in the field. When misconceptions arise in previous material, students will likely encounter similar misconceptions in subsequent concepts (Duskri, et al., 2014).

One common misconception among students when solving problems lies in the realm of exponentials (Angraini & Siregar, 2020; Wahyuni & Nurhadi, 2018; Pinahayu, 2015). This aligns with the observations of Nur'aini & Munandar (2021), who highlight that students frequently err in understanding exponentials at a conceptual level. Additionally, errors arise in comprehending the concept of exponential functions and their components (Topa, et al., 2018). For instance, students often make mistakes in understanding the exponent properties in multiplication operations. They may incorrectly multiply the base numbers in the exponents and then add the exponents, failing to recognize that this property only applies when the base numbers are identical (Pinahayu, 2015).

Exponents or power numbers, constitute a fundamental topic covered in the first semester of Grade X in high school. John Napier (1550-1617), a mathematician and nobleman from Merchiston, Scotland, is credited with the initial discovery of power numbers or exponents. The use of exponent notation significantly enhances the efficiency of conveying numerical or quantitative information (Susanti, et al., 2018). Acquiring conceptual understanding in this area is crucial for students to grasp exponential laws effectively (Hewson, 2013).

Based on interviews with a mathematics teacher at SMA Ma'arif Karangawen, most students understand the theory and properties of exponents. However, they encounter difficulties when applying these concepts to problem-solving. Students often struggle to apply the theories and properties they've learned, leading to confusion during problem-solving. Consequently, some students receive grades below the Minimum Completion Criteria (KKM) in exams covering exponent topics. The KKM for

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

mathematics, particularly the specialization subject at SMA Ma'arif Karangawen, is 70. These difficulties students face in exponent topics may indicate a less than-optimal understanding of the concepts.

The tests administered by teachers to students have mainly been used to assess their learning outcomes. According to Sheehan (1997), tests not only determine whether students are correct or incorrect but also provide insights into students' abilities to achieve proficiency. However, the tests used have not precisely identified the common difficulties or mistakes students encounter related to their understanding of mathematical concepts. Designing an effective test is not a one-time task but requires effort, time, accuracy, and diligence. Tests must be well-designed and closely aligned with the educational or instructional goals, serving both as an assessment tool and a means to achieve those goals (Nurlaeliana & Ruslan, 2018).

One type of test that can assist in identifying students' errors is diagnostic testing. According to Arikunto (2007), diagnostic tests are used to pinpoint students' weaknesses, which then inform appropriate corrective measures. Using diagnostic tests in instructional materials makes it easier to gauge students' mastery of the material and address students who may struggle or lack understanding of the concepts (Shalihah, et al., 2016).

Various types of diagnostic tests exist, including one-tier, two-tier, and three-tier diagnostic tests. This study specifically employs a three-tier diagnostic test, which comprises three levels. Three-tier diagnostic tests are deemed more reliable in discerning students' grasp of concepts and identifying misconceptions compared to one-tier or two-tier tests (Wahyudi, et al., 2021). According to Kamilah & Suwarna (2016), the three-tier format offers the advantage of distinguishing between misconceptions and mere lack of understanding or conceptual misunderstanding, thus providing an accurate assessment of students' misconceptions.

Past research predominantly focused on the application of three-tier diagnostic tests in topics like circles, algebra, and systems of linear equations and inequalities (Murniasih, et al., 2018; Abidin, et al., 2019; Dedeng, et al., 2020). These studies have significantly contributed to shedding light on the analysis of students' misconceptions. However, there's been a noticeable gap in research and development regarding three-tier diagnostic tests concerning exponential properties. This current research and development initiative involves crafting test items designed to pinpoint misconceptions, followed by testing their effectiveness. Validation testing is conducted to ensure that the created diagnostic test items effectively identify misconceptions among students.

Several findings indicating students' low conceptual understanding suggest an underlying issue contributing to this situation. This issue typically stems from misconceptions among students. Therefore, there's a clear need for a diagnostic test specifically tailored to identify students' misconceptions. This test takes the form of a three-tier diagnostic test. Consequently, it is hoped that educators and aspiring teachers alike can utilize and implement this test to effectively identify misconceptions in the realm of exponential properties.

METHODS

The research method employed in this study is the Research and Development (R&D) method. The development aspect of this research involves the creation of a three-tier diagnostic test on exponential topics for Grade X, Semester 1, following the 4D model (Thiagarajan et al., 1974). The 4D development model includes the Define, Design, Develop, and Disseminate stages. However, this study only progresses up to the development stage. The developmental stages of the three-tier diagnostic test to identify misconceptions regarding exponential properties for Grade X high school students are as follows: (1) The Define stage involves analyzing literature studies on previous research related to misconceptions and diagnostic tests. There are five activities in the Define stage (Thiagarajan et al., 1974), including Front-end Analysis, Learner Analysis, Learner Analysis, Concept Analysis, and Specifying Instructional Objectives. (2) Design stage, where there are four steps, including Constructing Criterion-Referenced Test, Media Selection, Format Selection, and Initial Design. (3) Develop stage, where the developed product is a three-tier diagnostic test comprising three levels. The first level includes questions to be tested. The second level includes reasons for the options given in the first level. The final level includes options for the students' confidence levels in their answers at the first and second levels. There are two steps in the development stage: Expert Appraisal and Developmental Testing.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Expert validation of the materials involved two mathematics lecturers and a high school mathematics teacher. Initially, two mathematics lecturers and one mathematics teacher validated the essay-format diagnostic test questions. Subsequently, they validated the multiple-choice questions in the three-tier diagnostic test. The test items consisted of both essay-format and multiple-choice questions. The essay-format test was administered to students to gather diverse responses, which would later inform the options for the multiple-choice section of the three-tier diagnostic test.

Data Analysis Methods

Analysis of the essay-format questions employed both qualitative and quantitative techniques. This analysis and validation focused specifically on the essay-format questions. Qualitative feedback was gathered from each validator regarding question clarity and alignment with the test objectives. Quantitative data, representing scores for the essay-format questions, were collected through material expert validation using a Likert scale. These scores were then qualitatively described. Criteria for question writing encompassed various aspects including question relevance, construction, and language. Both qualitative and quantitative data analysis were employed to assess the effectiveness and appropriateness of the essay-format diagnostic test questions. In this study, a Likert scale with five levels was utilized: Highly Suitable (HS) with a score of 5, Suitable (S) with a score of 4, Moderately Suitable (MS) with a score of 3, Unsuitable (U) with a score of 2, and Highly Unsuitable (HU) with a score of 1. Research scores were deemed achieved if the average assessment on the validation sheet fell within the high category.

The analysis of the multiple-choice questions in the three-tier diagnostic test was based on content validity results, which evaluated the alignment of question indicators with the developed items. Aiken's coefficient calculation method was employed for data analysis. Aiken, in his 1985 paper titled "Three Coefficients for Analyzing the Reliability and Validity of Ratings," outlined the formula for computing Aiken's V validity coefficient (as cited in Azwar, 2012).

Following content validation using Aiken's validity coefficient, product revisions were undertaken for the three-tier diagnostic test multiple-choice questions. Once the validation results of the developed product were obtained, data on questions meeting the validity criteria were acquired. Any questions failing to meet the validity criteria were revised based on feedback from validators. Subsequent adjustments were made to ensure the developed product was suitable for limited testing, aiming to assess the validity of the three-tier diagnostic test multiple-choice questions in identifying misconceptions related to exponential properties.

Following this, a limited test was conducted using a purposive sampling technique. As outlined by Sugiyono (2017), purposive sampling involves selecting samples based on specific considerations. In this case, the selection was informed by interviews with mathematics teachers from Class X Science 3, chosen due to its inclusion in both the Science and Social Studies tracks, and its timetable allowing for a three-hour gap suitable for testing. Consequently, Class X Science 3 was selected for this research.

The sample comprised students who had received instruction on exponential topics, specifically exponential properties. Thirty students from Class X at SMA Ma'arif Karangawen were selected for the limited test. According to Firman (2015), the scoring criteria for the three-tier diagnostic test involve scoring at each level. For Stage 1, correct answers receive a score of 1, while incorrect ones receive a score of 0. Table 1 shows the scoring criteria for Stage 1.

Table 1. Scoring Criteria for Stage 1

Criteria	Score
True	1
Wrong	0

Stage 2, assessment is obtained from the answers given at the first and second levels. Table 2 shows the scoring criteria for Stage 2:

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Table 2. Scoring Criteria for Stage 2

One-Tier	Two-Tier	Score
True (1)	True (1)	1
True (1)	Wrong (0)	0
Wrong (0)	True (1)	0
Wrong (0)	Wrong (0)	0

Stage 3 involves assessment obtained from all responses at each level, namely the three-tier diagnostic test in multiple-choice format. Table 3 shows the scoring criteria for Stage 3:

Table 3. Scoring Criteria for Stage 3

One-Tier	Two-Tier	Three-Tier	Score	Category
True (1)	True (1)	Certain (1)	1	Understand the concept
True (1)	True (1)	Uncertain (0)	0	Do not understand the concept
True (1)	Wrong (0)	Certain (1)	0	
True (1)	Wrong (0)	Uncertain (0)	0	
Wrong (0)	True (1)	Certain (1)	0	
Wrong (0)	True (1)	Uncertain (0)	0	Misconception (False negative)
Wrong (0)	Wrong (0)	Certain (1)	0	
Wrong (0)	Wrong (0)	Uncertain (0)	0	Misconception (False positive)

The acquired data is subsequently qualitatively analyzed to pinpoint student misconceptions regarding exponential properties. Following the testing of each item, grouping is conducted based on potential answers. Identified are student misconceptions (both false positives and false negatives) as well as instances of lacking knowledge. The combinations of answers in the three-tier diagnostic test are outlined in (Nabilah, 2019).

Validity Test

In order to assess the validity of the instrument, a validity test is carried out (Nurhayati, et al., 2019). The formula applied is the product moment correlation formula (Arikunto, 2013):

$$r_{xy} = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{(N\sum X^2 - (\sum X^2)(N\sum Y^2 - (\sum Y)^2)}}$$

Description

r_{xy} = The correlation coefficient between X and Y
N = The number of students investigated
X = Item question score
Y = total score
$\sum X$ = Total item score
$\sum Y$ = Total item score
$\sum X^2$ = Sum of squares of item scores
$\sum Y^2$ = Sum of squares of item scores
$\sum XY$ = Sum of the product of item scores and total score

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Harga r yang diperoleh kemudian dikonsultasikan dengan r_{tabel} *product moment* dengan taraf signifikansi 5%. Jika $r_{XY} > r_{tabel}$ dengan $\alpha = 5\%$, maka item soal yang diujikan valid. apabila jika $r_{XY} < r_{tabel}$, maka item soal yang diujikan tidak valid.
The obtained value of r is then consulted with the product-moment r_{tabel} at a significance level of 5%. If $r_{XY} > r_{tabel}$ with α=5%, then the tested item is valid. If $r_{XY} < r_{tabel}$, then the tested item is considered invalid.

Reliability Test
The instrument's reliability index is calculated using the K-R 20 formula (Arikunto, 2013):

$$r_{11} = \left(\frac{n}{n-1}\right)\left(\frac{S^2 - \sum pq}{S^2}\right)$$

Description:
r_{11} = Overall test reliability
p = Proportion of subjects answering the item correctly
q = Proportion of subjects answering the item incorrectly (q = 1 – p)
$\sum pq$ = The sum of the products of p and q
n = The number of items
S = The standard deviation of the test
The obtained r_{11} result is consulted with r_{tabel} with $\alpha = 5\%$. If $r_{11} > r_{tabel}$, therefore, the test is considered reliable. Table 4 shows the criterion for interpreting the level of reliability.

Table 4. The criterion for interpreting the level of reliability

Range	Description
0,00-0,30	Difficult
0,31-0,70	Moderate
0,71-1,00	Easy

The Difficulty Level Test
The difficulty index in multiple-choice questions can be obtained using the following formula (Arikunto, 2013, p. 223). Table 5 shows the difficulty level criteria.
Formula: $P = \frac{B}{JS}$
Description:
P = Difficulty index
B = The number of students who answered the question correctly
JS= The total number of students participating in the test

Table 5. Difficulty Level

Range	Description
0,81-1,00	Very high
0,61-0,80	High
0,41-0,60	Moderate
0,21-0,40	Low
0,00-0,20	Very Low

Discriminant Power Test

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

To calculate the discriminant power of each item, the following formula can be used (Arikunto, 2013, p. 228):

$$D = \frac{BA}{JA} - \frac{BB}{JB} = PA - PB$$

Description:
D = discriminant index
BA = number of top group participants who answered the item correctly
BB = number of bottom group participants who answered the item correctly
JA = number of participants in the top group
JB = number of participants in the bottom group
PA = proportion of top group participants who answered correctly
PB = proportion of bottom group participants who answered correctly
Classification of discriminant power is as follows:
D: 0.00 – 0.20 : poor
D: 0.21 – 0.40 : satisfactory
D: 0.41 – 0.70 : good
D: 0.71 – 1.00 : excellent
D : Negative, all are not good, if all items have negative D values, they should not be used (Arikunto, 2013).

After undergoing several rounds of limited testing, the revised product is refined further. The limited testing phase reveals any shortcomings in the developed product, prompting refinement to address these deficiencies.

RESULTS AND DISCUSSIONS

The research sample comprised students from class X IPA 3 at SMA Ma'arif Karangawen. In the defining phase, insights from field studies with math teachers revealed that some students were scoring below the Minimum Mastery Criteria (KKM) in exams covering exponent topics. Students faced challenges in applying theories and properties while solving exponent problems. The school follows the 2013 curriculum. Data indicated that the tests used so far primarily aimed at assessing student learning outcomes without addressing their specific difficulties. Subsequently, the researchers analyzed the students involved in this study, particularly those who had covered exponent properties. Students need to grasp and apply exponent properties to tackle problems effectively (Junengsih & Sutrisna, 2022). Literature reviews emphasized that misconceptions pose the most significant challenge compared to other errors. For instance, there's a common misconception regarding exponent multiplication properties, where students mistakenly multiply the base number by the exponent and then add the exponent. This misconception arises because students often memorize that exponentiation involves adding exponents in multiplication and subtracting them in division. However, they overlook that exponent properties apply only to base numbers with the same base (Pinahayu, 2015). Therefore, the development of a three-tier diagnostic test in a multiple-choice format becomes imperative to pinpoint student misconceptions.

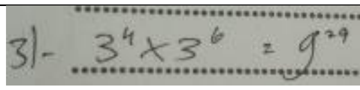
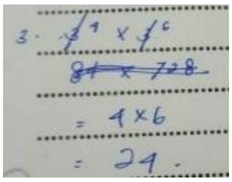
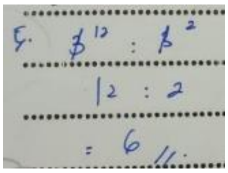
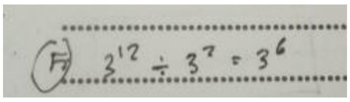
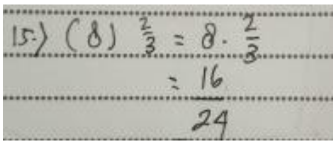
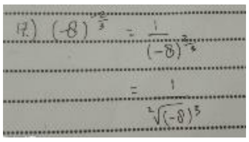
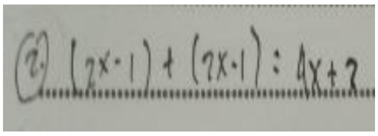
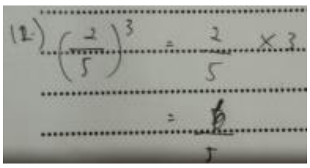
During the design phase of developing the diagnostic test, researchers initially selected the content to be included. They determined the fundamental competencies, indicators of competency achievement, question indicators, and cognitive levels. The diagnostic test questions were initially in an open-ended format. Researchers created a grid for the open-ended diagnostic test questions, including the questions themselves and the answer keys, to capture various student responses. The open-ended diagnostic test was administered to 15 students selected through purposive sampling, considering that they had covered exponent topics and the timing of the class period was suitable for the test.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

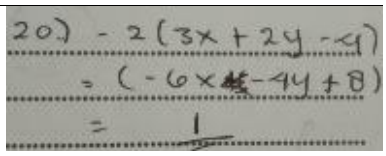
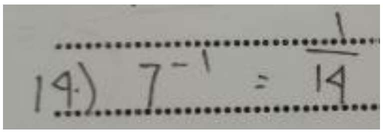
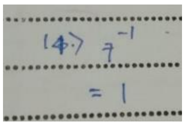
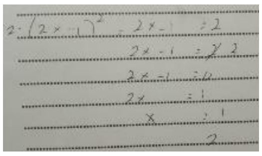
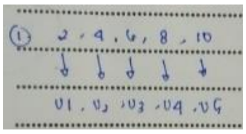
Before administering the test to the students, the questions were validated by three expert validators who assessed the construction, content, and language aspects. The expert validation scores, obtained using a Likert scale, yielded a percentage score of 84.24%, falling within the range of 81% - 100%, indicating excellent quality. Feedback from the validators was utilized to refine the test questions, focusing on the question grid, the number of questions tested, and the allotted time. After assessment and refinement, the open-ended diagnostic test comprised 20 questions.

Researchers then administered the open-ended diagnostic test to 15 students. The students' responses were analyzed to identify misconceptions related to exponent topics. Misconceptions in exponent topics included generalization misconceptions, notation misconceptions, specialization misconceptions, and language misconceptions (Nurkamilah & Afriansyah, 2021). These are detailed in the table 6.

Table 6. Misconceptions and Student Responses

Types of Misconceptions	Indicators of Misconceptions	Student Responses
Generalization	Simplfying form $a^m \times a^n$ to $(a \times a)^{m\times n}$	
	Simplifying form $a^n \times a^m$ to $(a \div a)^{n\times m}$	
	Simplifying form $a^n \div a^m$ to $(a \div a)^{n\div m}$,	
	Simplifying form $a^n \div a^m$ to $a^{n\div m}$	
	Simplifying form $a^{\frac{m}{n}}$ to $a^{\frac{m}{n}} = a \times \frac{m}{n}$	
	Determining the outcome of the property $a^{-\frac{m}{n}}$ to $\frac{1}{\sqrt[m]{a^n}}$	
Notation	The mistake lies in expressing exponentiation, where an addition sign is present between two base numbers.	
Specialization	Solving problems involving exponentials $\left(\frac{a}{b}\right)^n, b \neq 0$ to $\left(\frac{a}{b}\right)^n = \frac{2}{5} \times n$	

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Types of Misconceptions	**Indicators of Misconceptions**	**Student Responses**
	Simplifying form $a^0 = 1$, The case where a number raised to the power of 0 is resolved first by multiplying the number in front of it.	
	Simplifying form a^{-n} to $a^{-n} = \frac{1}{a^2}$	
	Simplifying form a^{-n} to $a^{-n} = 1$	
	Expanding exponential numbers involves expressing them in their expanded form a^n to $a^n = a = n$	
Language	Unable to illustrate real-life situations related to determining the general formula of exponents.	

Afterward, questions were formulated along with answer choices derived from student responses to the diagnostic test questions in essay format, as depicted in Figure 1.

Nomor 1

a. 3^{24} c. 9^{10} d. 3^{-2}

b. 3^{10} d. 9^{24}

Figure 1. An example of responses to the diagnostic test in essay form, which are provided as options.

Below are the outcomes of developing the multiple-choice format of the three-tier diagnostic test, as depicted in Figure 2.

1. Bentuk sederhana dari $3^4 \times 3^6$ adalah…

a. 3^{24} c. 9^{10} e. 3^{-2}

b. 3^{10} d. 9^{24}

Bagaimana alasan yang melandasi penyelesaian soal tersebut?

a. Mengalikan kedua pangkat, dimana $a^n \times a^m = a^{n \times m}$

b. Mengaliakan basisnya dan menjumlahkan kedua pangkat, dimana $a^n \times a^m = (a \times a)^{n+m}$

c. Mengalikan basisnya dan mengalikan kedua pangkat, dimana $a^n \times a^m = (a \times a)^{n \times m}$

d. Menjumlahkan kedua pangkat, dimana $a^n \times a^m = a^{n+m}$

e. Menguangkan kedua pangkat, dimana $a^n \times a^m = a^{n-m}$

Apakah Anda yakin dengan jawaban yang dipilih?

a. Yakin b. Tidak yakin

Figure 2. Example of the Development Results of Three-Tier Diagnostic Test

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

The validation of the diagnostic test questions in the three-tier multiple-choice format yielded a percentage of 91.76%, falling within the range of 81% - 100%, indicating excellent quality and suitability for use. Feedback was provided for improving the questions and adjusting the number of options for high school-level questions. Subsequently, the diagnostic test questions underwent limited testing to identify questions suitable for detecting student misconceptions. This limited-scale testing involved 30 students, followed by an analysis of question suitability using validity tests, reliability tests, difficulty level tests, and discriminant power tests. The validation analysis using the product moment correlation formula identified 11 valid items and 9 invalid items. The invalid test questions were disregarded as per the computation results using the product moment correlation, where the correlation coefficient $r_{xy} < r_{tabel}$, $\alpha = 5\%$. The reliability test results using the K-R 20 formula yielded a value of 0.6131, indicating that the questions used are reliable. Reliability is crucial in determining the accuracy of a measurement. This aligns with prior research emphasizing the importance of reliability in ensuring accurate test measurements (Nurhayati, et al., 2019). Hence, it can be concluded that the developed three-tier diagnostic test questions offer precise measurements, given the reliability test results indicating their reliability. Regarding difficulty levels, 9 questions were rated moderate, while 11 were deemed difficult, constituting 45% and 55% of the total respectively. Prior studies suggest that all difficulty levels are effective in identifying misconceptions (Leoni, at al., 2020). As for discriminative power, 3 items were deemed good, 7 fair, and 10 poor. This discriminative power testing aimed to distinguish between students of varying abilities. Previous research indicates that these test items effectively differentiate between those who have mastered the material and those who haven't (Laksono, 2020).

Hence, it can be concluded that 8 questions meet the validity criteria, exhibiting moderate to difficult levels of difficulty, and demonstrating sufficient discriminative power. These questions are deemed appropriate for identifying student misconceptions regarding exponent properties. Additionally, student responses are categorized to determine the percentage of those who comprehend the concept, those who do not, and those with misconceptions. This can be observed in Figure 3.

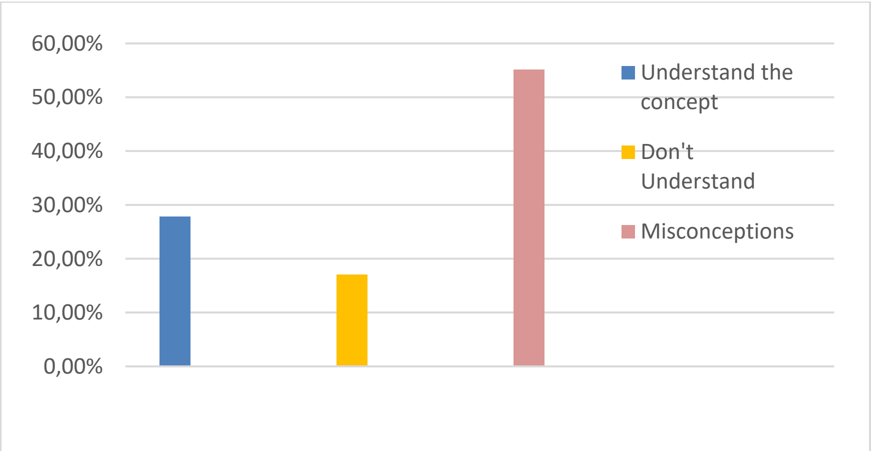


Figure 3. Student Response Percentage

The bar graph illustrates that 27.83% of students grasp the concept, 17% do not, and 55.17% have misconceptions, comprising 11% false positives and 44.1% false negatives. Previous research findings reveal that the analysis of the three-tier diagnostic test results yielded a higher percentage of misconceptions (false positives and false negatives) compared to those who understand and those who do not (Nabilah, 2019). This indicates that the developed three-tier diagnostic test questions can pinpoint misconceptions in students because the questions at the second level include reasoning options underlying students' answers at the first level. Previous research suggests that the advantage of the three-tier diagnostic test lies in its ability to estimate the percentage of false positives and false negatives (Shalihah, et al., 2016). False positive misconceptions stem from students' incomplete understanding,

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

while false negative misconceptions occur when students only receive partial information (Khairaty, et al., 2018). This aligns with the explanation of misconceptions' origins, which can arise from students, teachers, teaching methods, textbooks, and context.

CONCLUSIONS

Based on the research findings, the development process of the three-tier diagnostic test comprised three stages. Initially, during the definition stage, insights into the issues faced by students were gathered. Consequently, the three-tier diagnostic test questions were formulated to pinpoint student misconceptions. Moving on to the design phase, questions for the three-tier diagnostic test were structured in a multiple-choice format. Before this, the questions were presented in an open-ended form to collect diverse student responses. These questions underwent testing on 15 students, featuring 20 items, with an expert validation rate of 84.24%. Subsequently, in the development phase, a limited trial of the multiple-choice version of the three-tier diagnostic test was conducted, yielding an expert validation rate of 94.28%. Following this, the test's suitability was assessed through validity, reliability, difficulty level, and discriminant power tests, resulting in the identification of 8 items suitable for identifying student misconceptions regarding exponent properties. The data showed that 27.83% of students understood the concept, 17% did not, and 55.17% exhibited misconceptions.

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