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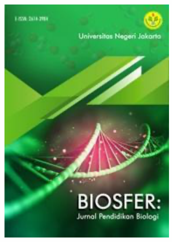

Diagnosis of plant morphology misconceptions using a two-tier diagnostic test

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ABSTRACT

Misconceptions are a problem in biology education because of the mismatch between individual knowledge and scientific concepts. Misconceptions need to be identified promptly to prevent them from hindering further knowledge construction. This study aims to identify misconceptions about plant morphology among 11th-grade high school students in Surabaya. The research design was a descriptive survey, with 114 11th-grade students from 9 high schools in Surabaya as participants. The research instrument was a plant morphology two-tier diagnostic test (PLANT-MOOD) consisting of 10 questions covering conceptual questions at the first level and reasons for answers at the second level. The research was carried out in two main stages, namely the test instrument development stage and the test implementation stage. PLANT-MOOD was highly valid (96.9%) as assessed by four botany experts and was declared 100% valid based on the MNSQ, ZSTD, and Pt Measure Corr criteria. PLANT-MOOD was also highly reliable with a Cronbach's alpha of 0.85. Data analysis used the Rasch option probability curve model and simple statistics expressed as percentages. The study found that students had a high level of misconceptions, namely 63% (17 misconceptions identified). The highest misconception was 77% regarding achene, known as strawberry seeds, and the lowest misconception was 38% regarding the concept of sweet potato tubers resulting from stem modification. The results of the misconception profile diagnosis provide educators with information for designing more effective learning strategies.

INTRODUCTION

Biology today serves not only as a means of learning but also as a way to directly impact the natural world. In biology, a deep understanding of plant morphology is one of the most essential foundations (O'Callaghan, 2011; Pedrera et al., 2025). This material is not just about memorizing the names and shapes of plant parts. Instead, studying plant morphology helps students recognize, classify, and understand the roles of each plant part, such as roots, stems, and leaves. Understanding this concept is very important for students in learning more complex biology material, such as physiology and taxonomy. Therefore, ensuring that students understand plant morphology well is a crucial first step in learning biology.

Given the importance of plant morphology in biology, the curriculum requires a deep understanding of plant morphology. However, in practice, several challenges persist, causing many 11th-grade high school students to still have difficulties and hold strong misconceptions about this material (Firdaus & Wisanti, 2021; Lubab et al., 2023). In plant morphology, there are specific terms (Mayoru et al., 2022). Sometimes, terms that are almost the same refer to structures that are very different. In addition, the variation in plants arising from different patterns of adaptation further complicates this material (Vigouroux et al., 2011). This can cause students to misinterpret a plant. This is a major factor in students' difficulty in understanding concepts and their susceptibility to misconceptions.

Misconceptions or incorrect interpretations of concepts have been the focus of in-depth research in various scientific and social fields since the early 1980s and have been a core focus of empirical research in learning science for the past 20 years (Suprapto, 2020). The term misconception refers to a condition where students' ideas are clearly inconsistent with widely accepted scientific views (Wynn et al., 2017). Based on research by Firdaus & Wisanti (2018), almost 50% of students in Sidoarjo and Surabaya have misconceptions in biology, especially regarding the kingdom Plantae. Teachers revealed that these misconceptions stem from learning resources or textbooks that contain misconceptions, inappropriate learning methods, or students' misinterpretation of phenomena (Coley & Tanner, 2012).

This misunderstanding not only hinders mastery of basic concepts but also makes it difficult for students to connect plant structures to their functions. Misconceptions can lead to misunderstandings of new information presented to students and hinder the process of constructing accurate knowledge. Misconceptions are resistant to change, meaning that these incorrect ideas are not easily eliminated or replaced with correct concepts, even after repeated explanations (Badenhorst et al., 2016; Bekkink et al., 2016). The presence of misconceptions significantly and negatively impacts students' overall learning achievement and hinders their progress in understanding more complex subject matter (Andriani et al., 2021; Versteeg et al., 2020).

Previous research identified five misconceptions related to leaf and flower morphology, including that oil palm leaves are incomplete leaves, cactus spines are modified stems, the broad green leaves on Acacia plants are leaves, sunflowers are single flowers, and the varied colored parts of bougainvillea flowers are petals (Jumiati & Hamid, 2015). In agreement with previous research, Hosic et al. (2025) also identified misconceptions similar to those reported by Jumiati & Hamid (2015). There was a misunderstanding regarding the structure of the stamens and pistils in Asteraceae plants, leading to the assumption that the Asteraceae group consisted of single-flower plants. This misconception is caused by students who tend to generalize morphological structures that appear similar and focus only on large structures (Hosic et al., 2025).

On the other hand, Maskour et al. (2019) highlight a different issue. Maskour et al. (2019) found that misconceptions are common regarding the classification of Gymnospermae plants due to a lack of understanding of their morphological structure. Gymnospermae are understood as flowering plants with ovules enclosed by an ovary. However, contrary to this statement, Firdaus & Wisanti (2021) explain that students understand Gymnospermae to be a group of plants with seeds borne outside the fruit. This understanding leads to another misconception: strawberries, cashews, and peanuts are classified as Gymnospermae because their seeds are visible outside the fruit. This misconception proves that students lack an understanding of plant morphology.

The misconceptions that arise reveal a gap between the ideal curriculum objectives and students' actual mastery of concepts. The existence of misconceptions has a significant negative impact on students' overall learning achievement. Therefore, it is important for educators to identify misconceptions in students. Misconceptions can be identified by developing a diagnostic test (Bessas et al., 2024; Desstya et al., 2025). This test contains a series of complex steps, including analysis, cause estimation, and observation, to reach the correct conclusion. The main purpose of the diagnostic test is to identify students' misconceptions and to serve as a basis for designing solutions to address the misconceptions identified (Idris et al., 2024).

Characterization of diagnostic tests is the process to assess learning difficulties. These tests are usually created by analyzing the source of the problem, are designed with concise answers, and allow follow-up to resolve identified issues. One type of diagnostic test is the two-tier diagnostic test (Ningroom et al., 2025). This research will combine the two-tier diagnostic test with option probability curve analysis. The advantage of the two-tier diagnostic test is that it reduces the ability to guess. In a regular multiple-choice test, if there are five answer choices, each answer choice has a 20% chance of being correct. Meanwhile, in a two-tier multiple-choice test, the probability of getting the correct answer (Afifah et al., 2022; Lian & Peng, 2021).

This study was conducted to identify misconceptions in plant morphology among 11th-grade high school students in Surabaya using the PLANT-MOOD (Plant Morphology Two-tier Diagnostic Test). The use of PLANT-MOOD can overcome the limitations of conventional tests, particularly for assessing students' understanding of plant morphology concepts that have not been widely explored. The results of this study accurately describe the levels of misconceptions, providing teachers with comprehensive information to design learning strategies. With empirical data on students' misconceptions, educational institutions can design more effective teaching programs. This will directly improve the quality of education, especially in biology, resulting in better graduates (Unaida et al., 2024).

METHODS

Research Design

This research is a descriptive survey used to describe or analyze research results and draw more general conclusions (Creswell & Creswell, 2022; Kintani & Heng, 2023). A diagnostic survey was conducted to identify students' misconceptions about plant morphology using the PLANT-MOOD test.

Population and Samples

The research sample consisted of 114 11th-grade students at high schools in Surabaya. The sampling technique used was simple random sampling, which involves selecting samples at random without regard to the population (Hilyati et al., 2023; Noor & Tajik, 2011). The demographic characteristics of the research sample are presented in Table 1.

Table 1.
Demographic Characteristics of the Research Sample

Characteristics	**Description**
School	Senior high school in Surabaya
Grade level	11th-grade
Number of students (n)	114 (51 male students and 63 female students in the age range of 17-18 years)
Sampling Technique	Simple random sampling

Instrument

This research instrument is a two-tier diagnostic test called PLANT-MOOD (Plant Morphology Two-Tier Diagnostic Test). PLANT-MOOD is used to identify misconceptions about plant morphology among 11th-grade high school students in Surabaya. The two-tier multiple-choice diagnostic test has two levels of questions (Zhou et al., 2021). The first level includes conceptual questions with two answer options, while the second level requires students to explain the reasons for their conceptual answer choices with five answer options. PLANT-MOOD consists of 10 questions with cognitive levels ranging from C1 to C5.

The PLANT-MOOD test was evaluated by four experts in plant morphology. The validation assessment instrument used a 4-point Likert scale, 1-4 (less valid-very valid) (Adelson & McCoach, 2010). The validation results show that PLANT-MOOD is very valid (96.9%). This criterion refers to Himmah & Sulaikho (2022), which states that an average validity score of 86%-100% is considered very valid. Validation tests were also conducted using Rasch model analysis based on MNSQ values (McLaughlin et al., 2023), ZSTD (Azizah & Wahyuningsih, 2020), and Pt Measure Corr (Sumintono & Widhiarso, 2015). The validation results show that PLANT-MOOD obtained an MNSQ value of 0.5-1.5, a

ZSTD value between -1.6 and 1.6, and a Pt Measure Corr value that was not negative between 0.3 and 0.6. Thus, PLANT-MOOD is declared 100% valid for both the first and second tiers after meeting the three specified criteria. Additionally, the reliability test showed that PLANT-MOOD is highly reliable with a Cronbach's alpha of 0.85.

Procedure

This study consists of two main stages, namely the test instrument development stage and the test implementation stage of the PLANT-MOOD test on 11th-grade high school students. The research procedure chart is presented in Figure 1.

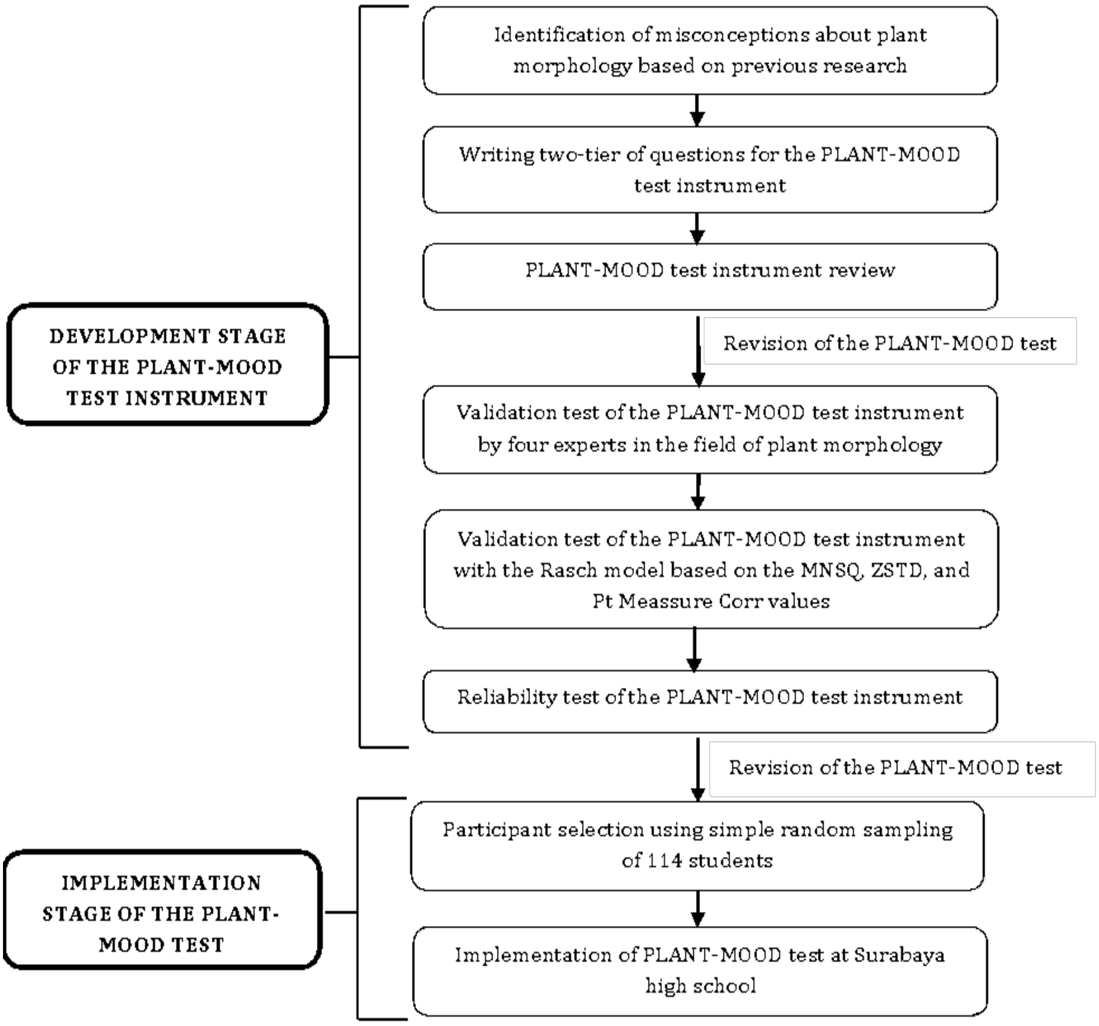


Figure 1. Research procedure

1. Test development stage

The PLANT-MOOD question development stage began with identifying misconceptions about plant morphology based on prior research. Each question was developed based on concepts prone to student misconceptions. The draft PLANT-MOOD was reviewed by two experts in plant morphology. Next, the PLANT-MOOD test was tested for validity and reliability.

2. Test implementation stage

The PLANT-MOOD test was administered to 114 11th-grade high school students in the Surabaya area offline via the Google Forms platform. This stage was conducted over two weeks, from October 27, 2025, to November 7, 2025. The PLANT-MOOD test accurately identified students' misconceptions about plant morphology.

Data Analysis Technique

The diagnostic test results were analyzed using the Rasch model with the OPC (Option Probability Curves) approach, which models the probability that students choose each answer option. The Rasch model provides information about the characteristics of test items and test takers simultaneously through Winsteps software (Bond, 2015; Nur Oktapiana et al., 2024). The OPC graph shows the x-axis logit score, which represents the test taker's ability and the level of difficulty of the test item, and the y-axis shows the probability of the student choosing each answer option (Lian & Peng, 2021). Therefore, the OPC graph provides information about how popular an answer choice is compared to other choices (Herrmann-Abell & Deboer, 2016). Another analysis technique is to categorize students into three levels based on their scores. Students with 0-3 misconceptions (0-30%) are categorized as having low misconceptions, 4-6 misconceptions (31-60%) are categorized as having moderate misconceptions, and 7-10 misconceptions (61-100%) are categorized as having high misconceptions (Robo et al., 2021).

RESULTS AND DISCUSSION

Based on the survey conducted using the PLANT-MOOD diagnostic test, the misconceptions of 11th-grade high school students in Surabaya are as follows.

1. Profile of Students' Misconceptions

In this study, data on student concept profiles were collected and divided into two categories, misconceptions and concept understanding (Srinadi et al., 2025). Based on the PLANT-MOOD test results, an average of 63% of 114 11th-grade high school students in Surabaya had misconceptions. A significant difference was observed in the average number of students who understood the concept, with only 37%. This proves that most students do not yet understand the correct concept of plant morphology. This inequality is also often found in other biology materials. Research by Idris et al. (2024) reports that 60% of students hold misconceptions, and only 5% understand the concepts in biotechnology. The average concept understanding of students' diagrams is presented in Figure 2.

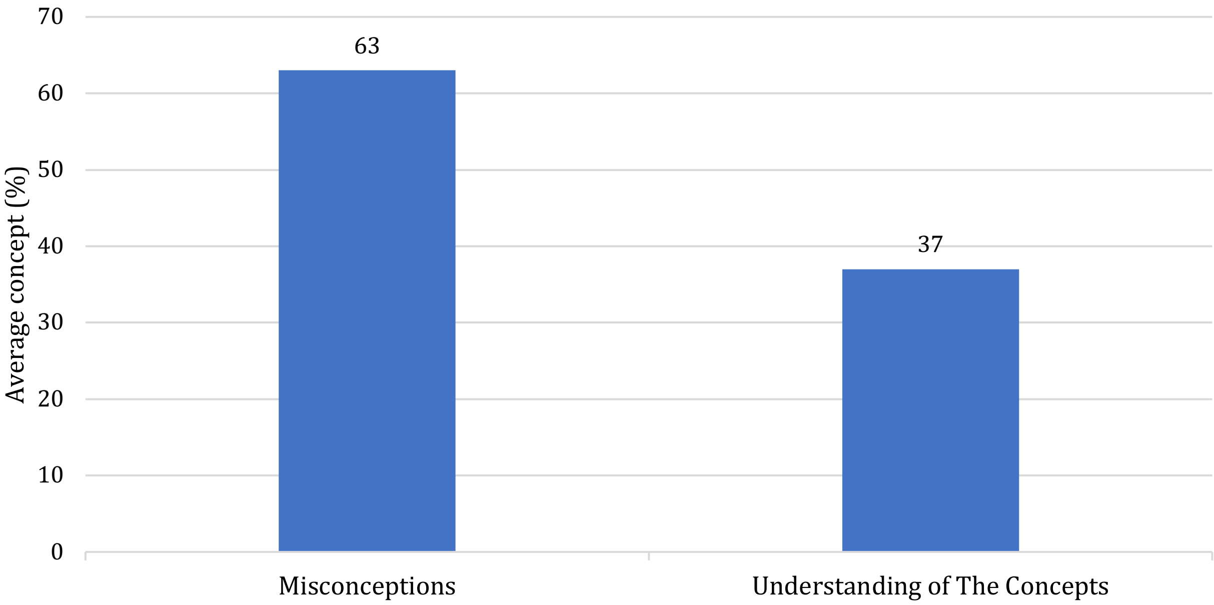


Figure 2. Average concept understanding of students

The students' misconceptions were classified into low, moderate, and high levels based on the percentage indicators (Suwarna, 2013). The results of the PLANT-MOOD diagnostic test revealed that among the 114 11th-grade high school students in Surabaya, 23% had low misconceptions, 26% had moderate misconceptions, and 51% had high misconceptions (Figure 3). Based on these results, there are still many students with high-level misconceptions compared with those with low or moderate levels.

The high level of misconception needs to be taken seriously by educators. Educators need to develop appropriate learning strategies to bridge the gap between scientific concepts and students' understanding. When viewed through the three concepts discussed earlier, misconceptions arise from errors in interpreting everyday phenomena or events (Duda, 2016). These inaccurate interpretations affect students' initial understanding of concepts, leading to persistent misconceptions. When students have initial concepts or preconceptions that conflict with agreed-upon concepts, this significantly affects their knowledge of a new concept (Duda et al., 2020).

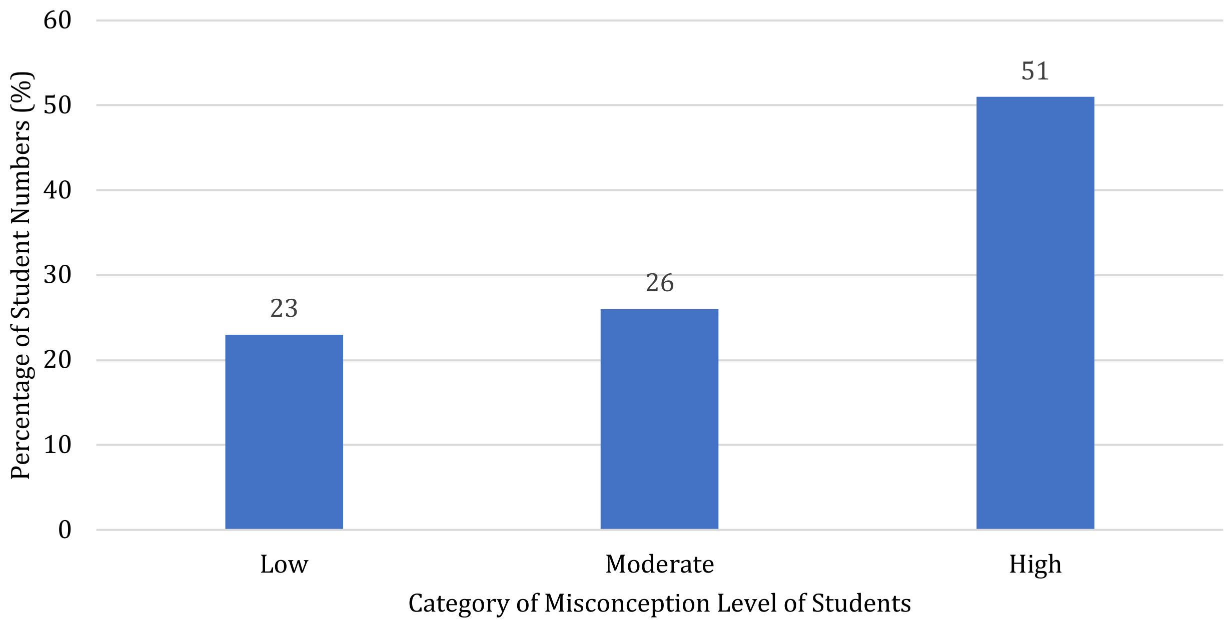


Figure 3. Categories of student misconception levels

The 17 misconceptions about plant morphology were identified among 11th-grade high school students in Surabaya using the PLANT-MOOD diagnostic test (Table 2). These misconceptions include the concept of perianth modification (6 misconceptions), the difference between true fruit and false fruit (7 misconceptions), the belief that sunflowers have compound flowers (1 misconception), the difference between single fruit and compound fruit (1 misconception), and plant organ modification (2 misconceptions).

Table 2.
Summary of misconceptions about plant morphology among 11th-grade high school students in Surabaya.

Concept	**Misconception**
The protective leaves of the bougainvillea flower.	1. The brightly colored and varied part of the bougainvillea flower is the corolla.
Modification of the stamens in the Canna flower.	1. The part of the Canna flower that appears wide and brightly colored is the corolla. 2. The part of the Canna flower that appears wide and brightly colored is the calyx. 3. The part of the Canna flower that appears wide and brightly colored is the protective leaf.
The flesh of an apple develops from the thickened receptacle.	1. The flesh of an apple develops from the ovary. 2. The flesh of an apple develops from the flower stalk.
The sunflower is a composite flower.	1. A sunflower is a single flower arranged on a single stem.
The fleshy part of the cashew nut develops from the flower stalk.	1. The flesh of the cashew fruit develops from the receptacle. 2. The flesh of the cashew fruit develops from the petals of the flower. 3. The flesh of the cashew fruit develops from the ovary.
The small dots on the surface of strawberries are true fruits.	1. The small dots on the surface of a strawberry are seeds. 2. The small dots on the surface of a strawberry are merely ornamental.
Grapes are single fruits.	1. Grapes are a compound fruit formed from a cluster of ovaries.
Rhizoids cannot be considered roots	1. Rhizoids can be regarded as roots.
Sweet potato tubers are the result of root modification.	1. Sweet potato tubers are the result of stem modification.
Some of the brightly colored petals on the Hibiscus flower are modified stamens.	1. All of the conspicuous, colored petals on the double flower are the corolla. 2. Some of the brightly colored parts of the hibiscus flower are protective leaves.

The most common misconception was item number 6, with a percentage of 77%. This item discussed the small structures on strawberries known as seeds. The second-highest misconception was item number 7 about the classification of grapes as a compound fruit, with a percentage of 75%. On the other hand, the lowest misconception percentage, at 38%, was for question 9, which concerned sweet potato tubers originating from stem modification. The test results on students' misconceptions were analyzed using an OPC graph to identify the most common misconceptions. The analysis was based on the most popular answer options or the options most frequently chosen by students (Lian & Peng, 2021).

2. Graphical Analysis of the Option Probability Curve

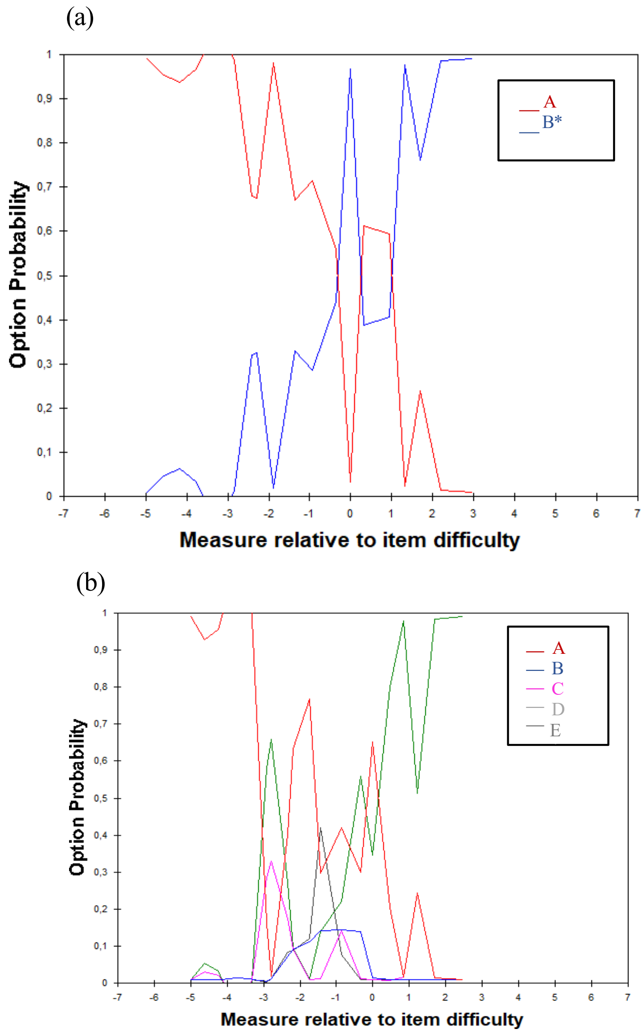
Question 6 indicates the highest misconception at 77%. This question discusses the concept of true fruit that forms small, brown structures scattered evenly across the surface of strawberries. The question specifically asks whether the small structures on the surface of the strawberry are actually seeds. The correct answer, option (B) "No" appears more frequently as students' ability increases from 1.0 logit to 3.0 logit, whereas the distractor option (A) "Yes" decreases as students' ability increases.

The second tier of question 6 shows the reasons students gave for their choices in the first tier (Figure 4). Students with low ability tended to choose options (A), (B), (C), and (D), which were distractors representing misconceptions. Conversely, students with high abilities, around 1.0 to 3.0 logits, tend to choose option (E), the correct answer. Among all the distractors, the most popular option is option (A). Therefore, the most common misconception among students is that the small black structures on the surface of strawberries are seeds. This finding is supported by Firdaus & Wisanti's (2021) research, which also states that 54% of students classified strawberries as Gymnospermae because they considered achenes to be seeds outside the fruit.

Strawberries have a characteristic that other fruits do not have, namely that their entire surface is covered with small brown dots called achenes (Asharo et al., 2022). Students believe that the small structures on the surface of strawberries are seeds. Its tiny size, approximately 1.00 mm, and its resemblance to a seed are the main reasons students form an inaccurate understanding (Tian et al., 2022). An achene is not a seed but a true fruit that develops from an ovary. Functionally, the achene contributes as a regulator of auxin hormone signals to trigger the growth *of pseudo-fruits* around it (Fait et al., 2008); see Figure 5.

The assumption that an achene is a seed is followed by the perception that the red, fleshy structure is the true fruit. This is because students tend to generalize too broadly, leading to a misunderstanding of the concept of true fruit structure. Every angiosperm has a fruit structure that develops from an ovary (Cerri & Reale, 2020). However, some plants also have fleshy structures that do not develop from the ovary, known as pseudo-fruits (Rahayu & Costa, 2025). The part of the strawberry that is often considered the fruit does not develop from the ovary and therefore cannot be called a true fruit. This part is a structure that develops from the receptacle or thickened flower (Schwieterman et al., 2014).

The second-highest percentage of misconceptions occurred in item 7, which asked whether grapes were classified as a single fruit. This item showed that 75% of the 114 students had misconceptions when categorizing grapes as a single fruit or a compound fruit. Students with an ability score above 1.0 logit preferred the correct answer option (A) "Yes" over the distractor option (B) "No"



(c)

Question 6A:
If observed carefully, the strawberry's surface has many small brown or black dots evenly distributed. Are the small dots on the surface of the strawberry seeds?

First tier question

(A) Yes (B) No*

First tier options

Question 6B:
The reason for your answer

Second tier question

A. Because the small dots on the surface of a strawberry are seeds that grow directly from the seedling.
B. Because the small dots on the surface of strawberries are merely ornaments that are not related to seed formation.
C. Because the small dots on the surface of strawberries are formed from the base of the flower that hardens after pollination.
D. Because the small dots on the surface of strawberries originate from pistils that did not develop into fully formed flower structures.
E. Because the small dots on the surface of strawberries are actually fruits formed from the fruit buds.*

(*) Correct Answer

Second tier options

Figure 4. Analysis of item 6: (a) OPC item 6A; (b) OPC item 6B; and (c) First-tier and second-tier question item 6 about the concept of true fruit in strawberries.

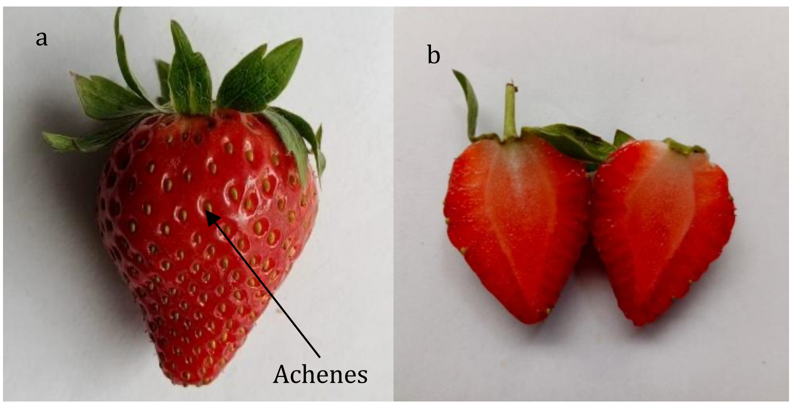


Figure 5. Strawberry: (a) Whole and (b) Transverse slice.

The same condition occurred when students were asked to give reasons in the second tier of question number 7 (Figure 6). Students with abilities below 1.0 logit mostly chose the distractor options (A), (B), (C), and (E), while students with high abilities or above 1.0 logit preferred the correct answer option (D). Among all distractors, the options with the highest probability among students with low ability were options (B) and (E), which classified grapes as a compound fruit. These two options illustrate that students held a misconception, classifying grapes as a compound fruit. Afidah & Wahyuni (2023) also stated that 35% of students failed to identify the difference between a single fruit and a compound fruit.

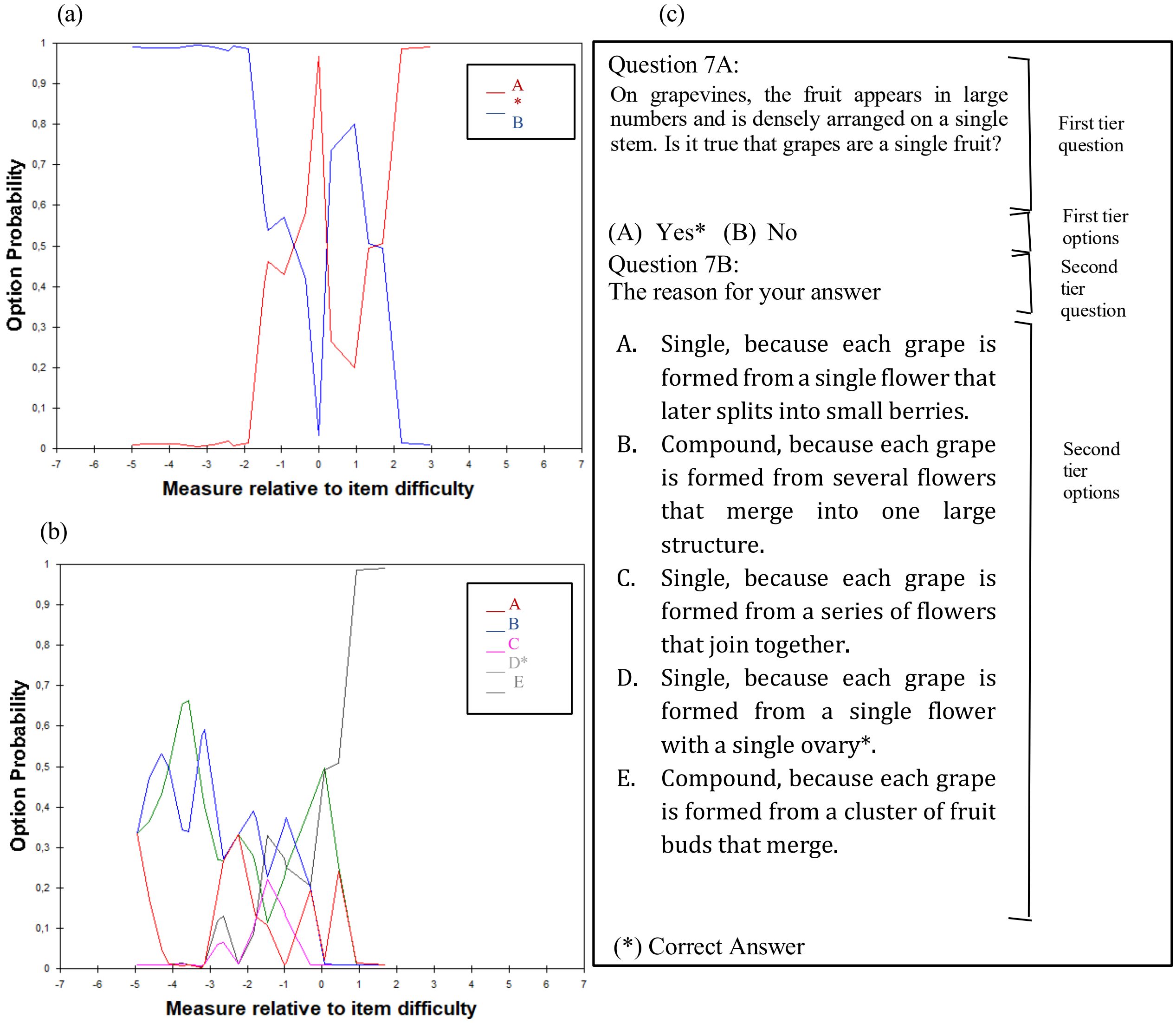


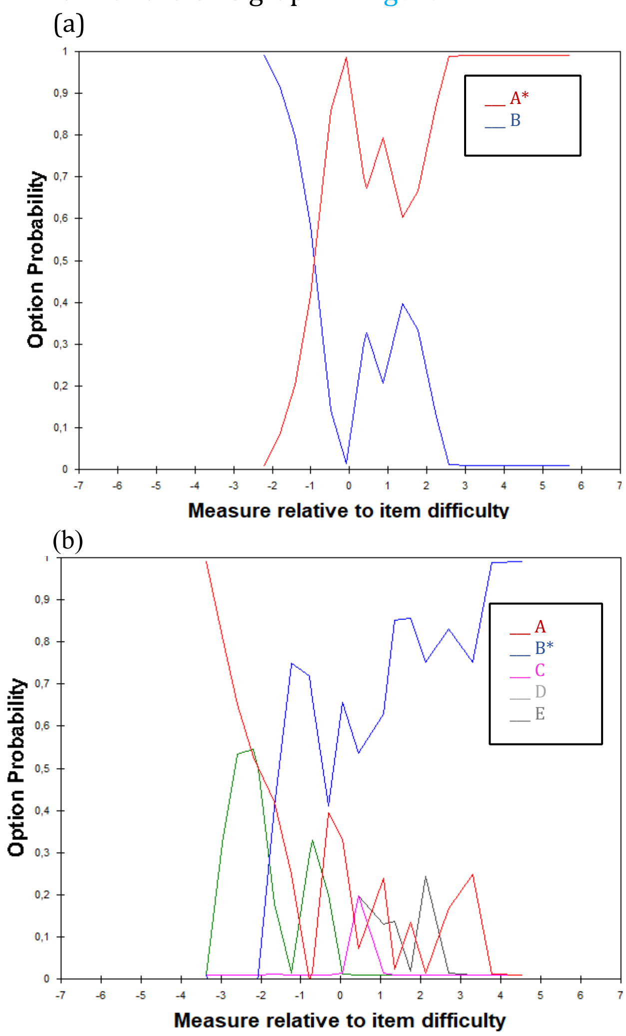
Figure 6. Analysis of item 7: (a) OPC item 7A; (b) OPC item 7B; and (c) First tier and second tier question item 7 about the concept of grapes as a single fruit.

Grapes are fruits that grow in clusters of 70 to 100 berries per bunch (Ardila et al., 2022). The morphology of grape clusters forms the basis for classifying grapes as compound fruits, according to most students. The actual concept is that grapes belong to the category of true single fruits formed from a single flower with a single ovary (Anggraeni et al., 2017; Zhang et al., 2021).

The basis for classifying fruits as simple or compound is their origin of development. A simple fruit is a fruit formed from a single flower with a single ovary (Dewi et al., 2023) . Conversely, a compound fruit is formed from several flowers (Salbila et al., 2023) . One example of a compound fruit is the pineapple, which is formed by 50 to 200 flowers joined together (Wang et al., 2020). All the ovaries from many small, closely spaced flowers will fuse with other parts of the flower, forming a large, compact fruit structure, and the stigma of the flower will develop into the pineapple's eyes (Chairani et al., 2021) .

Unlike items 6 and 7, item 9, about the truth that sweet potato tubers are a modification of roots, had the lowest percentage of misconceptions, namely 38%. The graph shows that the correct answer, option (A) "Yes" became the most popular choice as students' ability increased. The probability of the correct answer option continued to increase as students' ability increased from 1.0 logit to 6.0 logit. Conversely, the distractor option (B) "No" became a popular choice among students with low ability, around -2.0 logit to 0 logit. The results of this study are supported by the findings of Darmastuti & Desstya (2024), which state that only 0.17% of students had misconceptions about the characteristics of root tubers.

The second tier of question number 9 discusses the reasons for the answers in the first tier. The test results reveal that the probability of the correct answer is option (B). because sweet potato tubers are roots that thicken to store food reserves) dominates over the distractor options. This condition proves that students have low misconceptions about question number 9. However, a small number of students chose options (A), (C), (D), and (E), which reflect misconceptions about organ modification in sweet potato tubers. Among the four distractor options, the most frequently chosen was (A), indicating that some students held misconceptions that if sweet potato tubers result from plant stem modification, in line with the OPC graph in Figure 7.



(c)

Question 9A:
The part called a tuber in sweet potato is the result of the modification of one of the plant organs that has changed form. Is it true that sweet potato tubers are the result of root modification?

(A)Yes* (B)
No Question 9B:
The reason for your answer

A. Because the sweet potato tuber is an enlarged underground stem.
B. Because the sweet potato tuber is a root that has thickened to store food reserves.*
C. Because the sweet potato tubers are thickened layers of leaves that extend into the soil.
D. Because the sweet potato tubers are thickened stems with bud eyes on their surface.
E. Because sweet potato tubers are enlarged fruits that appear like thickened roots.

(*) Correct Answer

First-tier question
First-tier options
Second-tier question
Second-tier options

Figure 7. Analysis of item 9: (a) OPC item 9A; (b) OPC item 9B; and (c) First tier and second tier question item 9 about the concept of root modification in sweet potatoes.

Sweet potato is a plant that forms tubers from the development of roots (Aisy et al., 2023; Rosidah, 2014). Sweet potato has a spreading growth pattern, causing each node that touches the soil surface to produce adventitious roots (Balogun et al., 2024; Duan et al., 2023). The roots that grow at each node will develop into root tubers, which store food reserves for the plant (Ula et al., 2024).

The high percentage of students with correct conceptual understanding does not rule out the possibility of misconceptions. A small number of students still have an incorrect understanding, believing that sweet potato tubers result from stem modification. This misconception arises because sweet potato tubers can form roots, as in stem-modified tubers (Figure 8). One example of a plant with tubers resulting from stem modification is the potato (Ramadhani et al., 2025). Potato tubers, which are the result of stem modification, have a special characteristic: the presence of buds that are morphologically axillary buds, or side shoots (Mustofa, 2019). The modified stem contains nutrients that can trigger the upward growth of shoots (new stems and leaves) and the downward growth of adventitious roots (Gu et al., 2024; Husen et al., 2021). Unlike potatoes, sweet potato tubers begin as root primordia on stem nodes that can develop into adventitious roots. Sweet potato's ability to regenerate does not come from true buds or axillary buds as in stem tubers, but from strong root initiation at the stem nodes (Wijewardana et al., 2018). This concept explains why sweet potato tubers can form adventitious shoots when planted.

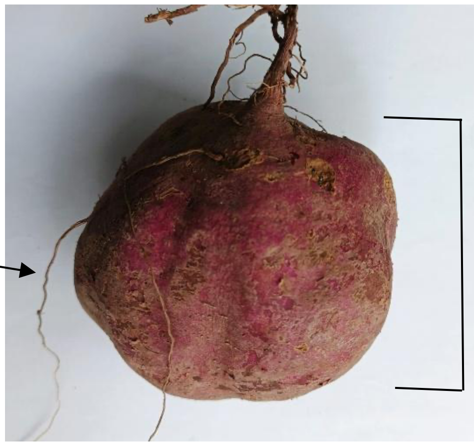


Figure 8. Sweet potato tubers

CONCLUSION

The PLANT-MOOD diagnostic test results showed that 63% of 114 11th-grade high school students in Surabaya had misconceptions about plant morphology, with 51% of students categorized as having high-level misconceptions. A total of 17 misconceptions about plant morphology were identified. The most common misconception was achene, known as strawberry seeds, at 77%, and the least common was sweet potato tubers, the result of stem modification, at 38%. The high percentage of misconceptions indicates that teachers need to implement effective media-assisted learning models to address misunderstandings about plant morphology.

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