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Identification of misconceptions in plant morphology using a four-tier diagnostic test

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ABSTRACT

This study aims to identify and map the highest levels of misconceptions regarding plant morphology among Grade 11 high school students in Surabaya. A descriptive survey involved 114 11th-grade students from nine high schools in Surabaya, selected through random sampling. Based on answer accuracy, reasoning accuracy, and confidence levels, students' responses were classified into conceptual understanding, partial understanding, lack of conceptual understanding, and misconception categories. Data were collected using the Four-Tier Diagnostic Test on Plant Morphology (MorforTest), consisting of 10 items. The instrument was validated by four biology experts and obtained a validity score of 90% (highly valid) and Cronbach alpha reliability score of 0.75 (reliable). Data were analyzed descriptively using percentages. The findings indicated that students exhibited misconceptions in the low (55%), moderate (40%), and high (5%) categories. The highest misconception rates were found in the concepts of Asteraceae inflorescences (45%) and the lamina and stamens of *Canna indica* (44%), whereas the lowest misconception rate was observed for moss rhizoids (14%). Thus, MorforTest can be recommended as a diagnostic tool to help teachers design learning strategies that minimize misconceptions in plant morphology.

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Introduction

Biology is the science that studies life scientifically through observation, experimentation, and reasoning to understand the structure, function, interactions, and processes that enable living organisms to survive and thrive on Earth (Scot et al., 2021). A deep understanding of plant morphology is an important foundation for learning biology because it enables students to recognize and understand plant structures and their functions (Pedrera et al., 2024). Plant morphology involves various structures and characteristics that require students to actively engage in learning and develop accurate conceptual understanding, when these concepts are not fully understood, students may develop misconceptions that can hinder their understanding of related biological concepts (Aleknaviciute et al., 2023).

Plant morphology represents a field of biological science concerned with investigating the form and structural features of plant organs, including roots, stems, leaves, flowers, fruits, and seeds (Sattler & Rutishauser, 2023). However, students often have misconceptions when understanding plant concepts, particularly regarding the identification of organs and their modifications (Wynn et al., 2017). These initial misunderstandings may arise because students are too confident in the concepts already in their minds, which can make it difficult for them to accept new concepts during the learning process (Neidorf et al., 2019). Such difficulties may occur because students rely on observable similarities when identifying structures, leading them to classify modified organs based on their appearance rather than their developmental origin and function. Students may also have difficulty distinguishing similar-looking structures, such as roots and root-like structures or floral organs and their modifications. These misunderstandings can be reinforced by students' prior experiences, everyday language, teachers, learning resources, and inappropriate teaching methods (Firdaus & Samsuri, 2018;Tekkaya, 2002). Therefore, identifying misconceptions related to the identification, structure, and modification of plant organs is important for determining appropriate corrective measures.

Previous studies have reported misconceptions across several plant morphology concepts, particularly in identifying plant organs, distinguishing organ modifications, and understanding floral and fruit structures. Misconceptions have been found in identifying incomplete leaves in oil palm, cactus spines as stem modifications, the lamina of Acacia mangium as a true leaf, and the conspicuous structures of sunflower and bougainvillea flowers (Jumiati & Hamid, 2015). According to Sari et al. (2017) , a common misconception regarding plant growth habits is that the sidaguri shrub (Sida rhombifolia) is often considered a perennial, when in fact it is a biennial because it completes its life cycle in more than one but less than two years. Another misconception is the classification of strawberries, cashews, and peanuts as members of the Gymnospermae group because the structures considered to be seeds are visible on the outside of the fruit (Firdaus & Wisanti, 2021). Research by (Maskour et al., 2019) reveals a misconception that flowering plants such as corn, grass, and sunflowers have identical reproductive structures; students tend to assume that every flower always has complete sepals, petals, stamens, and a pistil, whereas some plants have modified or differently arranged reproductive organs depending on their species. These findings indicate that students consistently experience difficulties in recognizing plant organs and their modifications, as well as distinguishing reproductive and fruit structures, suggesting that these concepts are particularly prone to misconceptions in plant morphology.

The persistence of misconceptions can hinder students' academic achievement and make it more difficult for them to develop an understanding of increasingly complex subject matter (Bekkink et al., 2016). The impact of these misconceptions cannot be ignored, as they can cause students to feel frustrated and dampen their expectations, thereby affecting their motivation and participation in learning (Chen et al., 2021). Therefore, a testing instrument is needed that can accurately identify misconceptions so that students' understanding of biological concepts can develop properly. The identification of students' misconceptions can be facilitated through the use of diagnostic tests (Salamah et al., 2020; Treagust, 2014). The use of diagnostic tests at the beginning and the end of instruction helps teachers identify students' misconceptions and evaluate their understanding of the concepts being learned (Gurel et al., 2015). One of the diagnostic instruments commonly employed to identify students' misconceptions is the Four-Tier Diagnostic Test. This instrument assesses four dimensions: answer selection, confidence in the selected answer, reasoning for the answer, and confidence in the reasoning provided (Fariyani et al., 2015). The combination of these four components enables researchers to distinguish misconceptions from lack of knowledge and uncertain or guessed responses, making the instrument particularly suitable for mapping students' misconceptions in plant morphology.

Numerous studies have used the Four-Tier Diagnostic Test to identify students' misconceptions and have demonstrated its ability to provide a comprehensive profile of conceptual understanding. The combining answer accuracy, reasoning, and confidence levels, the instrument can distinguish conceptual understanding, misconceptions, lack of understanding, and guessing (Febriana & Margereta, 2026). However, previous studies have primarily focused on other biological topics and populations, leaving plant morphology relatively less explored using this diagnostic approach. Therefore, this study applies the Four-Tier Diagnostic Test to 11th-grade high school students in Surabaya to identify and map the levels of misconceptions and determine the most problematic concepts in plant morphology. This study thus extends previous research by focusing on plant morphology and providing a concept-specific profile of students' misconceptions.

Based on the above discussion, this study aims to identify and map misconceptions in plant morphology using the MorforTest (Four-Tier Diagnostic Test on Plant Morphology) among 11th-grade high school students in Surabaya. MorforTest provides a concept-specific diagnostic instrument covering key plant morphology concepts, including floral structures, inflorescences, organ modifications, and fruit types. This specificity enables the instrument to reveal misconceptions at the level of particular plant morphology concepts and provide a basis for teachers to develop more targeted learning strategies (Salamah et al., 2020 ; Sari et al., 2024).

Method

This study is a descriptive survey designed to objectively describe misconceptions and the categories of misconception levels in plant morphology material at the high school level. The study participants were 114 11th-grade science students from 9 public and private high schools in Surabaya. Simple random sampling was used as the data collection technique.

The instrument used was the Four-Tier Diagnostic Test on Plant Morphology (Morfortest). This instrument consists of four tiers: answer choices, level of confidence in the answer, reasons for selecting the answer, and level of confidence in the selected reasons. The Morfortest has undergone validation using a 4-point Likert scale, 1–4 (less valid–very valid), and reliability testing based on Cronbach's Alpha (KR-20) (Jebb et al., 2021) . The validation assessed the instrument's content and item quality, and the validity percentage was calculated by dividing the total score obtained from the validators by the maximum possible score and multiplying by 100%. The validation results from four biology experts showed an average of 90%, falling into the "highly valid" category (Taherdoost et al., 2016) however, one item was deemed invalid. The reliability test of the Morfortest instrument showed a reliability coefficient of 0.75, falling into the "highly reliable" category (Chen et al., 2021).

The research procedure consisted of two main stages the development of the Morfortest instrument and the administration of the Morfortest to 11th-grade high school students.

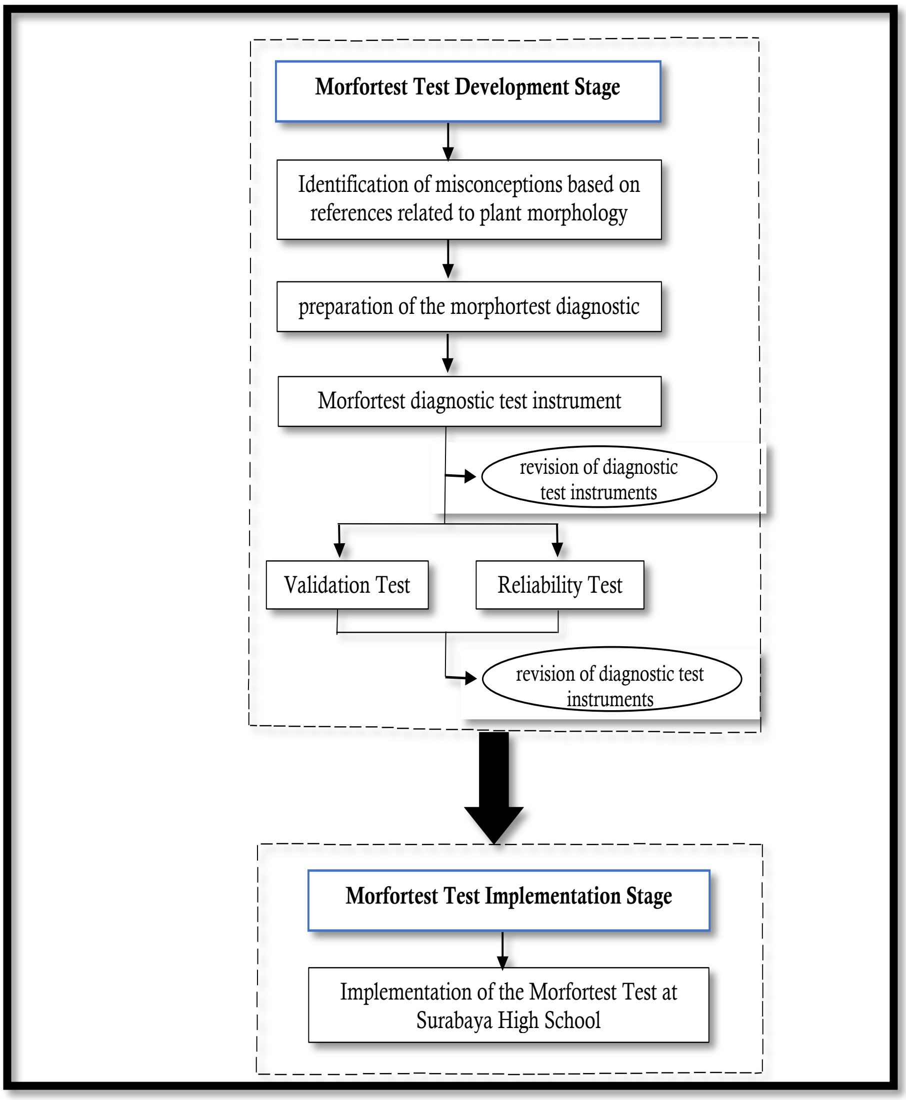

Figure 1. Research Stages

The test development phase involved the creation of the Morfortest item bank. Development began with a review of various sources, such as textbooks and previous research related to plant morphology. The resulting draft of the Morfortest consisted of 10 items, which were then reviewed by two experts in the field of botany.

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Based on this review, the Morfortest draft was revised to produce the final Morfortest draft. This stage concluded with validation and reliability tests of the Morfortest test instrument.

The Morfortest was administered to 114 11th-grade high school students in Surabaya in person via Google Forms to map patterns of conceptual errors in plant morphology. The test is expected to identify patterns of conceptual errors in plant morphology accurately.

Each student's test results were analyzed using conceptual categorization groups, which included "concept understood," "concept not understood," "misconception," and "partially understood" (Sandika, 2020) (Table 1). The data for each category, determined based on the number of students, were analyzed using simple statistics in the form of percentages. In addition, misconceptions were grouped into three levels: high (7–10 misconceptions, 61–100%), moderate (4–6 misconceptions, 31–60%), and low (0–3 misconceptions, 0–30%) (Irianti, 2021). This categorization is based on the analysis model proposed by, which posits that the higher the percentage of misconceptions, the greater the need for instructional intervention. Subsequently, the percentage of students in each level was determined.

Table 1. Categorization of Students' Misconceptions Based on the Four-Tier Test

No.	Category	Option	Level of Confidence	Reason	Confidence Level
1	Understand the Concept	True	Confident	Correct	Confident
2	Partially Understand (PS)	Correct	Confident	Correct	Not Sure
3		True	Not Sure	True	Sure
4		True	Not Sure	True	Not Sure
5		True	Sure	Wrong	Sure
6		True	Sure	Wrong	Not Sure
7		True	Not Sure	Wrong	Sure
8		True	Not Sure	Wrong	Not Sure
9		Wrong	Sure	Correct	Sure
10		Wrong	Sure	True	Not Sure
11		Wrong	Not Sure	True	Sure
12		Wrong	Not Sure	True	Not Sure
13	Misconception	Wrong	Sure	Wrong	Correct
14	Lack of Conceptual Understanding (LCU)	Wrong	Confident	Wrong	Not Sure
15		Wrong	Not Sure	Wrong	Sure
16		Wrong	Not Sure	Wrong	Not Sure

The technique for analyzing students' misconceptions based on test results can be calculated using Formula 1.

$P = \frac{F}{N} X\ 100\%$
Explanation:
P = Validity percentage (%)
F = Number of aspects scoring 1 on each test item
N = Number of individuals

Results and Discussion

This study produced data on students' misconceptions profiles, the level of misconceptions, and the percentage of correct concept understanding for each question. Data were collected using the Four-Tier Diagnostic Test (Morfortest), which consists of 10 items. Based on these results, students' misconceptions were classified into four categories: concept understanding (CU), partial understanding (PU), misconceptions (M), and Not Understanding (NU). The "conceptual understanding" category indicates that students fully understand the concept of plant morphology; "partial understanding" indicates that students understand only part of the concept; while "misconception" indicates that students' understanding does not align with the scientific concept (Sandika, 2020) .

The results regarding students' misconceptions can be seen in Figure 1, which shows that the "partially understand" category was the most common among students, at 32%. This percentage indicates that students have not yet fully understood the concept of plant morphology.

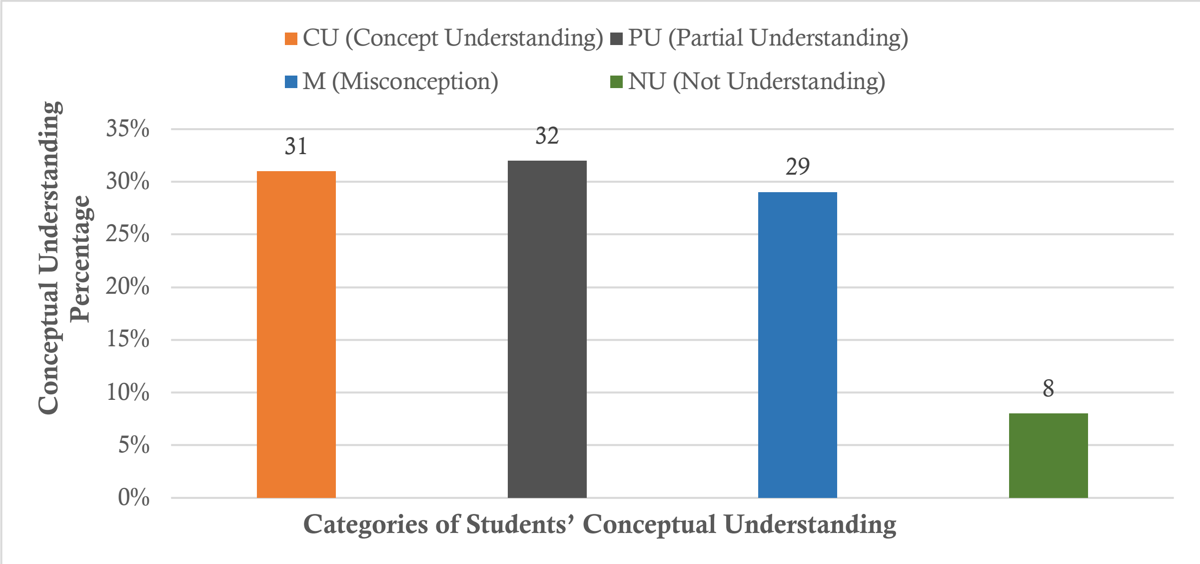

Figure 2. Graph of Students' Conceptual Understanding Percentages

The results of the Morfortest diagnostic test revealed that out of 114 11th-grade high school students in Surabaya, 55% had low-level misconceptions, 40% had moderate-level misconceptions, and 5% had high-level misconceptions, as shown in the graph in Figure 2.

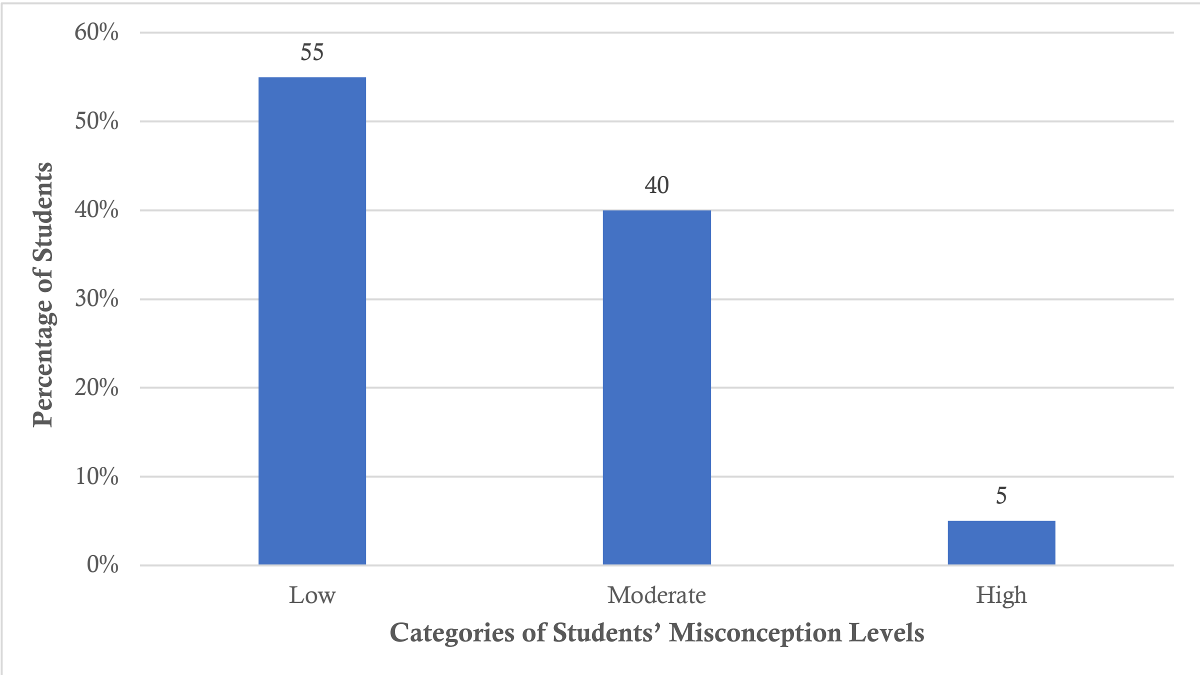

Figure 3. Graph of Misconception Levels by Category Among Students

Misconceptions among 11th-grade students occurred across all concepts. Table 2 shows that the concept of Asteraceae inflorescences (sunflowers) is the concept most prone to misconceptions, with the highest percentage at 45%. Furthermore, the concept of the kana flowers also showed a high percentage of misconceptions, at 44%. Conversely, the concept of rhizoids in mosses had the lowest percentage of misconceptions, at 14%.

Table 2. Percentage of Correct Conceptual Understanding for Each Morfortest Item

Concept	CU	PU	M	NU
Cashew fruit	18	52	22	9
Asteraceae inflorescences (Sunflower)*	25	22	45	8
Bougainvillea Bractea (Paper Flower)	25	30	37	8
Sweet Potato Tubers	44	35	20	1
Canna Flower*	29	13	44	14
Stamens and pistils of the hibiscus	34	44	19	3
Apple	42	37	15	6
Strawberries	32	25	36	7
Rhizoid*	45	35	14	6
Simple fruit, compound fruit	20	24	42	14
Average	31	32	29	8

Note: CU: Concept Understanding, PU: Partial Understanding, M: Misconception, NU: Not Understanding

Many 11th-grade students showed misconceptions on question 2 concerning the Asteraceae inflorescence, with a misconception rate of 45%. The dominant response indicated that students considered the sunflower head to be a single flower, reflecting an incorrect understanding of its inflorescence structure. This response pattern suggests that the sunflower's flower-like appearance contributed to students' difficulty in distinguishing an inflorescence from a single flower.

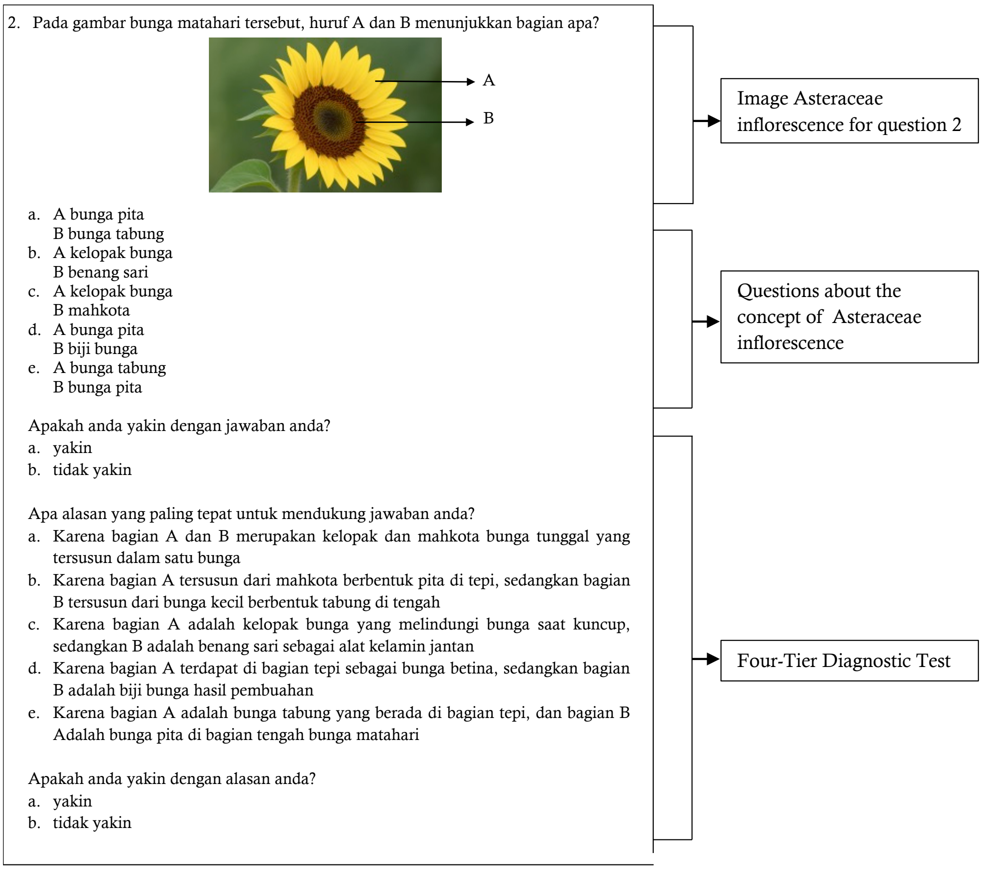

Figure 4. Question Number 2 on Asteraceae Inflorescences

This misconception is consistent with previous studies reporting students' difficulties in distinguishing simple and compound flowers in the Asteraceae family (Jumiati & Hamid, 2015). This is consistent with the study by Mifsud & Owen (2020), similarly found that many students considered the capitulum a single flower rather than an inflorescence composed of tubular and ray flowers. The 45% misconception rate found in this study reflects a similar pattern of conceptual difficulty, particularly in recognizing the capitulum as an inflorescence. This difficulty may be reinforced by the visual structure of the capitulum, in which numerous florets are highly compressed and arranged to resemble a single flower. In addition, the showy ray flowers resemble petals, while the surrounding involucral bracts provide a flower-like appearance (Chen et al., 2018; Zhang & Elomaa, 2024).

Consequently, students who rely mainly on visible morphological characteristics may interpret the entire capitulum as a single flower rather than as an inflorescence composed of multiple florets.

The most common misconception after the Asteraceae inflorescence was found in question 5 concerning the Canna flower, with a misconception rate of 44%. The dominant response pattern showed that students identified the prominent floral structure as the corolla and provided a corresponding reason with high confidence. This combination of an incorrect answer, incorrect reasoning, and high confidence indicates a misconception rather than a lack of knowledge or guessing. In fact, the conspicuous structure is a sterile structure derived from modified stamens (staminodes), not a true corolla. Its petal-like appearance may therefore contribute to students' persistent misunderstanding of the Canna flower structure.

Previous research has shown that the Canna flower is one of the concepts that may lead to misconceptions among students (Maskour et al., 2019; Wynn et al., 2017). In this study, the dominant response pattern indicated that students identified the conspicuous part of the Canna indica flower as the corolla, with high confidence in their answer and reasoning. This suggests that students relied on the petal-like appearance of the structure when identifying its floral identity. In fact, Canna possesses true petals as well as conspicuous petaloid structures derived from modified androecial organs, particularly staminodes (Hancock et al., 2024; Yu et al., 2022). The broad and petal-like morphology of these staminodes may make them difficult to distinguish from true petals based solely on external appearance. Thus, the combination of an incorrect answer, supporting reasoning, and high confidence illustrates how the Four-Tier Diagnostic Test can reveal a persistent misconception rather than merely an incorrect response.

Unlike the previous two concepts, question number 9 concerning moss showed the lowest misconception rate, at 14%. This indicates that misconceptions were less prevalent for this concept than for the other concepts examined. Among the students classified as having misconceptions, some equated rhizoids with roots. Misconception is that moss rhizoids are roots because they perform similar functions, such as anchorage and water absorption (Shortlidge & Hashimoto, 2015; Wynn et al., 2017).

Previous research has shown that students may have difficulty distinguishing structures of nonvascular and vascular plants, including mistaking moss rhizoids for true roots (Jones & Dolan, 2012). In this study, students classified as having misconceptions tended to identify rhizoids as roots, suggesting that they relied on the root-like appearance and similar anchoring function of rhizoids when identifying the structure. Although rhizoids and true roots differ in structure and development, their similar external appearance may lead students to associate rhizoids with roots (Motte & Parizot, 2021). Thus, the students' responses indicate that the misconception was related to interpreting structural similarity as evidence of the same organ identity.

According to Jones & Dolan (2012) rhizoids are filamentous structures that develop primarily on the gametophytes of land plants and function mainly in anchorage. In mosses, rhizoids are multicellular and differ from true roots in their structural and developmental characteristics. However, their root-like appearance and anchoring function may make them difficult for students to distinguish from true roots. In this study, students who classified rhizoids as roots may therefore have relied on these observable similarities rather than recognizing differences in their developmental origin and structural organization. Similar functional characteristics between rhizoids and root hairs have also been reported in bryophytes, which may further contribute to confusion when students identify these structures based primarily on appearance and function (Frangedakis et al., 2021; Hetherington & Dolan, 2018).

Conclusions

Based on the results and discussion of this study, it can be concluded that students' understanding of plant morphology using the Morfortest was dominated by the partial understanding category, indicating that many 11th-grade students had not yet fully mastered the concepts. Misconceptions were identified at varying levels, with the highest occurrence found in the concepts of Asteraceae inflorescences (sunflower) and *Canna* flowers, while the lowest occurred in the concept of moss rhizoids. These findings indicate that students' difficulties were mainly related to recognizing plant organs and their modifications. Therefore, the Morfortest can be recommended as a diagnostic tool to help teachers identify students' conceptual difficulties and design appropriate learning strategies to minimize misconceptions in plant morphology.

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