EPJ Web of Conferences **344**, 01038 (2025) https://doi.org/10.1051/epjconf/202534401038
AIPTEC 2025

Mapping secondary school students' botanical literacy using rasch analysis to support deep learning in science

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Abstract. The Merdeka Curriculum emphasizes deep learning in science education, where students connect ideas, reason scientifically, and apply concepts to real-life contexts. However, many students still demonstrate basic understanding, especially in understanding plant concepts. The contribution of this study is to provide a diagnostic profile of students' botanical literacy abilities that can guide teachers in enhancing in-depth learning. This study aims to map secondary school students' botanical literacy using Rasch analysis to support the implementation of deep learning in science education. A total of 253 ninth-grade students participated in a 30-item botanical literacy test covering five aspects of plant knowledge. Data were analyzed using the Rasch Model through Winsteps software. The analysis produced a Wright Map showing item difficulty ranging from basic recall (easy) to higher-order thinking (difficult). This finding indicates that the instrument effectively measures multiple botanical literacy levels. Furthermore, data obtained showed that most students had moderate botanical literacy abilities across all aspects. This suggests that students' understanding of plants remains at a basic level. Mapping through Rasch analysis provides diagnostic insights for teachers to identify learning gaps and plan lessons that promote conceptual understanding and reasoning, which are essential components of deep learning in science.

1 Introduction

Students' understanding of plant concepts remains limited; most of them are still unable to explain the relationships among plant structures, functions, and their roles in maintaining ecosystem balance [1], [2]. This situation reflects what is known as *Plant Awareness Disparity* or *plant blindness*, referring to the human tendency to overlook plants and to underestimate their importance for life [3], [4]. Research shows that many students struggle to recognize local plant species and often hold misconceptions about basic processes such as photosynthesis, plant growth, and plant–environment interactions [5], [6]. One contributing factor is the limited representation of botanical content in science curricula, where animal-related topics are often more emphasized than plant-related ones [1], [2] (Pedrera *et al*., 2021; Marcos-Walias, 2023). This imbalance prevents students from gaining meaningful learning experiences that could develop their appreciation of biodiversity and their ability to think ecologically [4], [7]. In fact, plants are the foundation of life on Earth, serving as oxygen producers, food sources, and stabilizers of ecosystems [2], [3].

Botanical literacy is defined as the ability to understand, appreciate, and apply plant-related knowledge in scientific and contextual ways [8], [9]. This literacy encompasses cognitive, affective, and psychomotor dimensions that together reflect a person's overall understanding and interaction with plants [3], [4]. The cognitive dimension involves understanding biological concepts related to plant morphology, physiology, ecology, and classification [5], [9]. The affective dimension reflects awareness, curiosity, and positive attitudes toward plants as living organisms essential for life and sustainability [7], [10]. The psychomotor dimension includes the ability to identify, cultivate, and utilize plants in daily life through observation and hands-on experience [4], [11]. As a component of broader *scientific literacy*, botanical literacy plays a crucial role in fostering environmental awareness, sustainable behavior, and meaningful engagement with nature [8], [9].

Although botanical literacy is recognized as an essential part of scientific literacy, various studies indicate that students' understanding of plants is still relatively low across educational levels [1], [5]. Students often memorize isolated facts about plants without connecting their structure, function, and ecological roles, which reflects a surface level of understanding in plant science [1], [11]. Findings from learning progression research show that most students are positioned at the intermediate level of botanical literacy, with only a few demonstrating high-level conceptual reasoning related to plant diversity and eco-physiology [11], [12]. Earlier evidence also suggests that students are generally more familiar with animal species than plants and are less aware of plants' ecological importance in sustaining life [4], [5]. In the

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Indonesian context, similar patterns have been observed where students' plant knowledge tends to focus on naming plant parts rather than understanding their interactions within ecosystems [9], [13].

The need for mapping botanical literacy lies in its potential to provide diagnostic information that helps teachers understand students' learning profiles and plan appropriate instruction [11], [14]. Mapping allows educators to identify which plant concepts are easy or difficult for students and to adjust learning strategies based on evidence rather than assumptions [9], [12]. This diagnostic process supports teachers in designing learning activities that address misconceptions and promote conceptual understanding in science classrooms [1], [13]. By revealing the distribution of students' abilities, mapping also helps align teaching practices with the principles of deep learning that emphasize understanding, connection, and application of knowledge [15]. Therefore, accurate mapping of botanical literacy is essential for developing effective, meaningful, and sustainable science education practices [16], [17].

Mapping students' botanical literacy is important to support the implementation of deep learning in science learning [9], [11]. Deep learning emphasizes learning experiences that are mindful, meaningful, and joyful, enabling students to construct understanding through critical reflection and contextual application of concepts [15]. This approach helps learners connect scientific ideas with real situations and promotes the development of higher-order thinking skills [16], [17]. The Merdeka Curriculum in Indonesia adopts this orientation through flexible, student-centered learning that strengthens conceptual reasoning and problem-solving [17], [18]. Mapping students' botanical literacy can therefore provide diagnostic insights that allow teachers to design deep learning-based instruction and facilitate students' meaningful understanding of plant science [9], [15].

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Accurate measurement of botanical literacy requires an analytical model that can produce objective and reliable data [14]. The Rasch model transforms raw scores into interval data, allowing the comparison of student ability and item difficulty on the same scale [19], [20]. This model provides diagnostic precision by identifying how well each item measures students' conceptual understanding and how individual abilities are distributed across a continuum [14], [21]. The Rasch approach also enables researchers to evaluate instrument validity, reliability, and unidimensionality, which are important indicators of measurement quality [22], [23]. With these advantages, the Rasch model is suitable for mapping students' botanical literacy to provide a clear picture of learning progression and conceptual mastery [11], [24].

The Rasch model has been widely applied in education to evaluate students' abilities, attitudes, and conceptual understanding across different subjects [24], [25]. Research using this model has successfully analyzed problem-solving skills, scientific reasoning, and learning outcomes in science education [26]. Studies also show that Rasch analysis provides teachers with evidence-based insights that can be used to improve classroom instruction and curriculum development [14], [22]. The visualization produced through Wright Maps allows researchers and educators to identify learning gaps and monitor progress over time [27]. These strengths demonstrate that the Rasch model can support detailed and valid mapping of students' botanical literacy levels in science learning [9], [11].

Although several studies have addressed botanical literacy, few have combined deep learning principles to systematically map students' understanding of plant concepts. Previous research has mainly focused on descriptive outcomes without exploring the diagnostic potential of Rasch-based measurement for identifying students' strengths and weaknesses. This research therefore aims to fill that gap by providing empirical evidence of students' botanical literacy levels through objective measurement. The purposes of this study are to analyze the item difficulty distribution of the botanical literacy test using the Rasch model, to describe students' plant literacy profiles across different aspects, and to examine students' literacy profiles per indicator to identify their strengths and weaknesses. Thus, the contribution of this study is to provide empirical and diagnostic evidence on students' botanical literacy levels through Rasch-based measurement, offering educators a detailed map of item difficulty and student abilities that supports the application of deep learning in science education.

2 Method

This study employed a quantitative research design to describe and measure students' botanical literacy through objective assessment. Quantitative research allows the identification of learning patterns and the analysis of relationships between test items and student abilities in a systematic and measurable way. The study was conducted with junior high school students in grade nine, involving a total of 253 participants who were selected using a purposive sampling technique to ensure that all respondents had received basic instruction on plant-related concepts.

The instrument used in this study was a Plant Literacy Test consisting of 30 items developed to measure students' conceptual and procedural

 https://doi.org/10.1051/epjconf/202534401038

understanding of plant science [11], [12]. The test included various question types such as true–false, short answer, matching, multiple-choice, complex multiple-choice, and essay to capture different levels of cognitive processing. The items were constructed based on indicators adapted from the botanical literacy framework of Pongsophon *et al.* [11], which integrates five aspects distributed across two domains: conceptual knowledge (plant diversity, plant morphology, and plant eco-physiology) and procedural knowledge (plant identification and planting and nurturing a garden). Each aspect represented a distinct set of indicators aligned with students' learning progression in understanding plant concepts.

Data were analyzed using the Rasch model, which provides a probabilistic approach to measuring the relationship between students' ability and item difficulty [19], [21]. The Rasch analysis converts ordinal scores into interval data, producing person and item measures that are directly comparable on a logit scale [14]. This approach allows the identification of item difficulty distribution and students' ability profiles, providing diagnostic insights into their strengths and weaknesses in botanical literacy [11], [14], [24]. The analysis was conducted with WINSTEPS software, focusing on Wright Map visualization to examine item difficulty distribution and students' literacy profiles by aspect and indicator [14]. The Rasch approach provided a clear representation of students' learning positions along a continuum, allowing for the identification of specific strengths and weaknesses in their botanical literacy [23], [24].

Fig. 1 flowchart of the research methodology showing the steps from instrument development to diagnostic interpretation using the Rasch model.

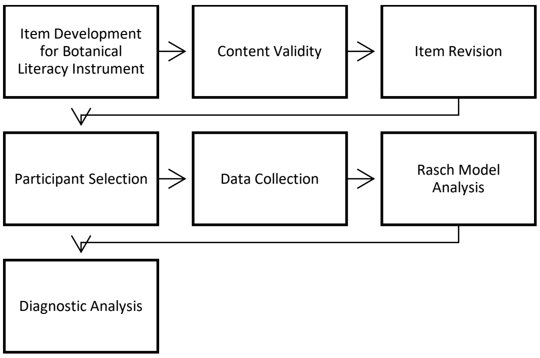

Fig. 1. Flowchart of the research methodology.

3 Results and discussion

This section presents and discusses the results of the botanical literacy mapping obtained through Rasch model analysis. The Rasch model enables the transformation of students' test responses into a measurable scale that compares item difficulty and student ability on the same continuum [14]. The results are presented in three parts: the distribution of item difficulty, students' botanical literacy profiles by aspect, and students' literacy profiles by indicator. Each result is followed by an interpretation that connects the empirical findings with theoretical perspectives of botanical literacy and deep learning. This integrated discussion aims to explain students' learning patterns and conceptual understanding of plant science, providing diagnostic insights that can inform meaningful learning improvement in science education [11], [15].

3.1 Item difficulty distribution

The Rasch analysis produced a Wright Map that displayed the distribution of item difficulty across different question types. The logit scale ranged from −1.0 to +1.5, showing that true–false items were the easiest while essay items were the most difficult. This variation indicates that the instrument successfully measured a wide range of cognitive levels, from basic recall to higher-order reasoning [28]. The item difficulty distribution based on the Rasch Wright Map is shown in Fig. 2. The ordering of question types follows a consistent cognitive progression: simple recognition questions such as true–false required minimal reasoning, while essay and complex multiple-choice items demanded deeper conceptual understanding and the ability to connect ideas [12].

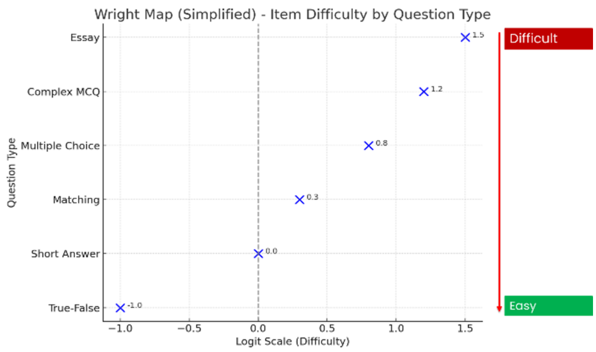

Fig. 2. Wright Map – item difficulty by question type.

The pattern of item difficulty also reflects the nature of students' learning approaches in science. Students found items that required reasoning and synthesis of plant functions more challenging than those that focused on factual knowledge. This finding aligns with studies showing that students often rely on memorization rather than conceptual reasoning when learning about plants [1], [5]. Similar trends were identified in research where students achieved intermediate levels of botanical literacy, particularly when items required analyzing plant processes instead of recognizing structural features [11], [12]. These findings confirm that conceptual understanding of plant science develops progressively and requires instructional approaches emphasizing reflection and interconnection rather than rote learning [8], [9].

The distribution of item difficulty further demonstrates the diagnostic capacity of the Rasch model in distinguishing different levels of student ability, which is one of the key [24] advantages of Rasch-based analysis [14]. The clear spacing between question types indicates that the items worked effectively along the continuum of difficulty, providing meaningful differentiation of cognitive demand [23], [25]. The increasing difficulty from factual to analytical question types shows that students' botanical literacy remains concentrated at lower cognitive levels, consistent with global findings that highlight plant awareness disparity and limited reasoning about plant functions [2], [4].

Overall, the Wright Map results suggest that students are more comfortable answering factual recognition questions than those requiring explanation or reasoning. This pattern indicates that most students' botanical literacy is still characterized by surface learning, emphasizing memorization instead of conceptual integration. Providing deep learning opportunities that encourage students to analyze and explain plant phenomena could help develop higher-level botanical literacy [15], [29]. Thus, the analysis of item difficulty offers diagnostic insights that can support teachers in designing instruction to strengthen students' reasoning and conceptual understanding of plant science [9], [11].

3.2 Students' botanical literacy profile by aspect

The analysis of students' botanical literacy by aspect shows that most students are at the medium level across all five aspects of plant literacy (Fig. 3). The highest proportion of students at the high level is found in the aspect of Plant Morphology (20.2%), while the lowest appears in Planting and Nurturing (11.0%). This distribution indicates that students understand visible plant structures better than the functional and applied aspects of plant care, reflecting an imbalance between conceptual and procedural knowledge [8], [11].

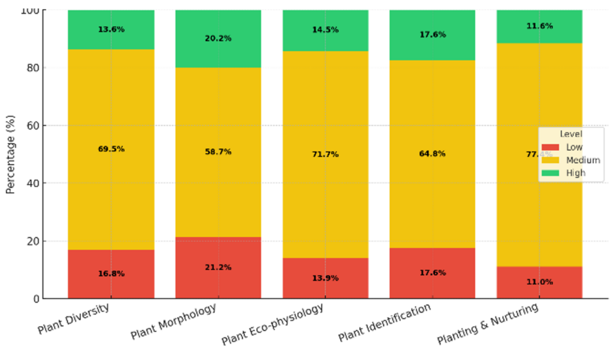

Fig. 3. Junior high school students' plant literacy profile by aspect.

The dominance of medium-level literacy across aspects suggests that students have achieved partial understanding but have not yet developed integrated reasoning about plant systems. Similar patterns were found in previous studies showing that students often perform better in factual or morphological topics than in ecological or procedural ones [1], [5]. The relatively low achievement in the Planting and Nurturing aspect indicates that learning experiences rarely involve direct engagement with plants, which limits students' ability to apply knowledge in real contexts [2], [13]. This finding also supports the notion that many classroom activities emphasize textbook-based content rather than experiential or inquiry-based learning [11], [12].

The results demonstrate that conceptual knowledge, such as plant morphology and diversity, tends to be more developed because it is frequently presented in visual and descriptive forms that are easy to memorize [4], [9]. In contrast, aspects requiring observation, experimentation, or long-term reflection such as planting, nurturing, and eco-physiology demand higher cognitive engagement and practical reasoning, which are less common in traditional science instruction [8], [30]. These differences highlight that students' botanical literacy remains focused on surface understanding, where learning outcomes are limited to recognition and recall rather than deep conceptual connection [2], [5].

Viewed from a deep learning perspective, these results indicate that students have not yet developed mindful, meaningful, and joyful engagement with plant-related learning [15], [29]. Deep learning requires that students not only remember plant facts but also interpret their relationships and relevance to real-life contexts, such as sustainability and biodiversity [17], [18]. The lack of hands-on and reflective learning experiences reduces opportunities for students to build such deep connections, especially in procedural aspects that involve active exploration and care for plants [9], [13].

The findings imply that science teachers need to integrate more inquiry-based, project-based, and experiential learning activities to promote deep understanding of plant concepts. Learning approaches that involve observation, experimentation, and plant cultivation can enhance students' ability to connect theoretical knowledge with practical experience [11], [12]. Therefore, improving students' botanical literacy across aspects requires learning designs aligned with deep learning principles, ensuring that conceptual, affective, and procedural dimensions are developed in balance to foster ecological awareness and sustainable thinking [15], [29].

3.3 Students' botanical literacy by indicator

The results of the botanical literacy profile by indicator reveal variation in students' performance across 30 indicators (Fig. 4). Indicators related to recognizing the characteristics of mosses, ferns, and gymnosperms show the lowest achievement, with a high proportion of students at the low level. In contrast, indicators such as identifying plants in the environment and classifying major plant groups record the highest achievement, with more students performing at the high level. This pattern indicates that students find it easier to identify and classify plants they encounter in their surroundings than to understand structural and reproductive characteristics of non-flowering plants [2], [5].

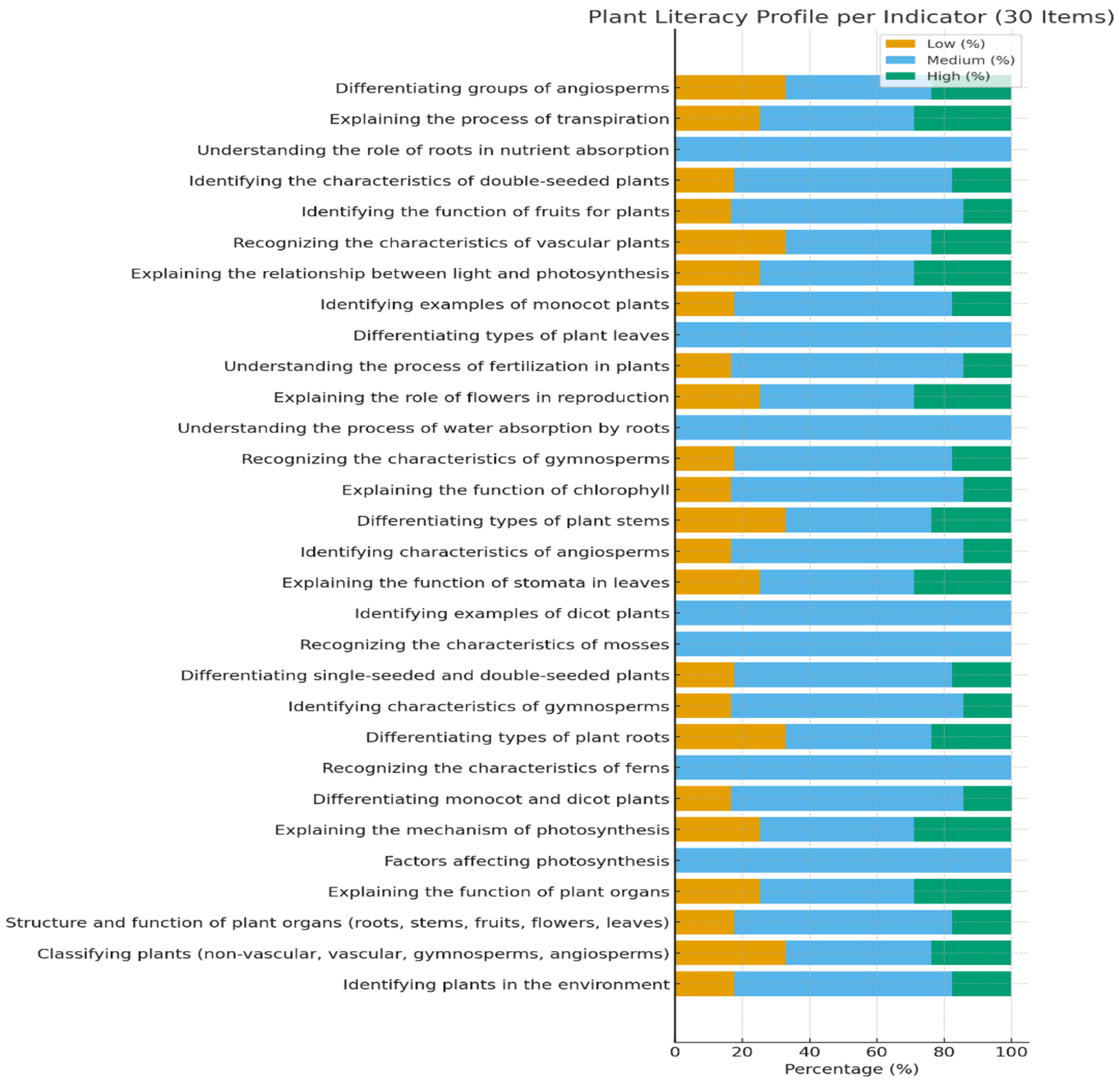

Fig. 4. Students' plant literacy profile per indicator (30 Items).

The diversity of performance across indicators reflects the uneven development of students' conceptual understanding. Students tend to achieve better results in indicators emphasizing observable characteristics and classification than those requiring abstract reasoning about plant physiology and reproduction [11], [30]. These findings are consistent with studies showing that many learners have limited exposure to direct observation or laboratory activities involving plant diversity, which leads to misconceptions about non-flowering and vascular plants [12], [13]. The uneven literacy pattern also indicates that students' learning experiences are often restricted to visual identification without engaging in analytical discussion about the ecological or functional roles of plants [4], [8].

The results confirm that students' strengths lie in factual and perceptual understanding, while weaknesses persist in indicators requiring causal or process-oriented reasoning. This condition aligns with the idea that plant-related learning in schools still emphasizes surface learning focused on recognition, rather than deep learning that integrates analysis, explanation, and reflection [29]. Students' limited understanding of non-flowering plants, for instance, suggests that they rarely engage in inquiry or experimental tasks that would help them connect plant structures with their ecological functions [9], [30]. Such patterns demonstrate the need to strengthen cognitive, affective, and psychomotor engagement simultaneously, so students can move from descriptive learning toward deeper conceptual reasoning [8], [11].

From a deep learning perspective, the variation across indicators reflects differences in how students construct meaning and transfer knowledge to real-life contexts. Deep learning emphasizes that students should not only identify or classify plants but also interpret their significance for sustainability and environmental balance [17]. The diagnostic profile in Fig. 3 provides teachers with concrete information to design learning activities that challenge higher-order thinking and promote reflective understanding of plant systems [24], [31]. Therefore, identifying students' strengths and weaknesses by indicator allows the development of instructional strategies that align with deep learning principles [16] and foster ecological awareness through more active [32] and inquiry-based science experiences [33].

4 Conclusion

Based on a Rasch analysis of students' botanical literacy, this study concluded that junior high school students generally exhibited moderate levels of literacy, with strengths in recognizing plant morphology and weaknesses in procedural aspects such as planting and care. The results also showed that across five aspects and thirty indicators, student understanding remained uneven, with students remaining weak in functional and ecological reasoning. These findings suggest that students' in-depth learning in botanical science remains limited, as they have not integrated conceptual knowledge into meaningful real-world contexts.

Theoretically, this study offers perspective on how item difficulty and student ability can be aligned to describe stages of botanical understanding within a deep learning framework.

A major limitation of this study lies in its sample size, which was limited to a single grade level, thus limiting the generalizability of the results. Future research should expand the participant pool, explore affective and environmental factors that influence botanical literacy, and examine the longitudinal effects of deep learning-based interventions. Such efforts will deepen theoretical understanding and foster the development of botanical literacy as an essential component of scientific literacy and environmental awareness.

This study was supported by the Research and Community Service Institute (LPPM) of Universitas Trunodjoyo Madura under the Independent Research Scheme for Beginner Researchers, Contract Number 132/UN46.4.1/PT.01.03/RISMAN/2025. The authors express sincere gratitude to the participating schools, teachers, and students for their cooperation and support during data collection. All data generated or analyzed during this study are available from the corresponding author upon reasonable request. All authors contributed equally to the design of the study, data collection, analysis, interpretation, and manuscript preparation.

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