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Instrument for assessing the attainment of students' scientific character indicators in cryptogamic botany laboratory activities

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Abstract

The integration of scientific character into learning, both explicitly and implicitly, is essential for fostering students' scientific attitudes and values. However, the assessment process is still often conducted directly and tends to be subjective. This study aimed to develop and validate an instrument for assessing the achievement of students' scientific character in the *Cryptogamic Botany* practicum. The instrument was trialed with 73 undergraduate students enrolled in the *Cryptogamic Botany* course. Data analysis involved *Pearson's* validity test and reliability analysis using *Cronbach's alpha* coefficient. The developed scientific character assessment instrument demonstrated strong validity, with 21 of 22 items meeting the criteria, and excellent reliability (*Cronbach's Alpha* = 0.962), confirming its feasibility for consistently measuring accuracy, curiosity, creativity, and honesty/objectivity in practicum contexts. The instrument offers a standardized and trustworthy tool for educators to evaluate scientific character development in practical learning settings.

Abstrak. *Integrasi karakter ilmiah ke dalam pembelajaran baik secara eksplisit maupun secara implisit menjadi sangat penting, namun proses penilaiannya masih dilakukan secara langsung dan cenderung lebih subjektif. Untuk mengatasi masalah tersebut dilakukan pengembangan instrumen untuk menilai ketercapaian karakter ilmiah. Tujuan penelitian untuk menguji kesahihan dan kehandalan instrumen penilaian karakter ilmiah mahasiswa pada kegiatan praktikum Cryptogamic Botany. Data dikumpulkan melalui uji coba instrumen yang telah disusun kepada 73 mahasiswa peserta mata kuliah Cryptogamic Botany. Analisis data dilakukan dengan uji validitas Pearson dan uji reliabilitas dengan standar Cronbach's alpha. Hasil penelitian menunjukkan terdapat 21 item indikator pernyataan dinyatakan valid dan 1 item dinyatakan tidak valid. Uji reliabilitas diperoleh nilai Cronbach's alpha sebesar 0,962 dengan kategori sangat reliabel. Hal ini mengindikasikan bahwa instrumen penilaian capaian karakter ilmiah mahasiswa ini dinyatakan sahih untuk digunakan, dan sangat handal untuk dipergunakan secara berulang dalam mengukur pencapaian karakter ilmiah teliti, rasa ingin tahu, kreatif, dan objektif atau jujur.*

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A. Introduction

Cryptogamic Botany is a 3-credit course that focuses on the study of lower plants, delivered through an integrated approach combining theoretical lectures and practical laboratory work. As a science-based course, it covers fundamental principles of botany, taxonomy, and nomenclature of lower plants, including algae, fungi, lichens, bryophytes, and pteridophytes. The course introduces students to the properties, characteristics, and phylogenetic relationships of major groups, as well as their taxonomic hierarchy, life history, geographical distribution, and significance to humans. The scope of the material includes external and internal structural features, anatomical characteristics, life cycle phases, ecological roles, and biodiversity. Overall, the intended learning outcome is for students to be able to analyze the morphological and anatomical characteristics of representative lower plant taxa.

Science education in twenty-first century emphasizes not only the mastery of scientific concepts but also the development and reinforcement of scientific character as an integral component of scientific literacy. One of the key principles of the scientific process is fostering a culture of integrity within the scientific endeavor itself (Kretser et al., 2019). Learning about lower plants (*Cryptogamic Botany*), which aims to develop an understanding of their characteristics, constitutes a scientific process that students must undertake. Strengthening character through such learning activities in higher education requires a well-integrated instructional plan (Wulansari et al., 2023).

Character education is essential for prospective biology teachers, encompassing the cultivation of values such as honesty, responsibility, tolerance, respect, and collaboration (Yusuf & Wulandari, 2025). Various instructional, learning, and pedagogical approaches have been proposed to foster morals, values, and ethics (Chowdhury, 2016). Furthermore, Błaszczak (2020) emphasizes academic honesty and encourages its practice in daily life, while Lal and Sharma (2023) promote research integrity through education and a culture of ethical conduct. In the effort to enhance individual quality, which in turn shapes a society that grows and develops through education, Manggaberani and Putro (2023) argue that the cultivation of good character serves as an internal motivation driving individuals to act in accordance with established norms. Good character encompasses aspects such as honesty, discipline, and social responsibility.

National Academies of Sciences (2017) states that scientific character encompasses adherence to moral principles such as integrity, objectivity, accountability, honesty, fairness, diligence, perseverance, creativity, cooperation, critical thinking, and independence. Scientific character reflects essential attitudes and values in scientific practice, including accuracy, curiosity, creativity, and honesty (OECD, 2019; Zeidler, 2014). Such character should be instilled early in learners, particularly pre-service teachers, so that they not only acquire cognitive understanding of science but also internalize scientific values as part of their professional identity (Kind & Osborne, 2016). Ajizah et al. (2024) sought to integrate scientific character into the *Cryptogamic Botany* laboratory manual as an effort to strengthen students' scientific character, an initiative that was well received by both lecturers and students. According to Iloka (2025) an important strategy for strengthening character is to integrate it across various fields of study.

Biology laboratory work serves as a strategic platform for developing and assessing scientific character. Through practical activities, students engage directly with natural phenomena, apply the scientific method, and confront challenges that require honesty, precision, and creative thinking. Laboratory experiences encourage students to think critically (Ali & Awan, 2021) and reflectively about natural phenomena, thereby supporting the development of scientific character, particularly curiosity and discipline in conducting research (Manishimwe et al., 2022), as well as fostering scientific integrity or honesty (Iloka, 2025). Therefore, it is essential to employ valid, reliable (Arifin et al., 2025; Manggaberani & Putro, 2023; Mistiani et al., 2022), and contextually appropriate instruments to assess the attainment of scientific character during laboratory activities.

Strengthening scientific character in laboratory activities is crucial, as it not only equips students with scientific skills but also fosters values aligned with scientific ethics, critical thinking, and social responsibility. Unfortunately, in higher education practice, the evaluation of scientific character is often implicit or poorly documented, partly due to the lack of valid and reliable assessment instruments (Kind & Osborne, 2016). In fact, systematic character assessment can serve as a vital foundation for improving learning processes, providing constructive feedback, and shaping graduates who excel academically while upholding scientific ethics (Bybee, 2013). Hidayah and Setiawati (2022) emphasize that character is part of the affective domain, and its evaluation necessitates both measurement and observation of how it is demonstrated in practice.

As a laboratory-based course, *Cryptogamic Botany* offers substantial opportunities for fostering and assessing students' scientific character. In practice, this course involves hands-on activities, microscopic examinations, as well as the determination and identification of lower plants such as algae, fungi, bryophytes, and pteridophytes—all of which demand precision, meticulous attention to detail, and adherence to scientific procedures. Nevertheless,

despite the suitability of such a learning environment for scientific character development, the assessment instruments employed are often unstandardized and lack psychometric validation, thereby limiting their reliability and generalizability.

This study aims to develop an observation instrument specifically designed to assess the attainment of students' scientific character during biology laboratory activities. The observed character dimensions include: (1) Accuracy, demonstrated through procedural precision and meticulous data recording; (2) Curiosity, reflected in exploration and critical questioning; (3) Creativity, shown in the ability to integrate observational findings with relevant literature; and (4) Honesty, evident in the truthful reporting of experimental results. The outcomes of this research are expected to contribute to the advancement of character assessment systems in science education, particularly within higher education contexts.

B. Material and method

This study employed a quantitative descriptive approach, beginning with the formulation of scientific character indicators to be observed. The scientific character indicators adapt the scientific attitude indicator formulation from Harlen (Wartawan, 2017). Then, the validity and reliability of the instrument were tested to assess students' scientific character achievement during the *Cryptogamic Botany* laboratory activities (see Figure 1). After developing a blueprint for each scientific character dimension potentially observable in each laboratory activity, achievement indicators were constructed in accordance with the specific characteristics of the practicum, as presented in Table 1. The instrument was piloted on 73 students. The sample was obtained through a census, with the students participating in the *Cryptogamic Botany* course, in the Department of Biology Education, Faculty of Teacher Training and Education, Lambung Mangkurat University, Banjarmasin, in May 2024. The trial data were analyzed using Pearson's Product Moment Correlation Test for validity (Cohen et al., 2017) and *Cronbach's Alpha* for reliability. Validity and reliability testing was conducted with the aid of SPSS version 26. Once proven valid and reliable, the instrument can be applied more broadly to assess the attainment of scientific character in Cryptogamic Botany laboratory activities.

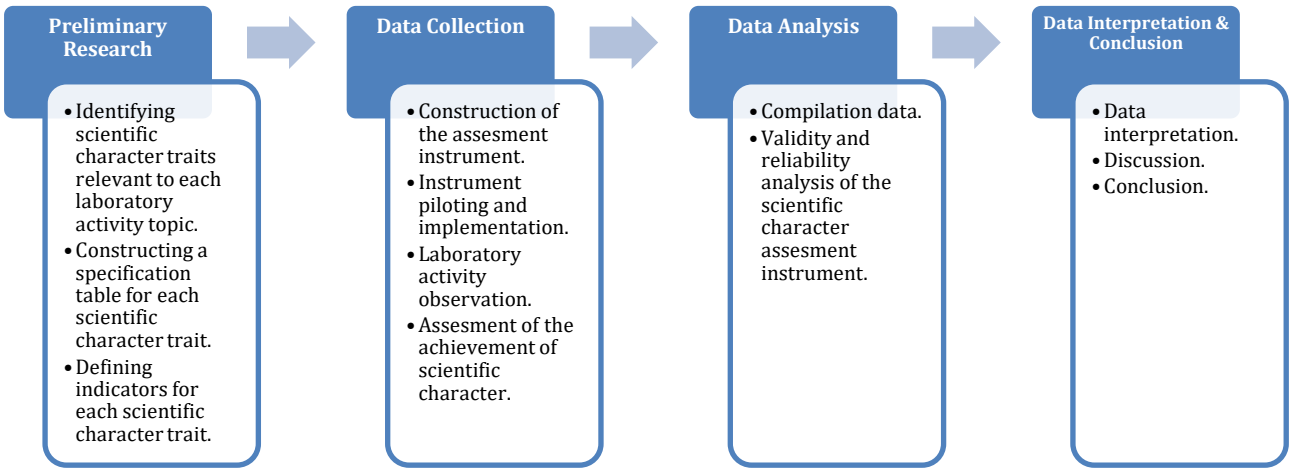

Figure 1 Procedures of instrument development

C. Results and discussion

Scientific character and Laboratory activities

A laboratory activity is a learning activity that involves observation, experimentation, and analysis of observed results. Laboratory activities are closely related to, and play a vital role in, the teaching and learning process of science (Putri et al., 2022), fostering the creation of knowledge, skills, and competencies in science education (Rakhmankulov & Usarov, 2019). Through laboratory work, learners can develop and refine their abilities and skills, and subsequently apply them in classroom learning (Thacker, 2024). Experiential learning through practice or demonstration also cultivates professional responsibility, honesty, and adherence to ethical principles (Mukharyamova et al., 2020).

Inquiry-based practice is highly recommended for educators as a means of enhancing scientific attitudes and learning outcomes in science (Zhang & Ma, 2023). Character education aims to shape individuals in accordance with moral and ethical values upheld by society. Certain character strengths—such as enthusiasm, perseverance, and perspective—are substantially and positively associated with learning enjoyment, academic self-efficacy, and school achievement (Amin et al., 2024; Weber & Harzer, 2022). Moreover, Alvarez et al. (2024) report that character strengths are significant predictors of self-efficacy among university students,

highlighting the need for their deliberate application in higher education.

Character education encompasses interrelated cognitive, affective, and psychomotor dimensions that mutually influence one another. The cultivation or development of character can be implemented through integrative and comprehensive approaches (Komalasari & Saripudin, 2022)—for instance, by embedding honesty and responsibility within academic subjects or learning activities to create an environment conducive to effective value internalization and have a positive impact where students develop honest and disciplined characters starting from morals, character, and attitudes (Astari et al., 2024). Its implementation in university courses requires integrated planning (Wulansari et al., 2023). In higher education, character education focuses on developing critical thinking and value-based skills relevant to future professional and personal challenges. While knowledge and skills may or may not be applied in future occupations, character qualities remain universally applicable across a wide range of professions (Bialik et al., 2015).

Scientific character encompasses adherence to moral principles such as integrity, objectivity, accountability, honesty, fairness, diligence, perseverance, creativity, cooperation, critical thinking, and independence (National Academies of Sciences, 2017). An important component of scientific character is the scientific attitude (Khun, 2021). Laboratory works are learning activities that engage students in scientific processes, requiring the demonstration of scientific attitudes such as honesty, objectivity, curiosity, openness to new ideas, and the ability to work systematically and collaboratively. Scientific character traits—such as accuracy, curiosity, honesty/objectivity, and cooperation—play a central role in laboratory activities (Gafur, 2014), each contributing to the enhancement of learning quality and research outcomes.

Laboratory activities aim not only to deepen students' understanding of subject matter but also to foster positive character traits that support their personal development. Character formation in students is the responsibility of every course (Kurniawaty et al., 2023). Several character values that can be developed through laboratory practicums include accuracy, responsibility, cooperation, perseverance, curiosity, and integrity (Gafur, 2014).

Accuracy is a critical aspect of laboratory activities. Scientists are required to perform measurements and observations with precision and to follow procedures meticulously. In the context of laboratory work, curiosity drives students or researchers to probe more deeply into observed phenomena and to test new hypotheses. A high level of curiosity motivates students to pursue further investigation beyond the prescribed procedures, which can lead to new findings and deepen their understanding of scientific concepts (Fauziah et al., 2019). Honesty and Objectivity are fundamental ethics in scientific practice. Laboratory activities require reporting experimental results truthfully, without data manipulation, thereby ensuring the integrity of science. The National Academies of Sciences (2017) emphasizes that objectivity in data collection and analysis is essential to ensuring that research findings are reliable and widely accepted within the scientific community. Creativity enables students not only to follow given instructions but also to develop innovative solutions, explore alternative approaches, and improvise when faced with complex experimental challenges. The study by Pinar et al. (2025) found that laboratory supportive of creativity tend to enhance student engagement in the learning process.

Instrument for assessing scientific character

The instrument was developed based on the previously formulated indicators of scientific character, with modifications to the scientific attitude assessment instrument proposed by Harlen (as cited in Suryani, 2016; Sole & Anggraeni, 2017). The development of the instrument items was derived from the classification of attitudes into dimensions or aspects of attitudes (Sole & Anggraeni, 2017). Furthermore, Harlen (as cited in Suryani, 2016) emphasized several principles in assessing scientific attitudes, namely: (1) assessment should be context-based, carried out while students are engaged in authentic scientific activities; (2) the focus should not be solely on the outcomes, but also on the processes of thinking and behaving; (3) it is essential to record evidence of actual behavior rather than assumptions; and (4) educators should apply clear and authentic criteria while avoiding subjective judgments or those based merely on general impressions. Furthermore, teachers are required to have the competence to design and develop assessment instruments as part of the learning process (Yanto et al., 2019).

The assessment of students' or pre-service teachers' performance in laboratory practicums was designed to align with curriculum demands, encompassing activities such as preparing measuring instruments, assembling apparatus, reading measurement results, recording data, analyzing data, and compiling reports (Rama, 2023). During practical work, students are essentially engaged in the scientific process. This process has the potential to foster the ability to act and behave scientifically; therefore, the scientific characters most likely to be involved in biology laboratory activities include accuracy, objectivity/honesty, curiosity, cooperation, discipline, and creativity (Gafur, 2014). In this study, the selected scientific characters were accuracy, curiosity, creativity, and objectivity/honesty, with the indicators for each character presented in Table 1.

Indicators for assessing the attainment of scientific character

The formulation of indicators for the attainment of scientific character is a strategic step in ensuring that the learning process is not solely oriented toward the mastery of concepts and scientific skills, but also toward fostering scientific attitudes and values in learners. Scientific character reflects personal qualities that support scientific thinking and behavior. The indicators, formulated in accordance with the characteristics of the scientific character traits of accuracy, curiosity, creativity, and objectivity/honesty, are compiled into an instrument designed to assess or observe the attainment of these traits in learners. The observation instrument, in the form of an observation guide, can be employed in systematic observations, wherein the observer conducts assessments based on pre-established guidelines. These guidelines contain a checklist of possible activities or activities to be observed (Aedi, 2010).

Table 1 Scientific character achievement assessment instrument

Achievement indicators of scientific character	Item	Notes
Accuracy		
- Demonstrates strong determination in completing assigned tasks	1	Valid
- Performs observations with care and thoroughness	2	Valid
- Complete observations carefully, so that you can immediately write down the results of the observations.	3	Valid
- Conducting cursory observations because the characteristics of the object are already in the teaching materials	4	Valid
- Observing objects down to the detailed parts (microscopic)	8	Invalid
- Focus more on observing things that are visible to the naked eye	9	Valid
- Prefer to complete observations immediately, so that you can complete the draft of the interim report.	19	Valid
- Expressing observation data as it appears at a glance.	21	Valid
Couriosity		
- Try to observe by detailing each object of observation	5	Valid
- Observe all morphological characteristics of the observed object	7	Valid
- Always seek information from literature and sources to complete observation reports.	13	Valid
- Always ask questions about things found during observations.	16	Valid
- Enjoy and be enthusiastic about observing every part of the object being observed	17	Valid
Creativty		
- Describe the characteristics of the object of observation by looking at the literature	6	Valid
- Demonstrates the ability to synthesize observational data with findings from literature or other relevant sources	12	Valid
- Seeks detailed morphological characteristics of each observed object through additional information sources	15	Valid
- Able to present observation results in a detailed and representative manner	18	Valid
- Demonstrates the ability to obtain information through books, other relevant sources, or online platforms	20	Valid
Objectivity/Honesty		
- Describes observation results in detail, accurately reflecting the findings obtained during the observation process.	10	Valid
- Utilizes or replicates characteristics found in examples and relevant literature	11	Valid
- Reports observation results exactly as found during the observation process	14	Valid
- Reports observation results exactly as found during the observation process, without referring to information from reading sources	22	Valid

Trial results of the scientific character achievement assessment instrument

The assessment instrument, developed based on indicators of accuracy, curiosity, creativity, and honesty/objectivity, was trialed with 73 students in the *Cryptogamic Botany* course at Universitas Lambung Mangkurat, focusing on the Lichenes practicum. The results of the instrument trial can be seen in Table 2.

Based on the data in Table 2, the data is then processed into a graph (Figure 2) to describe the variation in the achievement of scientific character indicators obtained by students more realistically. Figure 2 presents the distribution of students' scores across 22 indicators of scientific character, assessed using the developed scientific character assessment instrument. Overall, the results show that most students obtained scores of 4 and 5 on nearly all indicators, reflecting a high to very high level of scientific character achievement. The predominance of yellow (score 4) and light blue (score 5) across the indicators illustrates that the traits of accuracy, curiosity, creativity, and honesty/objectivity are well-established among the majority of students. These findings support Harlen's assertion that scientific character can be effectively fostered through learning activities that provide opportunities for exploration, observation, and independent reflection. Nevertheless,

three indicators were predominantly represented by grey (score 3), indicating that not all aspects of scientific character were optimally achieved by the students, particularly those related to problem-solving through creative thinking. This phenomenon suggests that although the majority of students demonstrated positive scientific character, further pedagogical reinforcement is still needed for certain indicators. Therefore, the integration of project-based, inquiry-based, and collaborative learning approaches is recommended to address these gaps (OECD, 2004; Chistyakov et al., 2023).

Table 2 Percentage of achievement of scientific character indicators

Indicators	Percentage of achievement of scientific character indicators				
	Score 1	Score 2	Score 3	Score 4	Score 5
1	0.0	3.1	3.1	71.9	21.9
2	0.0	6.3	12.5	50.0	31.3
3	0.0	9.4	12.5	62.5	15.6
4	0.0	6.3	46.9	37.5	9.4
5	0.0	0.0	15.6	68.8	15.6
6	0.0	0.0	18.8	68.8	12.5
7	0.0	0.0	12.5	68.8	18.8
8	0.0	9.4	31.3	46.9	12.5
9	0.0	15.6	37.5	31.3	15.6
10	0.0	3.1	31.3	53.1	12.5
11	0.0	0.0	25.0	56.3	18.8
12	0.0	3.1	25.0	59.4	12.5
13	0.0	0.0	25.0	56.3	18.8
14	0.0	0.0	21.9	56.3	21.9
15	0.0	0.0	21.9	62.5	15.6
16	0.0	0.0	18.8	59.4	21.9
17	0.0	0.0	9.4	59.4	31.3
18	0.0	15.6	37.5	46.9	0.0
19	0.0	15.6	50.0	31.3	3.1
20	0.0	9.4	21.9	53.1	15.6
21	0.0	0.0	50.0	46.9	3.1
22	0.0	6.3	56.3	37.5	0.0

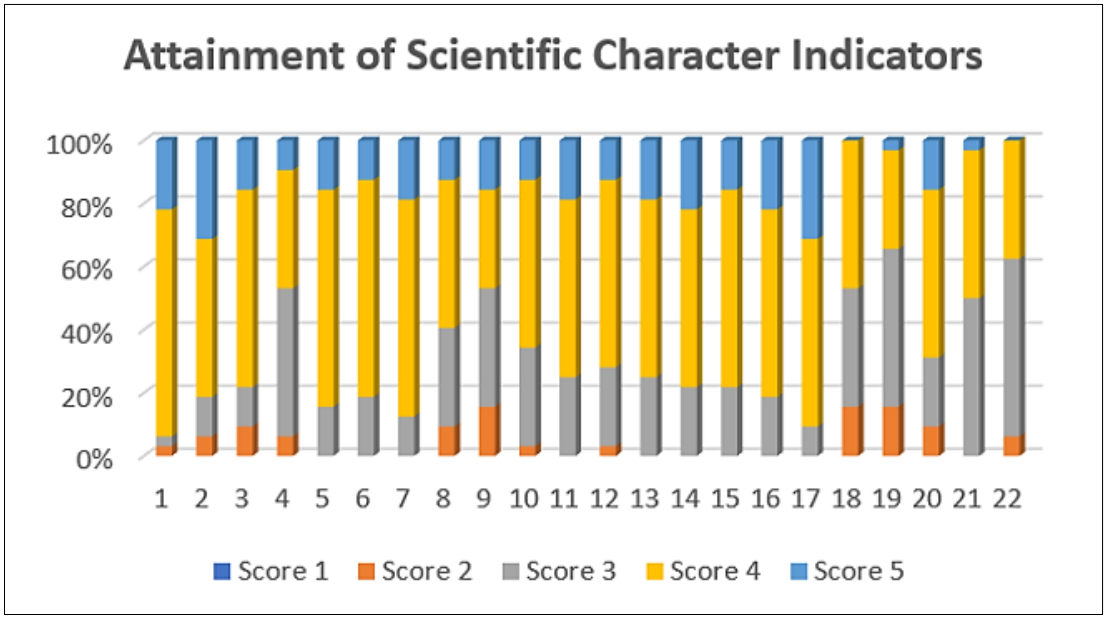

Figure 2 Attainment of scientific character indicators

Instrument of validity and reliability test

Validity refers to the meaningfulness of the research components, ensuring that researchers are able to measure what they intend to measure Cohen et al. (2017). The validity test aims to examine the extent to which the items in the instrument represent all aspects of the construct being measured. Reliability testing, on the other hand, seeks to determine the extent to which an instrument can produce consistent and stable results over time. In this study, reliability was assessed

through Internal Consistency Reliability, which evaluates the consistency of responses across items within the same instrument, using *Cronbach's Alpha* coefficient. An instrument is considered reliable if the Cronbach's Alpha value is ≥ 0.60. Conducting both validity and reliability testing is essential to ensure that the data obtained from the instrument are accurate and dependable.

The results of the instrument validation showed that there were 21 statement items declared valid with a range of r values (0.387-0.895) with a minimum r value at a 95% confidence level of 0.367. However, there was 1 statement item (item 8) that was invalid with an r value of 0.145. The item stated whether the respondent had conducted more detailed observations of objects down to microscopic parts. t. When the majority of items are valid and adequately represent the construct being measured, the instrument remains feasible for use, for instance by revising or removing the invalid item (Nunnally & Bernstein, 2025). This finding indicates that the instrument is still appropriate for assessing the achievement of scientific character in practicum activities. Validity testing aims to measure the extent to which an instrument or measuring tool can measure what it should measure (Cohen et al., 2017; Morad et al., 2021).

To ensure consistency of measurement, a reliability test was also conducted. Reliability refers to the extent to which an instrument yields consistent results when applied repeatedly, whether across different individuals, times, or conditions, using alternative instruments intended to measure the same construct (Cohen et al., 2017; Morad et al., 2021). As shown in Table 2, the elimination of the invalid item did not compromise the overall construct representation, as the remaining items sufficiently covered the intended dimensions of scientific character. Furthermore, the reliability analysis using *Cronbach's Alpha* demonstrated that the instrument possessed high internal consistency, confirming its feasibility for use in assessing students' scientific character achievement during practicum activities.

Table 3 Percentage of achievement of scientific character indicators

Reliability statistics	
Cronbach's Alpha	**N of items**
.962	21

A *Cronbach's Alpha* value of 0.962, indicating an exceptionally high level of internal consistency across all items in the instrument (see Table 3). Reliability is a crucial indicator of the extent to which an instrument can yield consistent measurement results over time and across different respondents. The high *Cronbach's Alpha* value suggests that the items are strongly intercorrelated in measuring the same construct—namely, students' scientific character—which encompasses dimensions such as accuracy, curiosity, honesty, and creativity.

Based on the *Cronbach's Alpha* criteria, a coefficient greater than 0.60 indicates that a questionnaire can be considered reliable. Referring to the classification proposed by George & Mallery (2024), an alpha value greater than 0.90 falls into the 'excellent' category. Therefore, the obtained value of 0.962 demonstrates that the instrument is highly reliable for use in assessing scientific character within practicum or project-based learning contexts. This implies that the questionnaire can be repeatedly administered to measure the achievement of scientific character in Cryptogamic Botany practicum activities.

The reliability test results further reinforce the feasibility of the developed instrument for consistently evaluating students' scientific character achievement. Instrument reliability constitutes a critical foundation for ensuring the validity of research findings and supports an objective and accurate evaluation process in science education.

D. Conclusion

In conclusion, the developed scientific character assessment instrument was found to be both valid and reliable. A total of 21 items were declared valid, with only one item not meeting the validity criteria, thereby confirming the adequacy of the instrument in measuring the targeted dimensions of scientific character, namely accuracy, curiosity, creativity, and honesty/objectivity. The obtained *Cronbach's Alpha* value of 0.962 indicates excellent reliability and internal consistency, suggesting that the instrument can be repeatedly applied to consistently assess students' scientific character achievement in practicum contexts.

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