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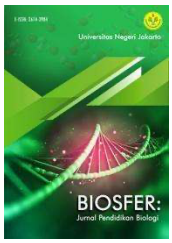

Development of instruments for problem-solving, cultural literacy, and conservation attitudes in biology education

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ABSTRACT

Assessment instruments are essential for evaluating students' competencies in biology learning, particularly problem-solving skills, cultural literacy, and conservation attitudes. However, validated instruments specifically designed for biosystematics and plant taxonomy learning are still limited. This study aims to develop assessment instruments that can be used to measure students' problem-solving skills, cultural literacy, and conservation attitudes in biosystematics and plant taxonomy learning. The study employed a research and development (R&D) approach by adapting the ADDIE model, focusing on the analyze, design, and develop stages. The instrument development process was carried out through theoretical studies, indicator determination, grid preparation, instrument item formulation, expert validation, limited testing, and validity and reliability analysis. The developed instruments consisted of a problem-solving skills test in the form of essay questions, a cultural literacy questionnaire, and a conservation attitude questionnaire using a Likert scale. Validation was conducted by two experts in Biology Education, assessing content, construct, language, appearance, and instruction aspects. The validation results indicated that all instruments were valid, with average scores of 4.25 for the problem-solving skills test, 4.375 for the cultural literacy questionnaire, and 4.25 for the conservation attitude questionnaire. Reliability analysis showed Cronbach's alpha values of 0.730, 0.910, and 0.733, respectively, indicating good to very high reliability. These findings demonstrate that the developed instruments are valid and reliable for assessing students' problem-solving skills, cultural literacy, and conservation attitudes. Future studies are recommended to conduct broader field testing to further examine the effectiveness and generalizability of the developed instruments.

INTRODUCTION

Biology education is oriented not only toward mastering concepts but also toward developing 21st-century competencies necessary in real life (Trilling & Fadel, 2009; Pamungkas et al., 2023). 21st-century skills include basic literacy, competencies, and character qualities that are increasingly important with the complexity of global challenges and the rapid development of digital technology (Yudhistian & Cintamulya, 2026). 21st-century learning emphasizes the development of critical thinking and problem-solving skills as essential competencies that students must master. Therefore, an assessment system is needed that accurately measures and reflects attainment of these competencies and is aligned with the intended learning objectives (Setiawan et al., 2021).

Problem-solving skills, cultural literacy, and conservation attitudes are three important competencies that should be developed through biology education, especially in the context of biosystematics and plant taxonomy. These three competencies not only support conceptual understanding of plant diversity and classification but can also help students relate scientific knowledge to the local environment and cultural context. Problem-solving skills enable students to systematically analyze and determine solutions to various biological problems (Hoskinson et al., 2014; Faizah et al., 2022), such as issues related to plant diversity and systematic conservation efforts. Cultural literacy helps students understand the relationships among biological knowledge, cultural practices, and the use of plants in community life (Aikenhead & Michell, 2011; Jamaluddin et al., 2025). A conservation attitude is important in biology learning because it fosters awareness and responsibility for biodiversity conservation (Palmberg et al., 2017; Ardoin et al., 2020). To systematically measure these abilities and attitudes, valid and reliable assessment instruments are needed.

Assessment is a crucial component of education that systematically and continuously measures students' abilities, and the quality of education is reflected in learning outcomes, which require the use of valid and reliable measurement instruments (Susilaningsih et al., 2026). Assessment instruments serve as tools for collecting data on students' abilities and attitudes, enabling accurate descriptions of learning outcomes. Instruments that have been tested for quality can obtain more accurate information about students' problem-solving abilities, cultural literacy, and conservation attitudes. The quality of an instrument is largely determined by its validity and reliability: a valid instrument measures the construct it is intended to measure, while a reliable instrument produces consistent data across conditions and over time. Testing validity and reliability is an important stage in the development of instruments to ensure that the data obtained represent the abilities and attitudes being measured (Sullivan, 2011). Assessment instruments with high validity and reliability enable researchers to obtain a more accurate picture of student learning outcomes and to evaluate the effectiveness of the learning process (Isnaini et al., 2025).

Previous studies have emphasized the importance of developing instruments for these three competencies in biology learning, but comprehensive assessment instruments that measure all three are still limited. Previous studies have developed instruments to measure attitudes toward the environment, interest in learning biology, research skills, scientific communication skills, and science literacy (Retnowati et al., 2020; Hardianti et al., 2017; Alfi et al., 2024; Marlina et al., 2025; Rahmawati et al., 2025). Other studies also use validated test instruments to measure students' biology literacy skills in the context of biology learning (Indriani et al., 2024). Most assessment instruments in biology learning still focus on measuring cognitive aspects, such as conceptual understanding and factual knowledge, while problem-solving skills, cultural literacy, and attitudes towards conservation have not been developed in an integrated manner.

The development of assessment instruments specifically designed for biosystematics and plant taxonomy courses is still limited, so efforts are needed to develop instruments that can measure these three aspects. The development of valid and reliable instruments is essential to obtain accurate information about student learning outcomes. The instruments developed in this study will be used to measure the effectiveness of *Culturally Responsive Teaching* (CRT)-based plant taxonomy e-modules in improving students' problem-solving skills, cultural literacy, and conservation attitudes. With instruments that have been tested for validity and reliability, the data obtained is expected to more accurately describe the impact of e-module use on student competency development.

The development of a good assessment instrument must go through a systematic process, including theoretical studies, indicator determination, instrument grid preparation, formulation of statement/question items, assessment rubric preparation (for tests), expert validation, instrument

testing, and validity and reliability analysis (DeVellis, 2021; Bandalos, 2018; Creswell & Creswell, 2018; Hinkin, 1998). Several studies have developed instruments for scientific literacy, environmental attitudes, and research competencies. However, existing instruments generally assess these constructs separately and are not specifically designed for biosystematics and plant taxonomy learning contexts. Moreover, limited attention has been given to cultural literacy and conservation attitudes as complementary competencies alongside problem-solving skills. Existing instruments also rarely incorporate the specific characteristics of biosystematics and plant taxonomy learning, where cultural knowledge and biodiversity conservation are strongly interconnected.

The novelty of this study lies in the development of an integrated assessment instrument that simultaneously measures students' problem-solving skills, cultural literacy, and conservation attitudes within the context of biosystematics and plant taxonomy. The development of this instrument is urgent because valid and reliable tools are required to accurately evaluate student competencies that extend beyond conceptual understanding. Based on the identified research gap and urgency, the research question is: What are the levels of content validity and reliability of the developed assessment instruments, as determined by expert evaluation and field-testing results?

METHODS

Research Design

This study uses a research and development (R&D) approach to develop and validate assessment instruments for biology learning. The development model used in this study adapts the ADDIE model**,** which consists of five stages, namely analyze, design, develop, implement, and evaluate (Branch, 2009). The present study focused on the development phase, which emphasizes expert validation and empirical testing of the developed instruments before their implementation in a broader educational setting. This phase is essential to ensure that the instruments meet acceptable standards of validity and reliability (DeVellis & Thorpe, 2021). The instruments developed included: (1) a problem-solving skills test, (2) a cultural literacy questionnaire, and (3) a conservation attitude questionnaire. These instruments were designed to support biology learning through a culturally responsive teaching (CRT) approach.

Research Procedure

This research focuses on the development and validation of an instrument to measure students' problem-solving skills, cultural literacy, and conservation attitudes. The research was conducted from initial construct identification to instrument validation and small-group trials. The study involved two expert validators in biology education and 10 undergraduate students who had completed the Biosystemics and Plant Taxonomy course for the small-group trials.

The instrument development process consisted of seven stages: 1) theoretical review, 2) indicator determination, 3) instrument grid development, 4) instrument item formulation, 5) expert validation, 6) instrument revision, and 7) small-group trials.

1. Theoretical review

A literature review was conducted to identify concepts and indicators relevant to problem-solving skills, cultural literacy, and conservation attitudes. Books, journal articles, and previous empirical studies were examined to establish a strong theoretical foundation for instrument development.

2. Determination of indicators

Based on the results of the theoretical study, the constructs to be measured are then broken down into several more specific indicators. Each indicator is designed to represent a dimension of the research variable, so that it can be used as a basis for developing instrument items.

3. Development of a grid

The instrument grid is developed as a guideline for developing questions or statements. The grid contains information about the indicators, indicator descriptions, and the number of statements/questions.

4. Formulation of statement/question items

Based on the grid that has been developed, the instrument items are then formulated in the form of statements or questions. For the cultural literacy and conservation attitude instruments, the items are formulated as closed statements using a Likert scale, whereas for the problem-solving ability test, the items are formulated as essay questions.

5. Expert validation

The instruments developed were then validated by two expert validators with competence in biology education. Validation was carried out to assess the suitability of the instructions, content, appearance, and language in each instrument. Input from the validators was used as a basis for revising and refining the instruments before testing.

6. Instrument revision

The instruments were revised based on feedback and recommendations provided by expert validators. Revisions included improvements to item wording, instruction clarity, language use, and alignment between items and indicators to enhance content validity.

7. Small-group trials

The revised instrument was then piloted in a small group on 10 students who had completed the Biosystematics and Plant Taxonomy course. Instrument testing was conducted to obtain empirical data for reliability analysis and to assess the readability of the instrument items.

Data Collection Techniques

The data obtained from the instrument's validation and testing were analyzed using statistical methods to determine its suitability. Content validity was assessed by two experts in Biology Education. The validators evaluated four aspects: content appropriateness, construction, language, and appearance. Each aspect was rated using a five-point Likert scale ranging from 1 (very poor) to 5 (excellent). In addition to assigning scores, the validators were encouraged to provide qualitative comments and suggestions for improvement. The pilot testing was conducted to obtain empirical data for evaluating the reliability of the instruments and to assess the readability and comprehensibility of the items. During the pilot test, participants were asked to complete all instrument components, including the problem-solving skills test, cultural literacy questionnaire, and conservation attitude questionnaire. Feedback from participants regarding unclear wording, ambiguous statements, or difficulties in understanding the items was also collected and used to improve the instruments.

Data Analysis Techniques

The determination of the total average validity (Va) of the instrument was carried out in several stages. First, the average score for each assessment aspect was calculated based on the results of expert validation. Next, the average across all aspects was calculated to obtain the Va value, an indicator of the instrument's overall validity. The validation scores obtained were then interpreted with reference to the criteria proposed by Hobri (2009), whereby the instrument was declared valid if the validity value (Va) was ≥ 4. The instrument's reliability was assessed using Cronbach's alpha, which measures the consistency of items. The Cronbach's alpha value obtained is then interpreted using the criterion that the instrument is considered to have good reliability if $\alpha \geq 0.70$ (Streiner, 2010), indicating that each item in the instrument has an adequate level of consistency in measuring the same variable.

RESULTS AND DISCUSSION

1. Instrument Development Results

The development of assessment instruments began with a theoretical study of problem-solving skills, cultural literacy, and conservation attitudes in biology education. Based on this study, each variable was broken down into several indicators, which were then used as the basis for developing the instrument grid. The indicators used in the problem-solving ability test were adapted from the framework proposed by Dörner & Funke (2017), which includes the abilities to a) define problems, b) find the causes of problems, c) select alternative solutions, and d) apply solutions effectively. The indicators used in the cultural literacy questionnaire refer to the dimensions of cultural literacy proposed by Hui & Cheung (2015), namely, a) multicultural literacy, b) global awareness, c) self-direction, d) higher-order thinking and good reasoning, e) cooperation and collaboration, f) interpersonal skills, g) personal responsibility, and h) social and civic responsibility. The conservation attitude indicators refer to Azwar (2013) attitude theory, which divides attitudes into three main components, namely a) cognitive, b) affective, and c) conative.

The instrument grid contains indicators, indicator descriptions, and the number of statements or questions developed. Based on this grid, an essay-type problem-solving test with 8 items was developed, with each indicator comprising 2 questions. Each question is assessed using a predetermined rubric, with a maximum score of 4 and a minimum of 1. The problem-solving test grid is shown in Table 1.

Table 1
Test Framework for Students' Problem-Solving Skills in Plant Taxonomy Learning

No.	Indicator	Description	Number of Questions
1	Defining the Problem	The ability to identify and clearly formulate problems based on available information, including determining the scope and understanding the context of the problem at hand	2
2	Finding the Cause of the Problem	The ability to analyze various factors that cause problems by examining the relationships between variables or conditions that affect the problem	2
3	Selecting Alternative Solutions	The ability to formulate several alternative solutions to a problem, then evaluate and select the most appropriate solution based on logical considerations and relevance to the problem	2
4	Effectively Implementi ng Solutions	The ability to implement the selected solution appropriately and evaluate the results of the solution's implementation to ensure that the problem is resolved properly	2
		Total	**8**

The cultural literacy questionnaire consisted of 32 statements, each indicator consisting of 4 statements. The statements were presented in a closed-ended format using a five-point Likert scale, :trongly agree, agree, disagree, strongly disagree, and very strongly disagree. The cultural literacy questionnaire grid can be seen in Table 2.

Table 2
Cultural Literacy Questionnaire Grid for Students in Plant Taxonomy Learning

No.	Indicator	Description	Number of Statements
1	Multicultural Literacy	The ability to understand, appreciate, and be open to cultural diversity, values, traditions, and different perspectives in society	4
2	Global Awareness	The ability to recognize intercultural connections and global issues and understand their impact on society	4
3	Self-Direction	The ability to manage and direct oneself in the learning process and develop a reflective attitude and responsibility for self-development in the context of cultural diversity.	4
4	Higher-Level Thinking and Good Reasoning	The ability to analyze, evaluate, and make decisions critically and logically about various social and cultural phenomena	4
5	Cooperation and Collaboration	Ability to work effectively with individuals from diverse cultural backgrounds to achieve common goals	4
6	Interpersonal skills	The ability to communicate, interact, and build positive relationships with others while respecting cultural differences	4
7	Personal Responsibility	The ability to demonstrate discipline, integrity, and commitment in carrying out personal roles and responsibilities in social and academic life	4
8	Social and Civic Responsibility	Ability to demonstrate concern, participation, and active contribution in community life and uphold civic values that respect cultural diversity	4
		Total	**32**

The conservation attitude questionnaire was developed into 30 statements, with each indicator consisting of 10 statements. The statements were arranged in a closed-ended format using a five-point Likert scale, namely very agree, agree, disagree, strongly disagree, and very strongly disagree. The conservation attitude questionnaire grid can be seen in Table 3.

Table 3
Conservation Attitude Questionnaire Grid for Students in Plant Taxonomy Learning

No.	Indicator	Description	Number of Statements
1	Cognitive	Components related to an individual's knowledge, understanding, beliefs, or perceptions of an attitude object	10
2	Affective	Components related to feelings, emotions, or individual assessments of an attitude object, such as liking or disliking, being interested or not interested in the object	10
3	Conative	Components related to behavioral tendencies or an individual's readiness to act toward an attitude object, as reflected in intentions, willingness, or actions taken	10
		Total	**30**

Each item of the instrument is designed with consideration given to the clarity of instructions, the suitability of content to indicators, neatness of appearance, and the use of language that is clear and easy for respondents to understand.

2. Expert Validation Results

The instruments that had been developed were then validated by two expert validators who were competent in the field of biology education. The validation was carried out to assess the suitability of the instruments, and the results of the validators' assessments are presented as follows. The assessment results for the problem-solving ability questions are presented in Table 4.

Table 4
Validity of Problem-Solving Ability Questions

No.	Aspect	Assessment Score		Average	Category
		Validator I	Validator II		
1	Construct	4.67	3.67	4.17	Valid
2	Content	4.67	4.00	4.33	Valid
3	Display	4.00	4.50	4.25	Valid
4	Language	4.00	4.50	4.25	Valid
	Average			4.25	Valid

The validation results for the problem-solving ability test instrument show that all aspects assessed by the validators are valid, with a total mean score of 4.25 on the scale. This shows that the developed instrument has been compiled with a systematic appearance and uses clear language that is easy for respondents to understand. These findings collectively suggest that the developed instrument is not merely valid in a statistical sense but also theoretically grounded and pedagogically coherent. The integration of construct, content, and presentation quality strengthens its potential use in authentic assessment contexts. This instrument can support lecturers in identifying students' problem-solving levels more accurately, while theoretically it reinforces the importance of aligning assessment design with both cognitive theory and domain-specific competencies in biology education, particularly in biosystematics and plant taxonomy learning. These findings are in line with the research by Setiawan et al. (2024), which states that construct and content validity are important evidence that the instrument accurately represents the competency indicators to be measured. The results of the study by Septiana & Hermanto (2024) show that clarity of language and systematic presentation are important components in instrument validation because they affect respondents' understanding of the questions. The results of the assessment of the cultural literacy questionnaire are presented in Table 5.

Table 5
Validity of the Student Cultural Literacy Questionnaire

No.	Aspect	Assessment Score		Average	Category
		Validator I	Validator II		
1	Instructions	5.00	4.50	4.75	Valid
2	Content	4.50	4.00	4.25	Valid
3	Display	4.00	4.50	4.25	Valid
4	Language	4.00	4.50	4.25	Valid
Total Average				**4.37**	**Valid**

The results of the validation of the student cultural literacy questionnaire also showed a valid category with a total average of 4.37, suggesting that it has met the essential requirements of content validity, construct alignment, and usability. These findings indicate that the questionnaire is not only statistically valid but also theoretically grounded and practically feasible for use in educational settings. It strengthens the idea that effective measurement of cultural literacy requires careful integration between conceptual indicators, linguistic clarity, and user-friendly design. The instrument can support lecturers and researchers in obtaining more accurate data on students' cultural literacy levels, while theoretically it contributes to the development of more refined and context-sensitive assessment tools in biology education and culturally responsive learning research. The results of the cultural literacy questionnaire validation, which showed a valid category, are also supported by the research of Cies´lak et al. (2025), which states that instruments for measuring cultural awareness need to undergo validity and reliability analysis so that each indicator can accurately represent cultural competence. The results of the conservation attitude questionnaire assessment are presented in Table 6.

Table 6
Validity of Student Conservation Attitude Questionnaire

No.	Aspect	Assessment Score		Average	Category
		Validator I	Validator II		
1	Instructions	4.50	4.50	4.50	Valid
2	Content	4.00	4.00	4.00	Valid
3	Display	4.00	4.50	4.25	Valid
4	Language	4.00	4.50	4.25	Valid
Average				**4.25**	**Valid**

The validation results for the student conservation attitude questionnaire indicate that all aspects of the assessment are valid, with a total averagmean25. These findings suggest that the conservation attitude questionnaire is both theoretically grounded and practically feasible for use in assessing students' attitudes toward conservation. It demonstrates coherence between theoretical constructs and operational indicators, while also maintaining user-friendly design principles. The instrument can be used to support educators in evaluating and fostering conservation attitudes in biology learning contexts, and theoretically, it reinforces the importance of integrating cognitive, affective, and behavioral dimensions in attitude measurement within environmental and biology education research. These results indicate that the developed conservation attitude instrument meets the validity criteria and is therefore suitable for measuring students' conservation attitudes in plant taxonomy and biosystematics learning. The results of the conservation attitude questionnaire validation, which fell within the valid range, indicate that each item accurately represented the measured attitude indicators. This is in line with the research by Milfont & Duckitt (2010), which shows that environmental attitude instruments developed through expert validation and psychometric analysis can comprehensively measure environmental attitude dimensions, including cognitive, affective, and behavioral components.

3. Reliability Test Results

The instrument's reliability was assessed using Cronbach's alpha to evaluate its internal consistency. The analysis showed that the developed instrument had a Cronbach's alpha≥ 0.70, indicating good reliability. The results of the reliability test of problem-solving skills are presented in Table 7.

Table 7
Reliability of Problem-Solving Ability Test

Cronbach's Alpha	N of Items
0.730	8

The reliability test for problem-solving ability yielded a Cronbach's Alpha of 0.730 with 8 items. This value indicates that the instrument has a high level of reliability, allowing it to consistently measure students' problem-solving abilities. The test instrument developed is capable of providing stable, relatively consistent measurement results when used with groups of respondents with similar characteristics. These results indicate that the developed problem-solving ability test meets the reliability criteria and is suitable for research to measure students' problem-solving abilities in biosystematics and plant taxonomy learning.

The problem-solving ability instrument developed in science education research shows good reliability, with a Cronbach's Alpha of 0.75, indicating adequate internal consistency for measuring students' problem-solving abilities (Ünal & Aral, 2014). Other research results also show that problem-solving ability tests have high reliability, with a Cronbach's Alpha of 0.825, indicating strong internal consistency in measuring students' problem-solving abilities (Rahmatullah et al., 2025). The results of the cultural literacy questionnaire reliability test are presented in Table 8.

Table 8
Reliability of the Cultural Literacy Questionnaire

Cronbach's Alpha	Number of Items
.910	32

The results of the cultural literacy questionnaire reliability test showed a Cronbach's Alpha of 0.910 with 32 items. A Cronbach's Alpha value above 0.90 is generally categorized as very high reliability, indicating that the instrument has very strong internal consistency. This value indicates that the developed cultural literacy questionnaire has a very high level of reliability. A high reliability coefficient indicates that each statement item in the instrument has good consistency in measuring students' cultural literacy levels.

The results of this study are in line with research on the development of a cultural competency questionnaire, which also obtained a Cronbach's Alpha value of 0.912, indicating that the instrument has very high reliability and can be used reliably to measure the construct being studied (Gol et al., 2019). Another study also reports that the cultural literacy instrument for students yielded a Cronbach's Alpha of 0.848, indicating high reliability and strong internal consistency (Takiddin et al., 2025). Furthermore, the results of the reliability test for the conservation attitude questionnaire are presented in Table 9.

Table 9
Reliability of the Conservation Attitude Questionnaire

Cronbach's Alpha	N of Items
0.733	30

The results of the conservation attitude questionnaire reliability test showed a Cronbach's Alpha of 0.733 with 30 items. This value indicates that the developed instrument has a good level of reliability. A reliability coefficient above 0.70 indicates that the questionnaire items are sufficiently consistent in measuring students' conservation attitudes. The results of this study are in line with the research by Panjaitan et al. (2022), namely that the pro-environmental conservation attitude instrument for students showed excellent reliability (Cronbach's Alpha = 0.90), indicating that the instrument was valid and reliable for measuring students' conservation attitudes. Another study on the development of an environmental attitude scale reported a Cronbach's Alpha of 0.76 for the developed scale, indicating adequate internal consistency in measuring environmental attitudes (Tan & Guler, 2024).

CONCLUSION

Based on the research findings, it can be concluded that the assessment instruments developed

to measure students' problem-solving skills, cultural literacy, and conservation attitudes in biosystematics and plant taxonomy learning have met the established feasibility criteria. Validation by two experts indicated that all instruments were categorized as valid, with average scores of 4.25 for the problem-solving skills test, 4.375 for the cultural literacy questionnaire, and 4.25 for the conservation attitude questionnaire. Furthermore, the reliability analysis demonstrated good internal consistency, with Cronbach's Alpha coefficients of 0.730, 0.910, and 0.733, respectively. These results confirm that the instruments are both valid and reliable for assessing the targeted competencies. The findings have important practical implications, as they provide educators and researchers with standardized assessment tools to evaluate and monitor students' development of higher-order competencies in biosystematics and plant taxonomy courses.

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