



Development and Validation of an Ethnochemistry-Based Cultural Literacy Instrument in Higher Education

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ABSTRACT

The problem and the aim of the study. Cultural literacy is an essential competency for students in multicultural higher education contexts. However, valid, reliable, and contextually grounded instruments for measuring students' cultural literacy, particularly those integrated with local potential, remain limited. *This study aims* to develop and validate an ethnochemistry-based cultural literacy instrument capable of measuring students' cross-cultural knowledge, attitudes, and skills.

Research Methods. This study employed a research and development approach using a modified Borg and Gall model, encompassing item formulation, instrument development, content validation, and construct validation. Content validity was established through expert judgment using Aiken's V, while construct validity was examined through Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and Partial Least Squares–Structural Equation Modeling (PLS-SEM) using SmartPLS. Data were collected from 250 students selected through proportional stratified random sampling.

Results. The analysis revealed a five-factor structure comprising 23 valid indicators after eliminating two items that did not meet the factor loading criteria. The data were suitable for factor analysis, as indicated by a KMO value of 0.853 and Bartlett's Test of Sphericity, $\chi^2 = 1626.684$, $df = 300$, $p < .001$. The CFA results supported the five-factor model, with $\chi^2 = 423.357$, $df = 265$, $p < .001$. The Composite Reliability values ranged from 0.718 to 0.765, while the Average Variance Extracted values ranged from 0.559 to 0.651, indicating acceptable construct reliability and convergent validity. The Fornell–Larcker results also confirmed discriminant validity, as the square roots of AVE exceeded inter-construct correlations.

Conclusion. Ethnochemistry-based cultural literacy constitutes a valid and reliable multidimensional construct, and the validated five-factor model contributes to strengthening culturally contextualized science education in higher education.

KEYWORDS

instrument development; instrument validation; construct validity; cultural literacy; ethnochemistry; partial least squares structural equation modeling (PLS-SEM); higher education

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INTRODUCTION

Twenty-first-century higher education is directed not only toward producing graduates with strong academic mastery and professional skills, but also toward shaping individuals who are able to live and contribute in a multicultural global society [1]. UNESCO emphasizes the importance of education that promotes respect for cultural diversity and intercultural dialogue [2]. In the same context, UNESCO also views global citizenship education as an effort to develop learners who are able to think critically, respect differences, and act responsibly in a global society [3]. The Council of Europe affirms that education needs to develop democratic and intercultural competences so that learners are able to live together in culturally diverse societies [4]. In line with this, the Education for Sustainable Development agenda positions education as a means of developing the knowledge, skills, values, and attitudes needed for sustainable living [5]. The Sustainable Development Goals agenda, particularly SDG 4, also emphasizes the importance of inclusive, equitable, and quality education that supports lifelong learning [6]. In this context, cultural literacy needs to be developed in higher education because it helps students understand cultural values, appreciate differences, build cross-cultural communication, and reflect on the relationship between knowledge, culture, and community sustainability [2].

In line with these international agendas, the relevance of developing cultural literacy in higher education can be explained through three main considerations.

1. Cultural literacy is an essential competence for students in facing the complexity of intercultural interactions [7]. Students are not only required to understand cultural differences but also to adapt, communicate, and build tolerant social relationships in academic life and society [8]. Therefore, higher education institutions have a strategic responsibility to equip students with socio-cultural skills, appreciative attitudes, collaborative abilities, and contextual learning experiences [9]. Strengthening these competences supports the formation of critical and reflective global citizens who are able to live harmoniously in multicultural societies [10]. In the Indonesian higher education context, this effort is also in line with the Merdeka Belajar Kampus Merdeka policy, which emphasizes the strengthening of soft skills and transformative learning experiences [11].

2. The integration of cultural literacy into higher education curricula promotes more inclusive learning environments [12] and enhances students' social awareness in understanding multicultural societal dynamics [13]. Intercultural understanding becomes stronger when supported by campus environments responsive to diversity [14]. Nevertheless, despite its strategic importance, assessment frameworks for measuring students' cultural literacy remain limited [15]. Existing instruments are often not developed through comprehensive validation processes [16]. Most studies have focused on other forms of literacy, such as digital literacy [17] and scientific literacy [18]. Available cultural literacy instruments tend to be descriptive and frequently rely solely on basic reliability testing [19]. Such methodological limitations may generate biased data [20], potentially affecting the effectiveness of multicultural educational interventions and policy formulation in higher education [21].

3. From a methodological perspective, instrument validation is a fundamental prerequisite to ensure accurate measurement of student competencies. Numerous studies have validated general literacy instruments, such as scientific and digital literacy, using Exploratory Factor Analysis (EFA) to identify factor structures [8], while Confirmatory Factor Analysis (CFA) has been widely employed to confirm construct validity [22]. However, comprehensive development of cultural literacy instruments remains scarce. Existing instruments often assess only knowledge and attitudes [9], neglecting intercultural skills relevant to global challenges [10]. Some studies emphasize students' perceptions of cultural literacy [13], while others integrate it with civic literacy [23], resulting in cultural literacy not being the primary focus. Moreover, most research has not adequately incorporated local contexts [15], despite Indonesia's cultural diversity necessitating instruments aligned with national higher education realities [20]. This condition indicates that cultural literacy in higher education remains underdeveloped and requires strengthening through more relevant and comprehensive instrument development [24].

Accordingly, the following practical needs emerge:

- the development of an integrated cultural literacy instrument measuring knowledge, attitudes, and intercultural skills;

- the development of contextually relevant instruments grounded in local potential-based learning, particularly ethnochemistry;
- the implementation of rigorous validation approaches to ensure instrument validity and reliability in higher education.

To address these needs, this study proposes a methodological framework combining factor analysis and SmartPLS-based Structural Equation Modeling (SEM) to ensure instrument validity and reliability [25]. Validation began with expert judgment to establish content validity [26], followed by Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) to identify and confirm the factor structure. Construct validity (convergent and discriminant) and reliability were subsequently tested using Partial Least Squares–Structural Equation Modeling (PLS-SEM) through Composite Reliability, Cronbach’s Alpha, and Average Variance Extracted (AVE) indicators [27].

Therefore, this study aims to develop and validate an ethnochemistry-based cultural literacy instrument for higher education students. The research hypothesis posits that the developed instrument demonstrates adequate validity and reliability, evidenced by an appropriate factor structure, fulfillment of construct validity criteria, and satisfactory internal reliability in accordance with higher education measurement standards.

MATERIALS AND METHODS

This study was conducted using a research and development (R&D) approach aimed at developing and validating an ethnochemistry-based cultural literacy instrument for higher education students. The instrument development framework was adapted from the Borg and Gall model, modified to align with the characteristics of higher education instrument research, particularly in the stages of indicator formulation, item development, and validity and reliability testing [28].

Methodologically, the study integrated both theoretical and empirical approaches. The theoretical approach was employed to examine the concepts of cultural literacy, intercultural competence, and the integration of ethnochemistry into local wisdom-based learning. The empirical approach involved field data collection and statistical analysis to ensure that the developed instrument constructs corresponded with empirical evidence [15].

The study was implemented in four main stages: (1) item formulation, (2) initial instrument development, (3) content validation, and (4) construct validation.

1. Item formulation was based on a conceptual framework of cultural literacy encompassing knowledge, attitudes, and intercultural skills. These dimensions were operationalized into indicators relevant to ethnochemistry learning contexts, particularly traditional Sasak natural dyeing practices. Indicator development considered intercultural communication studies emphasizing students’ adaptive and interactive competencies [8], as well as contextual learning approaches integrating local cultural values into higher education [22].

2. Instrument development involved constructing an initial draft in the form of a closed-ended questionnaire using a five-point Likert scale. Items were developed through literature review, focus group discussions with students, and input from course instructors. The instrument was administered in printed format to ensure distribution consistency. Each item was clearly worded, contextually grounded, and included both positively and negatively phrased statements to minimize response bias [29].

3. Content validation was conducted through expert judgment involving three experts in education, culture, and research methodology. Experts assessed the alignment between indicators, items, and the cultural literacy construct. Content validity was analyzed using Aiken’s V coefficient [30], a widely used technique in educational instrument development research [31].

4. Construct validation was conducted using multivariate statistical analysis. Initially, Exploratory Factor Analysis (EFA) was applied to identify the latent factor structure and determine the number of retained factors [32]. The resulting structure was subsequently tested using Confirmatory Factor Analysis (CFA) to assess model fit with empirical data [33]. CFA enabled rigorous examination of relationships between observed indicators and latent constructs and ensured consistency with the

conceptual framework [34]. To strengthen construct validation, Partial Least Squares Structural Equation Modeling (PLS-SEM) was applied using SmartPLS version 4. This approach assessed convergent validity, discriminant validity, and construct reliability through factor loadings, Composite Reliability, and Average Variance Extracted (AVE) [35].

The study involved 250 higher education students selected through proportional stratified random sampling to ensure representation across academic programs. Data were collected offline using printed questionnaires to maintain response consistency and minimize misunderstanding [27].

Data analysis proceeded systematically according to the development and validation objectives. Preliminary tests included Kaiser–Meyer–Olkin (KMO) and Bartlett’s Test of Sphericity to assess data adequacy. EFA and CFA were sequentially applied to evaluate construct stability and clarity. Reliability was assessed using Cronbach’s Alpha to determine internal consistency [35], while Composite Reliability and AVE were used to confirm construct reliability and convergent validity [36]. Through these procedures, a valid, reliable, and contextually grounded instrument suitable for higher education based on local wisdom was obtained.

RESEARCH RESULTS

This section presents the results of the development and validation of the ethnochemistry-based cultural literacy instrument for higher education students, conducted using a research and development approach, as described below.

1. Item formulation

Item formulation was based on a conceptual framework of cultural literacy encompassing three primary dimensions: knowledge, attitudes, and intercultural skills. These dimensions were operationalized into indicators relevant to the ethnochemistry learning context, particularly traditional Sasak natural dyeing practices. The knowledge dimension focused on students’ understanding of the scientific principles underlying natural dyeing processes, including acid–base concepts, reaction rates, chemical bonding, and the influence of pH and temperature on color stability. The attitude dimension emphasized students’ awareness and commitment to preserving local culture, including appreciation of the symbolic values and cultural identity embedded in traditional dyeing practices. Meanwhile, the intercultural skills dimension included students’ ability to interact, adapt, and actively participate in culturally grounded exploratory activities using scientific approaches, in line with intercultural communication studies that highlight contextual adaptation and interaction [9]. The integration of local cultural values into learning also considered contextual learning approaches relevant to higher education [22]. Based on the mapping of these indicators, 25 initial Likert-scale items were developed. All items were designed to proportionally represent the integration of scientific aspects and cultural values. The outcome of this stage was the initial draft of the ethnochemistry-based cultural literacy instrument consisting of 25 items.

2. Initial instrument development

The initial instrument was developed based on the previously formulated indicators in the form of a closed-ended questionnaire using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The instrument was prepared in printed format to ensure ease of distribution and consistency in responses. Item construction followed several systematic steps:

- a literature review on cultural literacy and contextual learning,
- limited focus group discussions with students to ensure clarity and comprehensibility of item wording, and
- input from course lecturers to ensure alignment with academic context.

A total of 25 initial items were constructed by integrating natural dye chemistry concepts with Sasak local cultural values. Each item was clearly and contextually worded and included a combination of positively and negatively phrased statements to minimize response bias, as recommended in educational instrument development [29]. To illustrate the scope of the instrument content, a summary of dimensions and representative item examples is presented in Table 1.

Table 1 Ethnochemistry-Based Cultural Literacy Instrument

Dimension	Representative Statements
Scientific Understanding of Dyeing (SUoD)	Students are able to explain the scientific relationship between traditional Sasak textile dyeing processes and local culture; understand chemical principles (acid–base reactions, chemical bonding, and reaction rates) involved in traditional dyeing; and explain the influence of pH and temperature on the stability of natural dyes.
Cultural Preservation Awareness (CPA)	Students understand the role of natural dyes as part of Sasak cultural identity, recognize the importance of preserving natural dyeing practices for cultural sustainability, and are able to analyze the challenges of maintaining natural dye traditions in the modern era and global market.
Exploration Interest and Participation (ElaP)	Students demonstrate interest in directly learning traditional Sasak dyeing processes, conducting field observations, testing color stability through scientific experiments, and participating in sustainable natural dye training activities.
Critical and Analytical Reflection (CaAR)	Students are able to critically evaluate the use of synthetic dyes compared to natural dyes, assess the environmental impacts of traditional dyeing processes, and reflect on the role of chemistry in preserving local cultural heritage.
Cultural Appreciation and Promotion (CAaP)	Students appreciate the diversity of traditional dyeing techniques in Indonesia and show willingness to promote scientifically grounded traditional textile dyeing practices to the broader community.

3. Content validation

Content validation was conducted through expert judgment involving three specialists in education, culture, and research methodology to assess the alignment among the indicators, item statements, and the ethnochemistry-based cultural literacy construct. Analysis using Aiken’s V coefficient indicated that all 25 items met the feasibility criteria, with values ranging from 0.83 to 0.95, reflecting a high level of expert agreement. Based on the validators’ feedback, several minor revisions were made to improve clarity and cultural contextual accuracy. No items were eliminated during the content validation stage.

4. Construct Validation

4.1 Data Adequacy Testing and Exploratory Factor Analysis (EFA). Data adequacy was examined using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett’s Test of Sphericity. The results revealed a KMO value of 0.853 and a Bartlett’s Test result of $\chi^2 = 1626.684$, $df = 300$, $p = 0.000$ (Table 2). These findings indicate significant inter-item correlations and confirm that the dataset was suitable for further analysis using factor analysis, consistent with construct validation approaches described by Ahmad et al. [37].

Table 2 KMO and Bartlett’s Test

Statistic	Value
Kaiser–Meyer–Olkin (KMO) Measure	0.853
Bartlett’s Test of Sphericity (Chi-square)	1626.684
Degrees of Freedom (df)	300
Significance (p-value)	0.000

The EFA results identified five factors with eigenvalues greater than 1.0. The scree plot (Figure 1) demonstrated a sharp decline up to the fifth factor, followed by a gradual leveling off, indicating that five factors were retained as the latent structure of the students’ cultural literacy instrument. The determination of the number of factors was based on the eigenvalue criterion and the scree plot inflection point, both of which are widely employed in prior research [38]. This approach is considered effective in identifying empirically stable factor structures [39] and is commonly applied in educational and social instrument development studies [40]. The consistent application of these procedures further strengthens the validity of the resulting factor structure [41].

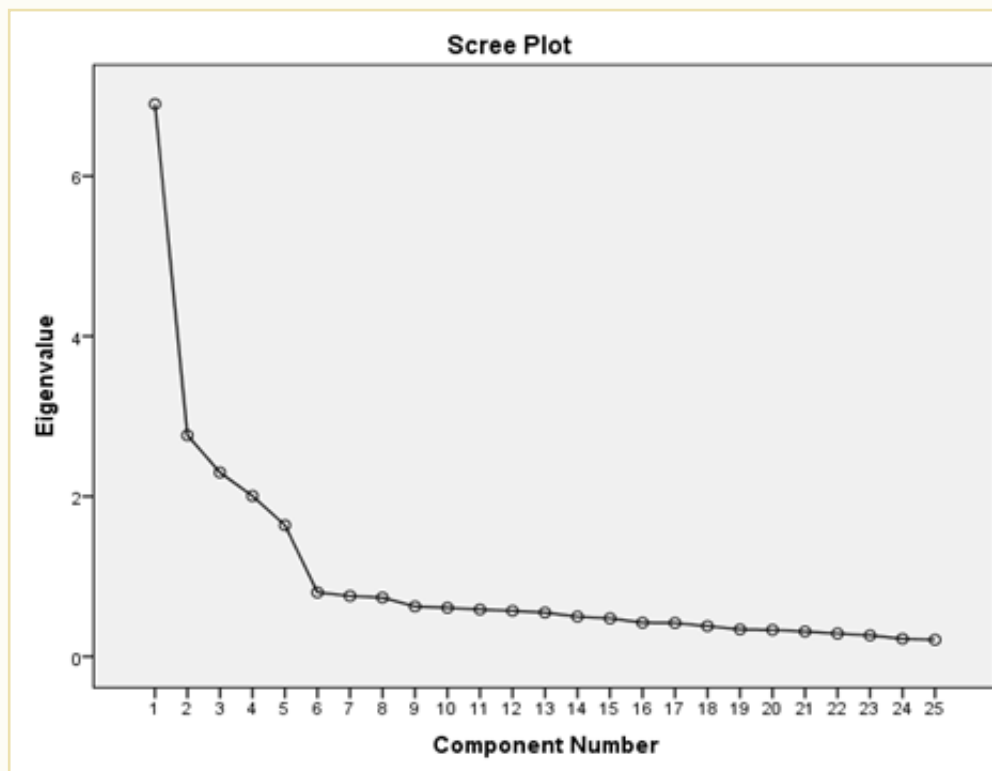


Figure 1 Scree Plot

The relationship between the number of extracted factors and the eigenvalues resulting from the Exploratory Factor Analysis (EFA)

4.2 Confirmatory Factor Analysis. The model fit results (Table 3) indicate that the five-factor model demonstrates a good fit to the data. The Chi-square value for the factor model ($\chi^2 = 423.357$; $df = 265$; $p < 0.001$) was lower than that of the baseline model ($\chi^2 = 1056.244$; $df = 300$), indicating an improvement in model fit [37]. This finding is consistent with previous research suggesting that lower Chi-square values reflect better model fit [34]. Model evaluation was further supported by additional fit indices, including $CFI \geq 0.95$ [42] and $RMSEA \leq 0.06$ [43]. Based on these indicators, the five-factor model demonstrates strong empirical and theoretical fit [36] and confirms the stability of the developed construct structure [44].

Table 3 Model Fit (Chi-square Test)

Model	χ^2	Df	p-value
Baseline model	1056.244	300	-
Factor model	423.357	265	< .001

The model evaluation showed that the indicators generally met the required criteria. Nevertheless, one item (C14) was eliminated because its factor loading was below 0.50. This refinement was conducted to strengthen the measurement structure and improve the empirical quality of the CFA model (Figure 2). This elimination was conducted to strengthen the Average Variance Extracted (AVE) and Composite Reliability values, in accordance with SEM analysis recommendations [35] and established CFA-based construct validation practices [34].

Covariance analysis revealed strong relationships among the five constructs, particularly between SUoD and CPA, and between CPA and CAaP, reflecting the integration of cognitive and affective dimensions in cultural literacy. This integration of scientific and cultural aspects aligns

with the characteristics of interdisciplinary learning grounded in local contexts [45]. The findings are consistent with prior studies emphasizing the importance of integrating conceptual dimensions and cultural values to enhance model validity [46], the effectiveness of structural approaches in constructing holistic literacy frameworks [47], and the cohesion among dimensions in cross-cultural educational measurement models [48]. These results are further supported by other latent construct-based instrument development and validation studies [49].

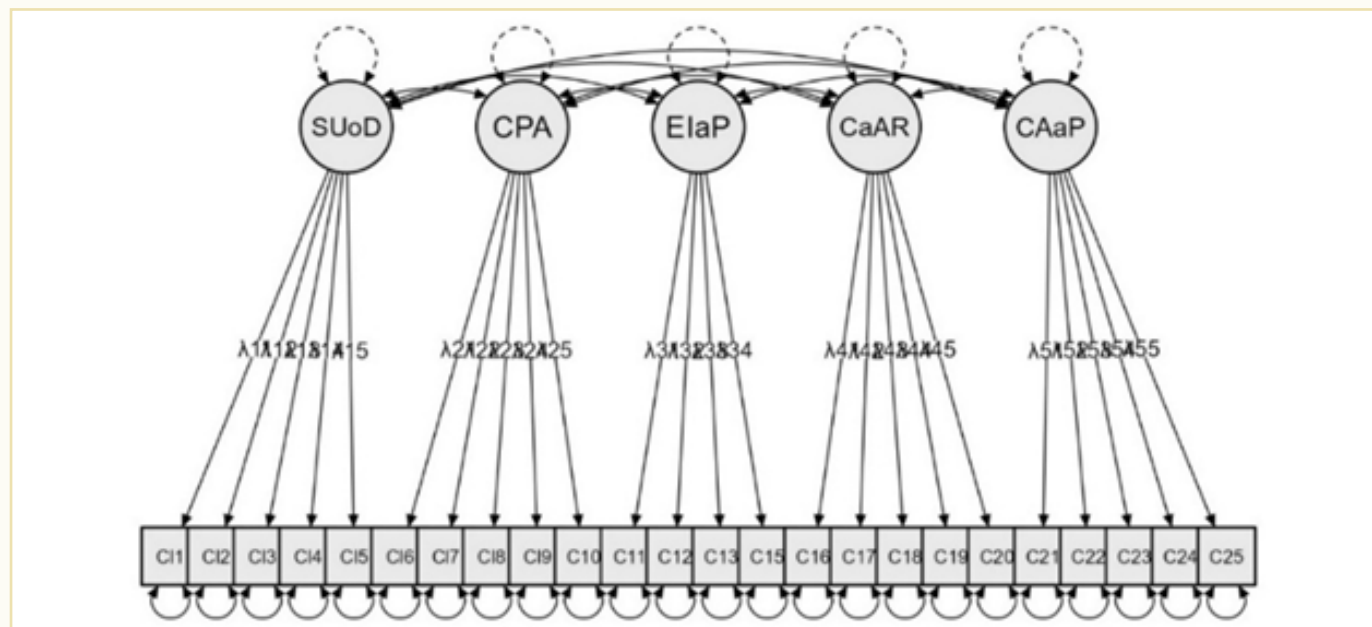


Figure 2 CFA Model after the Elimination of One Item with a Factor Loading < 0.50

4.3 Reliability Testing. The reliability analysis yielded a Cronbach's Alpha value of 0.749, with a 95% confidence interval ranging from 0.635 to 0.838, indicating stable internal consistency after the refinement of items with inadequate factor loadings. This finding supports the use of Cronbach's Alpha as an effective measure for assessing the stability of educational instruments grounded in local contexts [29]. The results are consistent with previous studies [40] and research on local potential-based instrument development [50]. Accordingly, the ethnochemistry-based cultural literacy instrument is considered reliable for consistently measuring the five principal dimensions: SUoD, CPA, EIaP, CaAR, and CAaP [27].

4.4 PLS-SEM Analysis. To further strengthen construct validation, PLS-SEM analysis was conducted using SmartPLS 4 as follows:

1. **Convergent Validity.** The outer model results indicated that most indicators had factor loadings > 0.70. One additional item (Q19) was eliminated for failing to meet this criterion. The final model consisted of 23 valid indicators. The Composite Reliability and Average Variance Extracted (AVE) values for all constructs are presented in Table 4.

Table 4 Construct Reliability and Validity

Construct	Composite Reliability	Average Variance Extracted (AVE)
Scientific Understanding of Dyeing (SUoD)	0.747	0.629
Cultural Preservation Awareness (CPA)	0.731	0.608
Exploration Interest and Participation (EIaP)	0.746	0.590
Critical and Analytical Reflection (CaAR)	0.718	0.559
Cultural Appreciation and Promotion (CAaP)	0.765	0.651

All constructs demonstrated Composite Reliability values > 0.70 and AVE values > 0.50 , indicating satisfactory reliability and convergent validity.

2. Discriminant Validity. The Fornell–Larcker criterion results showed that the square root of AVE values (0.748–0.807) exceeded the inter-construct correlations (0.224–0.426). These findings satisfy the discriminant validity criteria, indicating that each construct empirically measures distinct aspects within the ethnochemistry-based cultural literacy model, consistent with latent construct evaluation guidelines [35].

3. Structural Model. The final PLS-SEM model consisted of 23 indicators after the elimination of two items (C14 during the CFA stage and Q19 during the PLS-SEM stage) due to factor loadings < 0.70 . All retained indicators demonstrated loadings ranging from 0.75 to 0.85. The R^2 values of endogenous constructs ranged from 0.049 to 0.221, indicating modest explanatory power. The relationships among constructs were positive and consistent with the theoretical framework of ethnochemistry-based cultural literacy. The structural relationships among constructs are presented in Figure 3. The indicator purification and model evaluation procedures followed the recommendations of Hair et al. [35] and Ghomi and Hussein [47].

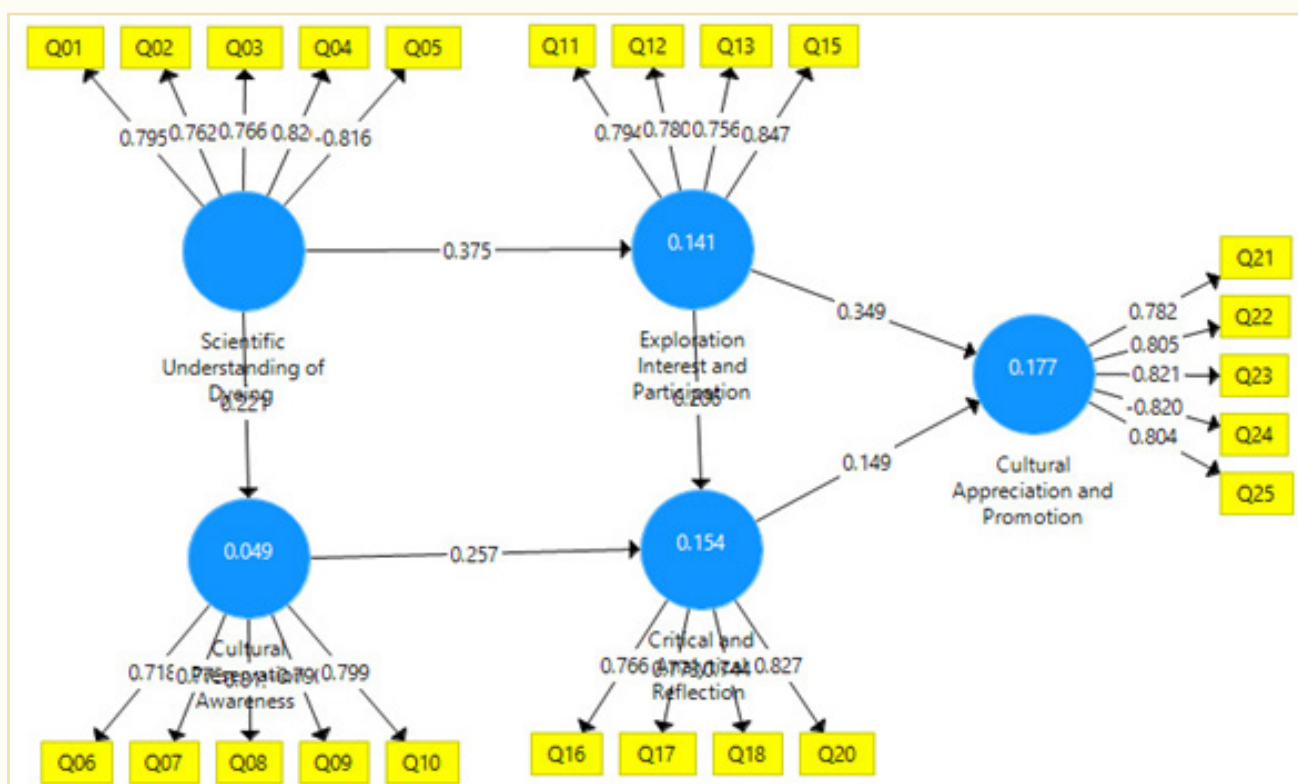


Figure 3 PLS-SEM Structural Model of Cultural Literacy

DISCUSSION

The findings of this study demonstrate that the ethnochemistry-based cultural literacy instrument possesses a stable and empirically consistent multidimensional structure. The five factors identified through EFA and CFA, Scientific Understanding of Dyeing, Cultural Preservation Awareness, Exploration Interest and Participation, Critical and Analytical Reflection, and Cultural Appreciation and Promotion, confirm that students' cultural literacy is not unidimensional but is constructed through the interaction between scientific knowledge and local cultural values [50]. This structure allows the present study to propose a variant of cultural literacy instrument development grounded in the integration of scientific understanding and local wisdom through an ethnochemistry approach.

The identified five-factor structure further indicates that students' cultural literacy reflects a staged internalization process. Each dimension represents a distinct yet interconnected phase: conceptual understanding of scientific principles, awareness of cultural sustainability, experiential

engagement, reflective evaluation, and socially oriented cultural promotion. This finding reinforces the view that cultural literacy extends beyond attitudinal dispositions and instead emerges from the dynamic interaction among knowledge, experience, and critical reflection within locally contextualized learning environments [49].

The strong relationship between scientific understanding of natural dyeing processes and cultural preservation awareness suggests that mastery of chemical concepts functions as an epistemological foundation for the development of cultural attitudes. Students who understand acid–base principles, reaction rates, and the influence of pH and temperature on color stability tend to exhibit stronger awareness of the importance of preserving traditional practices. This finding indicates that the integration of science and culture is not merely symbolic but forms a causal linkage within the structure of students' cultural literacy [45].

Moreover, the association between cultural preservation awareness and the dimensions of cultural appreciation and promotion reveals a transformation from internal consciousness to broader communicative and social orientation. Cultural literacy thus progresses from conceptual understanding to reflective engagement and social action, supporting the perspective that literacy development involves stages of comprehension, evaluation, and value-based action [46].

The dimensions of exploratory participation and critical reflection occupy a strategic position as bridges between cognitive and affective components. Active engagement in traditional dyeing exploration, field observation, and scientific experimentation facilitates evidence-based reflection while strengthening awareness of environmental sustainability and cultural relevance in contemporary contexts. This integration supports structural approaches that combine scientific reasoning and reflective inquiry in constructing holistic literacy frameworks [47].

From a methodological standpoint, the stability of the measurement model following item elimination indicates that instrument refinement enhanced rather than diminished conceptual clarity. The purification process conducted during CFA and PLS-SEM strengthened construct validity and improved model quality, consistent with best practices in educational instrument development [35]. The fulfillment of discriminant validity criteria further confirms that the five dimensions measure distinct yet complementary aspects within the ethnochemistry-based cultural literacy framework [36].

Overall, the developed instrument contributes both theoretically and pedagogically. Theoretically, it advances the conceptualization of cultural literacy as an integrated system linking cognitive, affective, and reflective dimensions within science education. Pedagogically, it provides educators with a comprehensive tool to assess how students understand, reflect upon, and internalize cultural values through scientific inquiry. In this sense, cultural literacy is repositioned not as an auxiliary competency but as an integral component of locally grounded, sustainability-oriented science learning in higher education.

CONCLUSION

This study confirms that students' cultural literacy in higher education constitutes a multidimensional construct integrating scientific understanding, cultural value awareness, exploratory participation, critical reflection, and appreciative and promotional orientations toward local culture. The ethnochemistry-based approach enables a systematic integration of scientific and cultural domains through the context of traditional Sasak natural dyeing practices.

The results of Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and PLS-SEM demonstrate that the developed five-dimensional structure exhibits satisfactory validity and reliability. The indicator refinement process resulted in a stable and consistent measurement model, indicating that the ethnochemistry-based cultural literacy instrument is appropriate for application in higher education contexts.

The resulting instrument functions not only as an assessment tool but also as an integrative conceptual model linking scientific knowledge with cultural values and sustainability. Methodologically, this study contributes to the development of contextually grounded cultural literacy instruments. Pedagogically, the findings support the implementation of science learning rooted in local wisdom and oriented toward strengthening students' cultural competence.

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