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The Validity and Reliability of the Cognitive Engagement Instrument (CEI) for Student Participation in Science-Based on Local Wisdom

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Abstract

Local wisdom-based approaches are an important strategy in making science learning more contextual and meaningful for students. However, there is no specific instrument available to measure students' cognitive engagement in local culture-based learning. The existing instruments are still general and do not reflect specific cultural dimensions. This study developed the Cognitive Engagement Instrument (CEI), a new measuring instrument that combines the ICAP (Interactive, Constructive, Active, Passive) theory with the context of local wisdom. The aim was to analyze the validity and reliability of the CEI in measuring students' cognitive engagement. A total of 711 junior high school students from various regions in Indonesia participated in an online survey using a 5-point Likert scale. The results showed 37 valid items in four factors. The CFA model showed a good fit, with high reliability ($\alpha = 0.756-0.938$; $\omega = 0.764-0.939$).

Keywords: Cognitive Engagement, Science Local Wisdom.

Introduction

Local wisdom-based science learning is essential to enhancing the relevance and significance of science materials in students' real lives. This approach facilitates the integration of scientific concepts with the cultural experiences of students, making the learning process more contextual and meaningful. In the context of science learning, various local traditions and practices in Indonesia have been utilized as teaching tools. For instance, the *Larung Sembonyo* tradition represents fluid physics concepts such as Archimedes' law, ocean waves, work, and energy (Rizkina et al., 2024); the traditional *Nekeran* game teaches momentum and impulse (Wardani & Mundilarto, 2021); plaiting activities in South Central Timor encompass concepts of force, friction, Newton's laws, acceleration, and pressure (Husin et al., 2022); and the *Ancak Robyong* tradition illustrates balance, Newton's laws, and light reflection (Nadzirin et al., 2024). Additionally, the concept of parabolic motion is demonstrated through the practice of carbide cannons (Matsun et al., 2019), while the physics parameters of the *Minangkabau* aerophone musical instrument are also incorporated into learning (Afrizon et al., 2020). Other forms of

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local wisdom, such as *Long Bumbung* (Hudan Ramadhan et al., 2019), traditional games related to impulse and momentum (Permata Sari et al., 2019), and case studies on sound misconceptions through the practice of Marinyo in the Tanimbar Island (Batlolona & Jamaludin, 2024) further enrich alternative approaches to contextual science learning.

The implementation of science learning based on local wisdom is a strategic step in realizing an education that is contextual, relevant, and supportive of the socio-cultural characteristics of students (Khusniati et al., 2017; Usmeldi & Amini, 2020). This approach accommodates cultural diversity as a source of learning and provides opportunities for students to build scientific understanding through experiences that reflect their reality (Anwari et al., 2016; Hastuti et al., 2020; Ilhami et al., 2019). However, the effectiveness of this approach has not been fully supported by adequate evaluative tools, especially in comprehensively measuring students' cognitive engagement. The limited instruments that can capture the dynamics of cognitive engagement in the context of local culture pose obstacles in empirically assessing the success of this learning strategy. The urgency of this research lies in the need to develop measuring instruments capable of evaluating students' cognitive engagement in science learning that is contextual and rooted in local culture. Currently, most student engagement measurement instruments are generic and do not consider cultural aspects integral to the learning process (Barlow et al., 2020; Greene, 2015; Smiley & Anderson, 2011; Tripathi et al., 2025). In fact, within the context of local wisdom-based education, culture serves as a background and a source of learning. This highlights a research gap that has not been widely addressed—the development of cognitive engagement measurement instruments that meet psychometric standards while being rooted in local values prevalent in society. This study presents novelty by developing a cognitive engagement instrument that explicitly integrates local cultural elements as the main variable. This represents the states of the art in science education evaluation studies as it combines a contextual pedagogical approach with an instrument design responsive to cultural diversity, an area that has been minimally.

Therefore, developing an instrument specifically designed to measure cognitive engagement in the context of local wisdom-based science learning is an urgent need in science learning and related to content that involves science in its processes. Such an instrument is needed to overcome the limitations of measuring instruments that have been generic and have not considered the cultural dimension as an integral part of the learning process. The development of the cognitive engagement instrument refers to the ICAP (Interactive, Constructive, Active, Passive) theoretical framework, which comprehensively classifies forms of learning engagement based on the level of cognitive activity involved (Chi et al., 2018; Chi & Wylie, 2014).

The integration of the principles in the ICAP (Interactive, Constructive, Active, Passive) framework with elements of local wisdom aims to develop an instrument that represents students' cognitive engagement contextually and meaningfully. This instrument is designed to measure the extent to which students are involved in the learning process, not only in physical and mental activities but also in relevant local cultural values that influence their daily lives. The instrument development process is conducted through a series of strict validation and reliability testing procedures to ensure the accuracy and consistency of the measurement results. These procedures include content validity, construct validity, and empirical validity tests, resulting in an instrument that is not only conceptually and contextually relevant but also meets scientific standards and is suitable for educational practice. Based on this background, this study aims to analyze the validity and reliability of the cognitive engagement instrument based on science and local wisdom. The main objective of this study is to validate and test the instrument's reliability

in identifying students' cognitive engagement in various science learning contexts rooted in local wisdom. This study is expected to contribute significantly to developing assessment instruments that are more sensitive to students' cultural and social aspects. This is important because effective science learning emphasizes mastery of scientific concepts and encourages students' active involvement in understanding and linking science to their experiences and cultural environment. Thus, the results of this study are expected to serve as a reference for educators in evaluating students' cognitive involvement in a more contextual, objective, and meaningful way. In addition, these findings can also enrich the approach to science learning or learning activities related to science based on local values.

Methods

Participants & procedure

This study involved 711 high school students from various regions, selected through a voluntary sampling technique that included 64% male and 36% female participants. This technique was chosen because it allows participants to engage in the study voluntarily, facilitating researchers' efforts to reach many respondents from different areas. Additionally, this approach is considered efficient given the limited time and resources. Data collection was conducted online using a previously prepared and validated digital questionnaire. Before distribution, this instrument was initially validated by two experts, including those in the field of education. The validation process ensured that each question in the questionnaire was clear, relevant, and capable of accurately measuring the intended aspects. Once validation was completed and the instrument was deemed feasible, the questionnaire was distributed to participants via various digital platforms. The experts provided feedback on the clarity of language, the appropriateness of the indicators for the concepts measured, and the relevance of the questions to the context of students in Indonesia. After making revisions based on this feedback, the instrument was tested on a limited basis to assess readability and internal consistency before being used for the main data collection. Subsequently, the questionnaire was distributed through social media and learning platforms commonly used by students, such as WhatsApp. Before completing the questionnaire, participants were informed about the research's purpose, data confidentiality guarantees, and their right to withdraw without facing consequences.

This theory categorizes learners' cognitive engagement into four main categories: Passive, Active, Constructive, and Interactive. In the Passive (receiving) category, learners absorb information without engaging in additional meaningful activities, such as merely listening to lectures or reading without taking notes. Meanwhile, in the Active (manipulating) category, learners perform simple physical or mental actions, such as highlighting text or copying notes, but have not yet created new knowledge. The Constructive (producing) category indicates learners' involvement in developing new understandings, such as compiling summaries in their own words or posing critical questions about the material being studied. The highest category, Interactive (dialogue), describes participation in two-way or collaborative discussions, where learners build on each other's ideas and refine their understanding.

This instrument was then modified to align with science-based local wisdom learning activities. The measurement scale used was a five-point Likert scale, with response options: 1 = Very Unsuitable, 2 = Unsuitable, 3 = Quite Suitable, 4 = Suitable, and 5 = Very Suitable. The instrument developed in this study consisted of 48 statement items arranged into four categories of cognitive engagement according to ICAP theory. Each category reflects the level of student involvement in science-based local wisdom learning through various individual and

collaborative activities. All statement items in this instrument are organized to represent each category of cognitive engagement and are systematically presented in Table 1.

Indicator	Item codes	Statement Items
Interactive	I-1	I discuss with friends about the relationship between local phenomena and science concepts.
	I-2	I work together with groups in completing observation-based tasks in the environment
	I-3	I give and receive ideas from friends in solving science problems related to local culture.
	I-4	I actively engage in dialogue in groups when discussing experimental results that contain elements of local culture.
	I-5	When discussing science problems based on local culture, I actively question/debate my friends' opinions
	I-6	I actively ask questions when discussing science materials based on local wisdom
	I-7	Through discussion activities, I am able to generalize new knowledge/deeper knowledge related to science materials based on local wisdom
	I-8	In science discussions based on local wisdom, there is an exchange of ideas between me and my friends, resulting in new ideas
	I-9	In dialogue with friends about I defend ideas when discussing learning materials based on local wisdom
	I-10	I actively assess/criticize my friends' ideas when discussing science materials based on local wisdom
Constructive	C-1	I develop conclusions from observations made in the field
	C-2	I try to explain natural phenomena by linking them to local community knowledge.
	C-3	I create new ideas or scientific solutions based on an understanding of local culture/wisdom.
	C-4	I write reports or create presentations that summarize scientific concepts from local practices.
	C-5	I take notes on local wisdom-based science learning materials using my own words
	C-6	In the process of learning local wisdom-based science, I try to compare the new knowledge gained with previous knowledge/other materials.
	C-7	To be able to understand science more deeply, I connect new knowledge with previous knowledge based on culture/local wisdom
	C-8	I develop new understanding from the results of science learning activities based on local wisdom
	C-9	I am able to explain aloud the new understanding obtained through science learning activities based on local wisdom
	C-10	I try to make a plan to solve problems/cases given by the teacher
	C-11	Produce predictions for the plans that have been formulated

Indicator	Item codes	Statement Items
	C-12	I try to connect the cause and effect of science material phenomena and relate them to local wisdom
	C-13	In the science learning process, I ask questions by relating them to local culture
	C-14	I formulate problems from the results of observing local culture in science learning
	C-15	Compare and contrast various cases in the field based on local culture in the science learning process
	C-16	I integrate information from various sources about the relationship between local phenomena and science concepts.
	C-17	I evaluate myself in terms of new knowledge/understanding with previous understanding of science concepts with local culture
Active	A-1	I take notes of important information when observing local cultural practices relevant to science.
	A-2	I carry out experiments according to the instructions/procedures given by the teacher in an effort to understand how science concepts relate to local culture
	A-3	I actively ask questions when I do not understand the relationship between science and local practices.
	A-4	I explore or search for additional information about the topic being discussed.
	A-5	I repeat the information obtained from the teacher
	A-6	I actively seek out local culture in the surrounding environment that is closely related to scientific concepts.
	A-7	When reading I underline or color important information about local science and cultural concepts.
	A-8	I summarize information while reading about science concepts and their relationship to local cultural practices.
	A-9	During the process of observing local culture relevant to science concepts using video media, I pause or slow down the video when I need time to understand it
Passive	P-1	I just listened to the teacher's explanation without participating in the discussion.
	P-2	I am not very involved in observation or exploration activities when studying outside the classroom.
	P-3	I am not interested in connecting science lessons with the local culture around me.
	P-4	I just did the assignment out of obligation, without really understanding the content.
	P-5	While reading I did not note down/summarize information related to scientific concepts and local wisdom.
	P-6	While reading, I did not underline/color information related to scientific concepts and local wisdom.

Indicator	Item codes	Statement Items
	P-7	During observation or exploration activities outside the classroom, I only observed without noting down important information that was relevant between local culture and science concepts.
	P-8	When the teacher explained the concept of science and its relationship to local culture, I just paid attention and listened to the lecture without doing anything else.

Table 1. Question Items for the Cognitive Engagement-Science-Local Wisdom Instrument

Data Analysis

Data analysis in this study was conducted through three stages: Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and internal consistency testing using Cronbach's Alpha. The EFA stage aims to explore the latent structure of the instrument and identify the factors that form the measured construct (Fabrigar et al., 1999). Furthermore, CFA is used to confirm the factor structure identified in the previous stage while also testing the model's suitability to empirical data using various goodness of fit indicators such as CFI, TLI, RMSEA, and SRMR (Mueller & Hancock, 2015; Smiley & Anderson, 2011; Streiner, 2006). Construct validity is assessed based on the loading factor value, ideally above 0.40, and a significant relationship between indicators and factors (Cheung et al., 2024; Shrestha, 2021). Meanwhile, the instrument's reliability is tested through Cronbach's Alpha, where a value above 0.70 indicates a good level of internal consistency between items in one construct (Taber, 2018; Trabelsi et al., 2024). Thus, the combination of EFA, CFA, and reliability analysis provides a strong body of information supporting the validity and reliability of the developed instrument.

The assessment criteria refer to several goodness-of-fit indicators recommended in the literature. The Chi-square/df index with a value of ≤ 2 indicates a perfect fit, while a value of ≤ 3 is still acceptable as a good fit (Kline, 2016). The RMSEA (*Root Mean Square Error of Approximation*) value of ≤ 0.05 indicates a perfect fit, while a value of ≤ 0.08 indicates a good fit (Norabuena-Figueroa et al., 2025). For RMR (*Root Mean Square Residual*), a value of ≤ 0.05 is categorized as a perfect fit, and a value of ≤ 0.08 is categorized as a good fit (Brown, 2006; Hu & Bentler, 1999). The SRMR (*Standardized Root Mean Square Residual*) with a value of ≤ 0.05 indicates a perfect fit, while a value of ≤ 0.08 is still considered good (Brown, 2006). Other indices, such as NFI (*Normed Fit Index*) and NNFI (*Non-Normed Fit Index*), with a value of ≥ 0.95 , are categorized as a perfect fit, and a value of ≥ 0.90 is categorized as a good fit (Hu & Bentler, 1999; Tabachnick & Fidell, 2007; Thompson, 2008). Meanwhile, CFI (*Comparative Fit Index*) with a value of ≥ 0.95 reflects a perfect fit (Hu & Bentler, 1999), and GFI (*Goodness of Fit Index*) ≥ 0.95 is included in the perfect fit category, but a value of ≥ 0.90 , although accepted, is considered a poor fit by some experts (Joreskog & Sorbom, 1993). The entire validation process was analyzed using Jamovi tools.

Results & Discussion

Preliminary Analysis

Before conducting the main analysis, a preliminary examination was carried out to understand the characteristics of the data and ensure that statistical assumptions were satisfied. This analysis includes descriptive statistics on the calibration sample used in the study. Descriptive statistics provide an overview of the data distribution, including the mean values and standard deviations

of each variable analyzed. This information is required to determine the data's eligibility for further analysis. Table 2 presents a summary of the descriptive statistics.

Indicator	Item codes	Statement Items	Mean	SD	Skewness	Kurtosis
Interactive	I-1	I discuss with friends about the relationship between local phenomena and science concepts.	3.58	0.91	-0.4255	0.17342
	I-2	I work together with groups in completing observation-based tasks in the environment	4.04	0.87	-0.8557	0.7778
	I-3	I give and receive ideas from friends in solving science problems related to local culture.	3.83	0.93	-0.5535	0.00307
	I-4	I actively engage in dialogue in groups when discussing experimental results that contain elements of local culture.	3.58	0.96	-0.2891	-0.274
	I-5	When discussing science problems based on local culture, I actively question/debate my friends' opinions	3.4	1.03	-0.2514	-0.4669
	I-6	I actively ask questions when discussing science materials based on local wisdom	3.49	0.99	-0.2086	-0.4761
	I-7	Through discussion activities, I am able to generalize new knowledge/deeper knowledge related to science materials based on local wisdom	3.74	0.94	-0.3122	-0.4498
	I-8	In science discussions based on local wisdom, there is an exchange of ideas between me and my friends, resulting in new ideas	3.95	0.91	-0.6602	0.1596
	I-9	In dialogue with friends about I defend ideas when discussing learning materials based on local wisdom	3.53	0.92	-0.3812	0.0213
	I-10	I actively assess/criticize my friends' ideas when discussing	3.46	1.03	-0.2945	-0.4423

		science materials based on local wisdom				
Constructive	C-1	I develop conclusions from observations made in the field	3.53	0.91	-0.2314	-0.1788
	C-2	I try to explain natural phenomena by linking them to local community knowledge.	3.48	0.88	-0.0945	-0.4774
	C-3	I create new ideas or scientific solutions based on an understanding of local culture/wisdom.	3.32	0.99	-0.0853	-0.5048
	C-4	I write reports or create presentations that summarize scientific concepts from local practices.	3.49	0.97	-0.2623	-0.2636
	C-5	I take notes on local wisdom-based science learning materials using my own words	3.53	0.95	-0.2351	-0.2314
	C-6	In the process of learning local wisdom-based science, I try to compare the new knowledge gained with previous knowledge/other materials.	3.57	0.9	-0.3553	0.05504
	C-7	To be able to understand science more deeply, I connect new knowledge with previous knowledge based on culture/local wisdom	3.63	0.88	-0.2988	-0.0078
	C-8	I develop new understanding from the results of science learning activities based on local wisdom	3.6	0.9	-0.2405	-0.2261
	C-9	I am able to explain aloud the new understanding obtained through science learning activities based on local wisdom	3.33	1	-0.0585	-0.518
	C-10	I try to make a plan to solve problems/cases given by the teacher	3.62	0.89	-0.3074	-0.0931
	C-11	Produce predictions for the plans that have been formulated	3.52	0.88	-0.2688	-0.0441
	C-12	I try to connect the cause and effect of science material phenomena and relate them to local wisdom	3.44	0.94	-0.2263	-0.167

	C-13	In the science learning process, I ask questions by relating them to local culture	3.3	0.97	-0.1536	-0.3502
	C-14	I formulate problems from the results of observing local culture in science learning	3.31	0.95	-0.1175	-0.2689
	C-15	Compare and contrast various cases in the field based on local culture in the science learning process	3.43	0.96	-0.2945	-0.1618
	C-16	I integrate information from various sources about the relationship between local phenomena and science concepts.	3.47	0.9	-0.184	-0.1985
	C-17	I evaluate myself in terms of new knowledge/understanding with previous understanding of science concepts with local culture	3.66	0.9	-0.2298	-0.3306
Active	A-1	I take notes of important information when observing local cultural practices relevant to science.	3.75	0.94	-0.493	0.07067
	A-2	I carry out experiments according to the instructions/procedures given by the teacher in an effort to understand how science concepts relate to local culture	3.79	0.89	-0.4208	-0.048
	A-3	I actively ask questions when I do not understand the relationship between science and local practices.	3.57	0.98	-0.3564	-0.2024
	A-4	I explore or search for additional information about the topic being discussed.	3.63	0.88	-0.1314	-0.34
	A-5	I repeat the information obtained from the teacher	3.67	0.88	-0.2541	-0.1581
	A-6	I actively seek out local culture in the surrounding environment that is closely related to scientific concepts.	3.44	0.93	-0.1106	-0.3715
	A-7	When reading I underline or color important information about local science and cultural concepts.	3.63	0.98	-0.4129	-0.1081

	A-8	I summarize information while reading about science concepts and their relationship to local cultural practices.	3.63	0.88	-0.2406	-0.1773
	A-9	During the process of observing local culture relevant to science concepts using video media, I pause or slow down the video when I need time to understand it.	3.77	0.96	-0.4493	-0.1691
Passive	P-1	I just listened to the teacher's explanation without participating in the discussion.	2.57	1.2	0.4421	-0.7371
	P-2	I am not very involved in observation or exploration activities when studying outside the classroom.	2.51	1.16	0.5203	-0.5742
	P-3	I am not interested in connecting science lessons with the local culture around me.	2.48	1.17	0.5216	-0.6237
	P-4	I just did the assignment out of obligation, without really understanding the content.	2.34	1.21	0.627	-0.5724
	P-5	While reading I did not note down/summarize information related to scientific concepts and local wisdom.	2.36	1.19	0.6036	-0.5703
	P-6	While reading, I did not underline/color information related to scientific concepts and local wisdom.	2.5	1.21	0.4858	-0.675
	P-7	During observation or exploration activities outside the classroom, I only observed without noting down important information that was relevant between local culture and science concepts.	2.49	1.16	0.5051	-0.5546
	P-8	When the teacher explained the concept of science and its relationship to local culture, I just paid attention and listened to the lecture without doing anything else.	2.77	1.24	0.1576	-0.9882

Table 2. Descriptive statistics of the calibration sample (n = 711). SD: Standard Deviation.

Based on the results of the analysis of the skewness and kurtosis coefficients, all data in this study met the acceptance criteria for the normality test. The normality assumption is considered unmet if the skewness coefficient falls outside the range of ± 2 and the kurtosis coefficient lie outside the range of ± 7 , as Hair et al. (2010) stated. Meanwhile, according to Kline (2011), the normality assumption is not satisfied if the skewness coefficient exceeds the range of ± 3 and the kurtosis coefficient exceeds the range of ± 8 . Thus, it can be concluded that the data in this study satisfy the assumption of normality based on the criteria established by Hair et al. (2010) and Kline (2011), allowing for further statistical analysis requiring normal distribution to be conducted accurately and validly.

Exploratory Factor Analysis (n = 711)

Exploratory Factor Analysis (EFA) was conducted to identify the latent structure of the developed instrument and to explore the number and pattern of relationships between statement items. This procedure serves as a crucial initial stage in ensuring the validity of the instrument construct before proceeding to the Confirmatory Factor Analysis (CFA). This analysis was performed on data collected from 711 respondents; a number considered adequate based on sample size guidelines for factor analysis. Assumption testing of the data was conducted using Bartlett's Test of Sphericity, which showed significance at the $p < 0.01$ level and a *Kaiser-Meyer-Olkin* (KMO) value of 0.961, indicating very good sample adequacy for factor analysis. The initial EFA results revealed that several items had factor loading values of less than 0.40 on all factors, while other items showed loadings of more than 0.40 on multiple factors, indicating cross-loading. These items were gradually eliminated one by one. Next, a review of the items with dominant saturation in factors that did not align with the original theoretical dimensions was conducted. These items were also progressively eliminated to enhance the clarity of the factor structure. Refining the factor structure was carried out iteratively by implementing 48 EFAs. Ultimately, the final factor structure consisted of 37 items spread across four main factors: interactive (5 items), constructive (16 items), active (7 items), and passive (8 items).

Exploratory Factor Analysis (EFA) conducted with the final 17 items was utilized for principal component extraction with Promax rotation (KMO = 0.96), and Bartlett's test was significant ($\chi^2 = 15.127, p < .000$), based on the EFA of the suggested theoretical model for the general construct of cognitive engagement in science local wisdom (Table 1). The obtained eigenvalues and scree tests were used to extract four factors. After factor analysis, items with factor saturation exceeding 0.40 were selected from the rotated component matrix (Promax Rotation). Factor 1 refers to the items encompassing the scale's interactive component. Factor 1 consists of six items with weights above 0.40, representing 22.70% of the variance. Factor 2 includes 16 items that form the construct components, representing 13.75% of the variance. Factor 3 consists of seven items with an active component and shows 9.79% of the variance, while Factor 4 consists of eight items that form a passive component and shows 5.61% of the variance corresponding to the Behavior component.

Exploratory Factor Analysis (EFA) was conducted on the final 17 items of the instrument using the Principal Component Analysis extraction method and Promax rotation, which is suitable for data that are assumed to exhibit correlations between factors. The test results showed that the *Kaiser-Meyer-Olkin* (KMO) value of 0.96 indicated very high sample adequacy, while Bartlett's Test of Sphericity revealed significant results ($\chi^2 = 15.127, p < 0.000$), confirming that the data were appropriate for further analysis using factor analysis techniques. This EFA procedure was based on a theoretical model representing the general construct of cognitive

engagement within the context of local wisdom-based science learning (Table 1). Determining the number of factors relied on eigenvalues and scree plot analysis, which consistently indicated that four factors represented the most suitable structure to extract. Items were selected based on factor loading values of ≥ 0.40 from the rotated component matrix. The analysis results show that Factor 1 reflects the interactive dimension, comprising six items with all loading values exceeding 0.40, explaining 22.70% of the total variance. Factor 2 includes 16 items that form the constructive dimension, explaining 13.75% of the variance. Factor 3 consists of seven items representing the active dimension, contributing 9.79% to the variance. Meanwhile, Factor 4 comprises eight items that form the passive dimension, explaining 5.61% of the variance, and is associated with aspects of less active learning behavior. Collectively, the four factors provide empirical support for the construct validity of the developed instrument and demonstrate alignment with the theoretical framework of cognitive engagement in science learning grounded in local values.

Indikator	Kode item	Item Pernyataan	Factor 1	Factor 2	Factor 3	Factor 4
Interactive	I-2	I work with groups to complete observation-based tasks in the environment.	0.486			
	I-3	I give and receive ideas from friends in solving science problems related to local culture.	0.708			
	I-7	Through discussion activities, I am able to generalize new knowledge/deeper knowledge related to local wisdom-based science material.	0.518			
	I-8	In a local wisdom-based science discussion, there was an exchange of ideas between me and my friend, resulting in new ideas.	0.546			
	I-10	I actively assess/criticize friends' ideas when discussing local wisdom-based science material.	0.453			
Constructive	C-1	I developed conclusions from the results of observations made in the field.		0.604		

Indikator	Kode item	Item Pernyataan	Factor 1	Factor 2	Factor 3	Factor 4
	C-2	I try to explain natural phenomena by linking them to local community knowledge.		0.688		
	C-3	I create new ideas or scientific solutions based on an understanding of local culture/wisdom.		0.748		
	C-4	I write reports or create presentations that summarize scientific concepts from local practices.		0.581		
	C-5	I wrote down local wisdom-based science learning materials using my own words.		0.54		
	C-6	In the process of learning science based on local wisdom, I try to compare the new knowledge obtained with previous knowledge/other materials.		0.646		
	C-7	In order to understand science more deeply, I connect new knowledge with previous knowledge based on culture/local wisdom.		0.611		
	C-8	I developed a new understanding from the results of local wisdom-based science learning activities.		0.6		
	C-9	I am able to explain aloud new understandings gained through local wisdom-based science learning activities.		0.896		
	C-10	I try to make a plan to solve the problem/case given by the teacher.		0.566		

Indikator	Kode item	Item Pernyataan	Factor 1	Factor 2	Factor 3	Factor 4
	C-11	Produce predictions regarding plans that have been formulated		0.765		
	C-12	I try to connect the cause and effect of scientific material phenomena and relate them to local wisdom.		0.767		
	C-13	In the process of learning science, I ask questions by linking them to local culture.		0.74		
	C-14	Data formulates problems from the results of local cultural observations in science learning		0.718		
	C-15	Comparing and contrasting various field cases based on local culture in the science learning process		0.563		
	C-16	I integrate information from multiple sources about the relationships between local phenomena and science concepts.		0.573		
Active	A-1	I noted important information when observing local cultural practices relevant to science.			0.543	
	A-2	I conducted experiments according to the instructions/procedures given by the teacher in an effort to understand how science concepts relate to local culture.			0.581	
	A-3	I actively ask questions when I don't understand the relationship between science and local practices.			0.594	
	A-4	I do exploration or search for additional information			0.524	

Indikator	Kode item	Item Pernyataan	Factor 1	Factor 2	Factor 3	Factor 4
		on the topic being discussed.				
	A-5	I repeat the information obtained from the teacher			0.604	
	A-7	When reading I underline or color important information about local science and cultural concepts.			0.535	
	A-8	I summarize information while reading about science concepts and their relationship to local cultural practices.			0.703	
	A-9	During the process of observing local culture relevant to science concepts using video media, I pause or slow down the video speed when I need time to understand it.			0.627	
Passive	P-1	I just listened to the teacher's explanation without participating in the discussion.				0.77
	P-2	I am not very involved in observation or exploration activities when studying outside the classroom.				0.792
	P-3	I am not interested in connecting science lessons with the local culture around me.				0.808
	P-4	I just did the assignment out of obligation, without really understanding the content.				0.825
	P-5	While reading I did not note down/summarize information related to scientific concepts and local wisdom.				0.803

Indikator	Kode item	Item Pernyataan	Factor 1	Factor 2	Factor 3	Factor 4
	P-6	While reading, I did not underline/color information related to scientific concepts and local wisdom.				0.793
	P-7	During observation or exploration activities outside the classroom, I only observed without noting down important information that was relevant between local culture and science concepts.				0.817
	P-8	When the teacher explained the concept of science and its relationship to local culture, I just paid attention and listened to the lecture without doing anything else.				0.73

Table 3. EVA Analysis Results (37 Items)

Confirmatory Factor Analysis (n = 711)

CFA aims to verify whether the items in the instrument accurately measure a particular construct or dimension according to theory (Mueller & Hancock, 2015; Rogers, 2024). CFA assesses whether each indicator (item) has a significant and strong loading on the appropriate factor, thereby indicating that the instrument is valid in measuring the intended construct. CFA was conducted to test two plausible models of cognitive engagement -science local wisdom for the 37 selected items. The results of the CFA analysis are presented in Table 4.

Factor	Indicator	Estimate	SE	Z	p
Interactive	I-2	0.489	0.0331	14.8	< .001
	I-3	0.596	0.0341	17.5	< .001
	I-7	0.702	0.0333	21.1	< .001
	I-8	0.635	0.0327	19.4	< .001
Constructive	C-1	0.627	0.0303	20.7	< .001
	C-2	0.61	0.0293	20.8	< .001
	C-3	0.678	0.033	20.6	< .001
	C-4	0.661	0.0326	20.3	< .001
	C-5	0.616	0.0324	19	< .001

Factor	Indicator	Estimate	SE	Z	p
	C-6	0.63	0.0299	21	< .001
	C-7	0.584	0.0297	19.7	< .001
	C-8	0.633	0.0299	21.2	< .001
	C-9	0.732	0.0326	22.4	< .001
	C-10	0.603	0.03	20.1	< .001
	C-11	0.601	0.0294	20.4	< .001
	C-12	0.709	0.0304	23.3	< .001
	C-13	0.71	0.0319	22.3	< .001
	C-14	0.676	0.0315	21.5	< .001
	C-15	0.662	0.032	20.7	< .001
	C-16	0.655	0.0293	22.4	< .001
Active	A-1	0.624	0.032	19.5	< .001
	A-2	0.577	0.0308	18.7	< .001
	A-3	0.696	0.0332	21	< .001
	A-4	0.637	0.0294	21.7	< .001
	A-5	0.619	0.0298	20.8	< .001
	A-7	0.656	0.0338	19.4	< .001
	A-8	0.654	0.0293	22.3	< .001
	A-9	0.629	0.0331	19	< .001
Passive	P-1	0.882	0.0395	22.4	< .001
	P-2	0.908	0.0369	24.6	< .001
	P-3	0.938	0.0363	25.8	< .001
	P-4	0.995	0.0378	26.3	< .001
	P-5	0.988	0.0368	26.9	< .001
	P-6	0.956	0.0382	25	< .001
	P-7	0.961	0.0361	26.6	< .001
	P-8	0.883	0.0413	21.4	< .001

Table 4. CFA Loading Factors

Based on the results of the Confirmatory Factor Analysis (CFA), all indicators in the Cognitive Engagement Instrument (CEI) displayed significant factor loading values ($p < .001$), indicating the statistical validity of each indicator in representing the measured construct. The Interactive factor has a loading value ranging from 0.489 to 0.702, where indicator I-2, though slightly below the ideal threshold, can still be categorized as an empirically acceptable indicator. The Constructive factor demonstrates good internal consistency with a loading range between 0.584 and 0.732. Likewise, the Active factor reflects adequate construct representation, with loading values between 0.577 and 0.696. Meanwhile, the Passive factor shows a very strong indicator contribution to its construct, with the highest loading value in the model, ranging from 0.882 to 0.995. These results indicate that the CEI instrument possesses good construct validity and can

effectively measure students' cognitive engagement in local wisdom-based science learning. This statement is supported by the fit-measure results, as shown in Table 5.

Test for Exact Fit			Fit Measures					
χ^2	df	<i>p</i>	CFI	TLI	SRMR	RMSEA	AIC	BIC
1712	581	< .001	0.92	0.92	0.039	0.0523	58288	58840

Table 5. Fit Measure

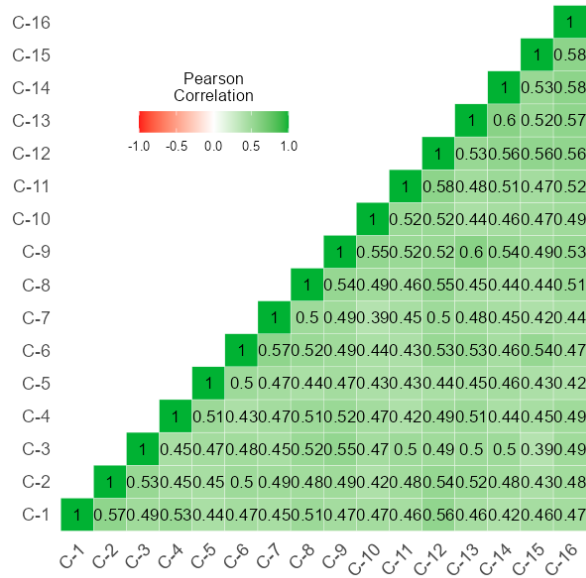
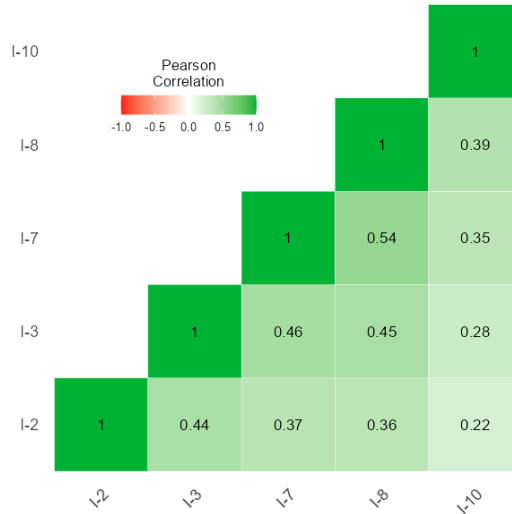
The results of model testing through various model fit indices in Table 5 demonstrate that the model fits the data well. The CFI and TLI values are each 0.92, exceeding the minimum threshold of 0.90, which indicates a good fit. The SRMR value of 0.039 and the RMSEA of 0.0523 also fall within the good category, as both are below the maximum limit of 0.08 and near the ideal value of less than 0.05. Although the χ^2 value shows significance ($p < .001$), this is common in large sample sizes and does not necessarily indicate a model misfit. The AIC and BIC values are recorded for model comparison, with respective values of 58288 and 58840. Overall, these results support the findings that the CEI measurement model possesses adequate construct validity and model fit, making it a reliable tool for measuring students' cognitive engagement in the context of local wisdom-based science learning.

Internal Consistency

To ensure the quality of the instrument used to measure students' cognitive participation in local wisdom-based science learning, an internal reliability analysis was conducted on each construct in the Cognitive Engagement Instrument (CEI). Internal reliability refers to the consistency of respondents' answers to items within the same construct. In this study, reliability testing utilized Cronbach's Alpha coefficient, which is generally used to determine the extent to which scale items correlate with each other and form a cohesive unit. The analysis results are presented in Table 6, which shows the reliability statistics for each scale in the CEI instrument.

Item	Mean	SD	Cronbach's α	McDonald's ω
Interactive	3.8	0.668	0.756	0.764
Construtive	3.47	0.671	0.938	0.939
Active	3.68	0.681	0.88	0.881
Passive	2.5	0.979	0.931	0.931
Overall Item	3.35	0.538	0.933	0.942

Table 6. Scale Reliability Statistics



(a)

(b)

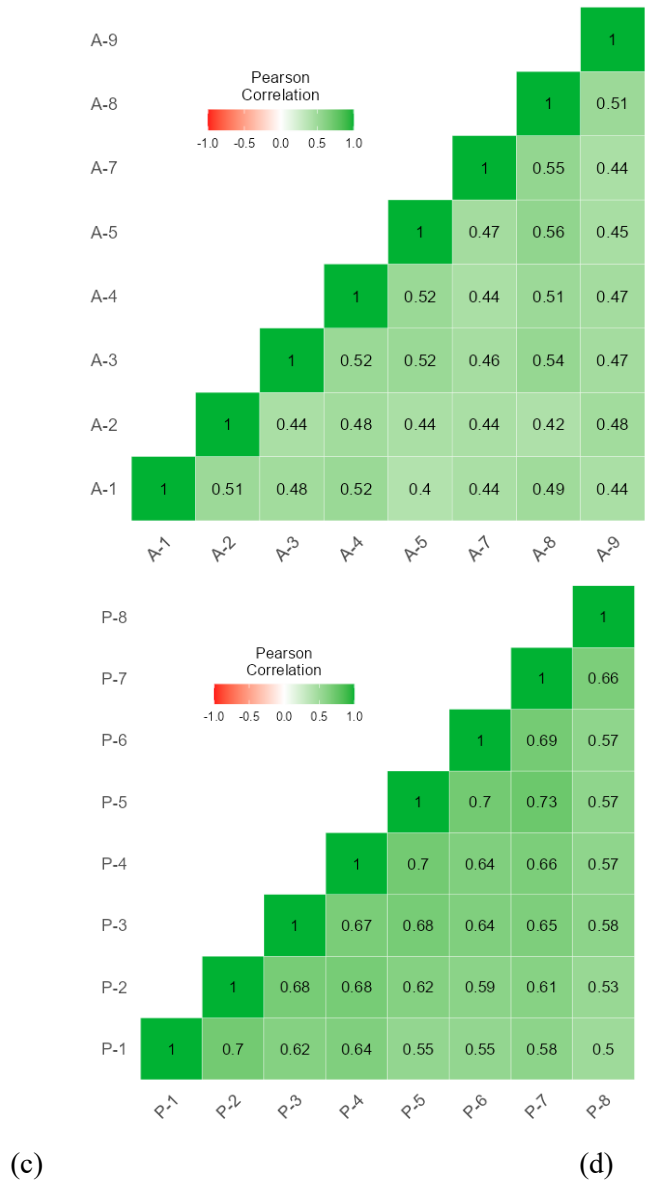


Figure 1.

Correlation Heatmap for each indicator (a) interactive, (b) constructive, (c) active, (d) passive Based on Table 6, the Cronbach's Alpha values range from 0.756 to 0.938, while the McDonald's Omega values range from 0.764 to 0.939. These values indicate that all constructs in the CEI instrument demonstrate very good reliability. The constructive dimension exhibits the highest reliability ($\alpha = 0.938$; $\omega = 0.939$), whereas the interactive dimension shows adequate reliability, even though it has the lowest value among the four constructs ($\alpha = 0.756$; $\omega = 0.764$). All of the item, the CEI instrument has high reliability ($\alpha = 0.933$; $\omega = 0.942$), making it suitable for

measuring students' cognitive engagement in the local context. Figure 1 reinforces the reliability results by displaying the correlation between items as a heatmap for each dimension. The correlation among indicators reveals a fairly strong positive relationship, particularly in the constructive and passive dimensions, indicating high internal consistency among items. This correlation pattern supports the statistical reliability findings and suggests that each dimension has good item cohesion in measuring students' cognitive engagement. Therefore, it can be concluded that the Cognitive Engagement Instrument (CEI) has a very good level of internal consistency and can be relied upon to measure students' cognitive engagement in local wisdom-based science learning. With the support of high-reliability values in each dimension and strong correlation patterns among items, this instrument can be used effectively in research and developing contextual science learning relevant to local values.

Discussion

Referring to the results of the validation and reliability analysis, it was found that the Cognitive Engagement Instrument (CEI) is classified as suitable for use in each indicator. This is demonstrated through the results of the Confirmatory Factor Analysis (CFA), which reveals significant factor loading values on all items ($p < .001$), as well as the goodness of fit model values that meet the criteria ($CFI = 0.92$; $TLI = 0.92$; $SRMR = 0.039$; $RMSEA = 0.0523$). Furthermore, the reliability test using Cronbach's Alpha and McDonald's Omega also showed high internal consistency, with alpha values ranging from 0.756 to 0.938. These findings indicate that each dimension of cognitive engagement—interactive, constructive, active, and passive—has been measured accurately and consistently, allowing the CEI to be used validly and reliably to evaluate student engagement in local wisdom-based science learning. This study shows that the ICAP framework can be effectively applied in various learning process activities (Chi et al., 2018; Chi & Wylie, 2014), including evaluating students' cognitive engagement participation, particularly in science. One of its implementations is observed in student craft-based activities integrating science concepts with local cultural practices. Through this approach, dimensions of cognitive engagement such as interactive, constructive, active, and passive can be identified more contextually, enabling teachers to understand how students construct new knowledge, engage in collaborative dialogue, and relate scientific knowledge to their real experiences. These findings enhance the potential of the ICAP framework as a pedagogical and evaluative reference responsive to the socio-cultural context in local wisdom-based science learning.

Furthermore, the development and use of the CEI align with several previous studies that have utilized the ICAP framework as a basis for measuring students' cognitive engagement (Barlow et al., 2020; Greene, 2015; Lutz et al., 2018). The ICAP framework itself assumes that interactive forms of engagement are the most effective in supporting learning, followed by constructive, active, and finally passive engagement—a sequence referred to as the ICAP hypothesis ($I > C > A > P$) (Thurn et al., 2023). This Interactive-Constructive-Active-Passive theory was developed as a conceptual approach to operationally defining cognitive engagement and active learning in order to promote deeper and more meaningful learning (Gürses & İnceelli, 2024). Additionally, the ICAP framework emphasizes open and observable learning activities that teachers can implement in classroom practice to enhance student engagement in the learning process (Pitterson et al., 2016). Therefore, the results of this study not only strengthen the validity of the CEI instrument but also provide an important contribution to the application of the ICAP framework as a pedagogical foundation within the context of local culture-based science learning.

Thus, the development and validation of the Cognitive Engagement Instrument (CEI) within the context of local wisdom-based science learning contributes to fulfilling the need for contextual and culturally sensitive instruments and strengthens the application of the ICAP theoretical framework in educational practice. This instrument has demonstrated high validity and reliability, accurately representing various forms of student cognitive engagement.

Conclusion

This study successfully developed and validated the Cognitive Engagement Instrument (CEI), which is designed to measure students' cognitive engagement in wisdom-based science learning. This instrument is based on the ICAP (Interactive, Constructive, Active, Passive) theoretical framework and is adapted to the local cultural context of Indonesia. Through a series of validity and reliability tests, including Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and internal consistency testing using Cronbach's Alpha and McDonald's Omega, the CEI has proven valid and reliable. The EFA results demonstrated a stable factor structure and aligned with the four dimensions of cognitive engagement. CFA confirmed that all items had significant loading factors ($p < .001$), and the model showed a good fit to the empirical data ($CFI = 0.92$; $TLI = 0.92$; $RMSEA = 0.0523$; $SRMR = 0.039$). All constructs exhibited high reliability, with α and ω values exceeding 0.75, reinforcing that this instrument has excellent internal consistency.

Limitations of the study: This study only involved high school students using a voluntary sampling method, which may introduce selection bias. Students with a greater interest in science learning or local culture may be more inclined to participate, meaning the data does not fully represent the entire student population. Additionally, while quantitative data can accurately measure the validity and reliability of the instrument, this approach has not fully captured students' subjective experiences in linking science concepts to local culture. Affective and narrative aspects remain absent from this study. *Future research* could integrate qualitative approaches, such as interviews or classroom observations, to enrich the understanding of forms of cognitive engagement that questionnaires do not detect and explore the personal meanings students construct during culture-based science learning.

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