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VALIDITY AND RELIABILITY OF ONLINE SOCIO-SCIENTIFIC ISSUE-BASED CRITICAL REASONING INSTRUMENT

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ABSTRACT

Information regarding the evaluation of reasoning skills related to online socio-scientific issues is still limited due to limited instruments. This research aims to determine the validity and reliability of an online socio-scientific issue-based critical reasoning instrument. Content validity was proven by the assessment method by five experts. Confirmatory factor analysis was carried out with the Lisrel 8.8 program to prove construct validity. Instrument testing was carried out on 145 grade 10 high school students. Convergent validity was determined through the Average Variance Extracted (AVE) calculation, and reliability was determined through Construct Reliability (CR). There are 12 items from four dimensions of critical reasoning based on online socio-scientific issues: (1) evaluating SSI information, (2) identifying SSI complexity, (3) checking the credibility of information sources, and (4) multiperspective. The results of the content validity test obtained the Aiken coefficient value in the valid category. Based on the analysis results, the GFI, RMSEA, and p-value of the instrument fit the model and have loading factors that meet the minimum criteria. In addition, the instrument meets convergent validity and internal consistency. Thus, it is concluded that the instrument is declared valid and reliable and can be used to measure critical reasoning based on online socio-scientific issues.

Keywords: critical reasoning; instrument; online; reliability; socio-scientific issue; validity

INTRODUCTION

Critical reasoning is a challenge for science education in the current era of misinformation. Critical reasoning is essential to evaluate various sources and information that are controversial or conflicting, such as climate change (Chu et al., 2023; Freiling & Matthes, 2023). If one does not have critical reasoning skills, there is the potential for misinformation (Nagel et al., 2022). Social media such as Facebook and Twitter/X tend to be a source of misinformation (Bizotto et al., 2023; Dallo et al., 2023; Hashemi, 2023), although research results state that misinformation on Facebook has decreased (Allcott et al., 2019). Misinformation is seen as a threat to evidence-based communication and decision-making. Previous research results report that students often mistake signs of weak credibilities, such as the display of the website, domain, content, and information provided. Misinformation has transcended international boundaries between languages and cultures (Lai et al., 2023). Critical reasoning skills help students overcome the subjectivity of sources, filter scientific information, and solve multidisciplinary problems in various contexts (Wiblom et al., 2019). Thus, information regarding students' critical reasoning skills is vital to face the threat of misinformation.

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Students' ability to engage in critical reasoning is vital to their development. Critical reasoning skill is an important learning goal, so students are prepared for life (Nunn et al., 2016; Chen et al., 2021). This importance is because critical reasoning influences one's beliefs and behavior in everyday life (Cohen et al., 2022). Critical reasoning skills are also closely related to preparing high school students for university (Wiblom et al., 2019). Education in the digital and information era fundamentally changes the way students learn and subject (Banerjee et al., 2020). Through critical reasoning, students can build, organize, and justify knowledge and create new ideas (Chen et al., 2021).

Critical reasoning refers to scientific reasoning in a social context. A complex social context will impact multidimensional situations (Wiblom et al., 2019). Social issues require different reasoning than well-structured logical problem. Conflicting perspectives and logic must be considered in generating solutions and justifying the knowledge that influences them (Saye & Brush, 2002; Kim et al., 2023). An essential element in solving social issues is reasoning, which requires a point of view (Parker et al., 1989; Saye & Brush, 2002). Students' engagement in reasoning about mass media and social justice reasoning has been reported to involve perspective-taking about the values they uphold (List, 2023). Thus, critical reasoning in complex social issues involves making decisions from multiple perspectives.

Socio-scientific issues are social issues that are substantially related to scientific principles, are complex, multidisciplinary, controversial, and contain dilemmas so that they require a process of evaluation and analysis to make decisions (Xiao & Sandoval, 2017; Bernard & Albert, 2018; Namdar & Namdar, 2022; Cebesoy & Rundgren, 2023). Proposed solutions to socio-scientific issues involve various perspectives from different scientific disciplines (Garrecht et al., 2021). Students can easily access complex socio-scientific issues as a context for building scientific knowledge through online media. The increasing flow of information and the need to deal with socio-scientific issues make critical reasoning relevant to training students. Internet resources are very open and allow students to find conflicting information, so students must be able to critically search, evaluate, and select online information and verify sources (McGrew et al., 2019). Socio-scientific issues (SSI) require policymakers and citizens to limit scientific knowledge from misinformation and disinformation to make wise decisions (Herman et al., 2022). Students from various backgrounds will undoubtedly have unique knowledge, values, and experiences that will influence their engagement with SSI differently (Cian, 2020). Knowledge structure refers to an individual's organized collection of information that provides a context that they can use to interpret media messages (Cho et al., 2022). Social media platforms allow users to seek information, advice, and social support from others and contribute knowledge and suggestions (Tam et al., 2022).

Previous research measures critical reasoning in the health sector from online information (Wiblom et al., 2019). Apart from that, the development of critical reasoning evaluation tools for web-based health information is still limited to the subjectivity of information sources and the activity of filtering scientific information called GATOR (Genuine, Accurate, Trustworthy, Origin, and Readability) (Weber et al., 2010). Therefore, opportunities to include multiple sources and perspectives are essential (Wiblom et al., 2019). Furthermore, the socio-scientific reasoning instrument abbreviated as QuASSR (Quantitative Assessment Socio-scientific Reasoning) was developed by Romine, consisting of 10 two-tier questions arranged with two scenarios and four dimensions: complexity, perspective-taking, inquiry, and skepticism (Romine et al., 2017). The QuASSR instrument developed has not considered aspects of information evaluation and the credibility of information sources accessed via the internet or online media. Other research has found critical online reasoning and evaluation frameworks to support students in learning to read with critical awareness. Online critical reasoning skills have three aspects: online information acquisition, critical information evaluation, and reasoning based on evidence, argumentation, and synthesis. Previous research finds that online critical reasoning has been developed but does not yet have the elements of complexity and multiperspective necessary to make information decisions. Critical reasoning studies by previous researchers are still limited to health problems. There is still a lack of comprehensive data on assessing critical reasoning skills related to online socio-scientific issues. Based on this, it is necessary to develop instruments to measure critical reasoning based on online sources, especially in socio-scientific issues. The online socio-scientific issue-based critical reasoning instrument has four different indicators from previous research: evaluating SSI information, identifying SSI complexity, assessing the credibility of SSI information sources, and multiperspective.

This research uses a socio-scientific context related to the problem of illegal mining and uses information sources from online news websites to present the problem. The information sources obtained require credibility checks to avoid misinformation. The context of illegal mining is a local issue that has become a complex and controversial global issue, so it requires critical reasoning from various perspectives. Thus, the instrument produced from this research is the first instrument designed to measure critical reasoning based on online socio-scientific issues. The resulting instrument will be known for its content validity, construct validity, and level of reliability. To bridge this gap, valid and reliable instruments are needed to assess critical reasoning skills related to online socio-scientific issues. Researchers and educators can obtain appropriate data to prove students' critical reasoning skills by carrying out this activity. The researchers investigate whether the resulting instrument is valid and reliable for measuring critical reasoning related to online socio-scientific issues.

METHODS

The instrument was prepared with the following four steps: item formulation, content validation, construct validation, and reliability calculation (Lombardi et al., 2023; Subiantoro & Treagust, 2021). This research aims to test the validity and reliability of a critical reasoning test instrument based on socio-scientific issues from the internet for grade 10 high school students.

The item formulation step was carried out by determining the purpose of preparing the instrument, looking for relevant theories or scope of material, formulating instrument item indicators, and arranging instrument items. Items were formulated by reviewing the literature on the SSI context and critical reasoning conceptually and operationally through identifying and limiting critical reasoning variables based on socio-scientific issues to be measured. After the literature review, the next step was to formulate items based on the key aspects determined.

The second step was content validation and revision based on input from expert validators. Content validity was proved by expert judgment (Retnawati, 2016b). Five experts were involved in proving content validity. The validity index proposed by Aiken (1980; 1985) was used to determine expert judgment.

The third step was to prove construct validity. Empirical trials were carried out to prove construct validity. The instrument was tested on 145 tenth-grade high school students consisting of 89 women and 56 men from three high schools in West Kalimantan, Indonesia. The tested participants were first-year students in high school. The sample was determined based on consideration of sampling locations in the provincial capital, district capital, and sub-district, each representing one school that has implemented the Emancipated Curriculum. According to Hair (2010), the sample size for maximum likelihood ranges from 100-400 samples. The data in this research was collected online using Google Forms. Responses to the test instrument are collected by completing each test item within a limited time. Students' responses to the test instruments were assessed in the range 1-4 (1=Poor, 2=Average, 3=Good, 4=Very Good).

Data from the test results were analyzed using the Kaiser–Meyer–Olkin (KMO) test and Bartlett's Test of Sphericity. This test was used to check the adequacy of data for factor analysis. The KMO test result was 0.91, exceeding the minimum value of 0.6, and the Bartlett Test revealed that $p = 0.00 < 0.05$, which confirmed the suitability of the data for factor analysis (Pallant, 2020). Based on these results, the data was analyzed using a first-order confirmatory factor analysis approach. Data analysis used LISREL 8.8 software. CFA aims to assess how well a particular model fits the data and estimates the factor loadings, variances, covariance of those factors, and residual error variances of the observed variables (Hox, 2021). The CFA model fit index criteria are based on the χ^2 value, p-value, root mean squared error of approximation (RMSEA), goodness of fit index (GFI), adjusted fit index (AGFI), and comparative fit index (CFI). The criterion for the Chi-square value is χ 2 / df $\leq$ 2, while the p-value is $\geq$0.05. RMSEA values <0.08, GFI$\geq$0.90, AGFI $\geq$0.80, and CFI >0.90, indicating a suitable model (Brown, 2003; Elastika et al., 2021; Hair et al., 2010). The fourth stage was an assessment of the Average Variance Extract (AVE) and Construct Reliability (CR) values, which was a further evaluation of construct validity. The minimum limits are AVE $\geq$ 0.5 and CR $\geq$ 0.7 (Khampirat, 2021).

RESULTS AND DISCUSSION

The preparation of items results in four dimensions: evaluating SSI information, identifying SSI complexity, assessing the credibility of SSI information sources, and multiperspective. Table 1 describes critical reasoning based on socio-scientific issues.

Table 1. Description of Critical Reasoning Based on Online Socio-scientific Issues

Dimension	Operational Definition	Indicator
Evaluating SSI information	Students' ability to examine or check the truth of information based on reliable information sources	Through illegal mining issues from online news, students can correctly check the correctness of information from various reliable sources.
Identifying SSI complexity	Students' ability to determine several causal relationships, pros and cons, or the relationship between social and scientific aspects of socio-scientific issues	Through illegal mining issues from online news, students can correctly determine multiple causal relationships, interrelationships, and pros and cons in social and scientific aspects.
Assessing the credibility of SSI information sources	Students' ability to determine reliable information sources	Through illegal mining issues from online news, students can correctly determine information sources free from conflicts of interest and bias.
Multiperspective	Students' ability to determine stakeholders' perspectives on socio-scientific issues	Through illegal mining issues from online news, students can determine multiple stakeholders' perspectives on socio-scientific issues.

After determining the limitations and indicators for each dimension, the test instruments are arranged as in Table 2.

Table 2. Indicators of Online SSI-Based Critical Reasoning Dimensions and Item Examples

Indicator	Item Example
Through illegal mining issues from online news, students can correctly check the correctness of information from various reliable sources.	Based on SSI (illegal mining) information from online news, is there information not following the expert judgment? Explain!
Through illegal mining issues from online news, students can correctly determine multiple causal relationships, interrelationships, and pros and cons in social and scientific aspects.	Based on SSI (illegal mining) information from online news, what is the issue in the article? Are there any causal relationships, interrelationships, and pros and cons in the issue? Explain!
Through illegal mining issues from online news, students can correctly determine information sources free from conflicts of interest and bias.	Does the information come from a reliable source? Explain!
Through illegal mining issues from online news, students can determine multiple stakeholders' perspectives on socio-scientific issues.	Based on this information, what actions and solutions do you think should be proposed by stakeholders? Explain!

Test questions are prepared based on the context of illegal mining from online news. The context of illegal mining in the test questions becomes a contextual stimulus because the issue of illegal mining is encountered in everyday life. The widespread cases of illegal mining have made it complex and controversial in society.

Proof of content validity is carried out quantitatively using the Aiken Formula. Aiken's V Index uses statements validated by five experts (raters). The score range used is 1-4, with score 1 = not suitable, score 2 = quite suitable, score 3 = suitable, score 4 = very suitable (significance 0.05), then the Aiken reference value is 0.87 (Aiken, 1985). The results of V Aiken's analysis of 12 items have an index above 0.87. Thus, all items are valid.

The construct variables of critical reasoning based on socio-scientific issues consist of information evaluation, credibility of information sources, complexity, and multiple perspectives on SSI. Trials are carried out to prove construct validity. The results of the construct validity test with Confirmatory Factor Analysis (CFA) using the Linear Structural Model are presented in Table 3.

Table 3. Model Fit Test Result

Indicator	Score Benchmark	Score Acquisition	Model Fit
Chi-Square/df	≤ 2.00	1.29	Good
Probability (p-value)	≥ 0.05	0.098	Good
Root Mean Square Error of Approximation (RMSEA)	≤ 0.08	0.045	Good
Goodness of Fit Index (GFI)	≥ 0.90	0.94	Good
Comparative Fit Index (CFI)	≥ 0.90	0.99	Good
Adjusted Goodness of Fit Index (AGFI)	≥ 0.90	0.89	Margin fit

Table 3 shows that the results of empirical tests in the field support the defined construct. In general, the model fit requirements meet the specified values. The CFA results show that the critical reasoning test instrument items based on online socio-scientific issues significantly affect the observed variables with a p-value of less than 0.05. After the model is proven suitable, analysis is carried out to determine construct validity. The construct validity test calculates each indicator or dimension's expected loading factor (LF) value. The factor loading results are presented in Figure 1.

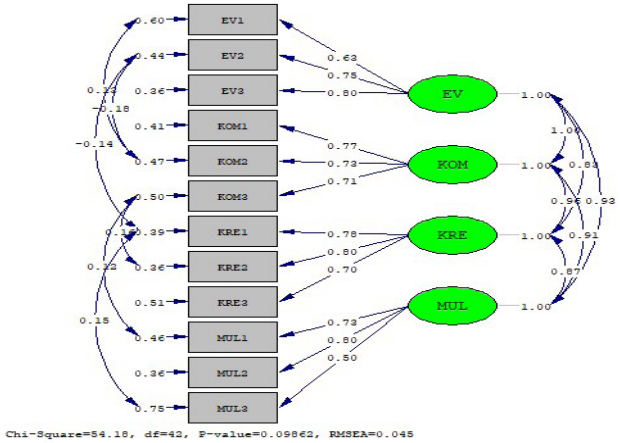

Figure 1. Output Path Diagram of Standardized Solution Analysis Results

Correlations between items and the four factors are presented in Table 4.

Table 4. Loading Factor Value Per Item

Dimension	No Item	Loading Factor	Corrected Total-Item Correlation
Evaluating SSI information	1a	0,77	0,41
	1b	0,73	0,47
	1c	0,71	0,50
Identifying SSI complexity	2a	0,62	0,60
	2b	0,75	0,44
	2c	0,80	0,36
Assessing the credibility of SSI information sources	3a	0,78	0,39
	3b	0,80	0,36
	3c	0,70	0,51
Multiperspective	4a	0,73	0,46
	4b	0,80	0,36
	4c	0,50	0,75

Figure 1 shows the loading factor for each item in the range of 0.5 to 0.80. This shows that the correlation between items and factors has reached the standard (minimum 0.5).

The next step is to test construct reliability and convergent validity by analyzing the Average Variance Extracted value. Construct reliability analysis aims to measure the extent of the reliability of the measurement model in measuring the latent construct in question (Roldán & Sánchez-Franco, 2012). Average Variance Extracted analysis aims to determine convergent validity. The convergent validity measure explains how the items measure the construct indicated by an AVE value with a minimum value of 0.5 (Alvarez-Risco et al., 2022; Hair et al., 2010). Assessment of Construct Reliability (CR) and AVE are presented in Table 5.

Table 5. Analysis of Construct Reliability (CR) and AVE

Dimensions of Online Socio-scientific Issue-Based Critical Reasoning	Construct Reliability (CR)	Category	Average Variance Extracted (AVE)	Category
Identifying SSI complexity	0,78	Reliable	0,53	Meets convergent validity
Evaluating SSI information	0,77	Reliable		
Assessing the credibility of SSI information sources	0,80	Reliable		
Multiperspective	0,72	Reliable		

Table 5 shows that the results of the construct reliability test on the four dimensions meet the reliability criteria. The indicator of a variable is said to be reliable if the CR value is ≥ 0.7. There are four dimensions of critical reasoning with an AVE value of more than 0.5.

The stages of preparing the instrument accommodate conceptually the principles of critical reasoning based on socio-scientific issues. Thus, there are four indicators of critical reasoning based on socio-scientific issues: evaluating information, assessing the credibility of information sources, complexity, and multiperspective based on the specific development of socio-scientific issues (illegal mining) from websites or online news (Table 1 and Table 2). These four indicators of critical reasoning based on online socio-scientific issues are developed with needs related to recent developments in the flow of information so that the tendency for students' activities to access various information from the internet is higher. The issue of illegal mining, which contains dilemmas, is controversial and complex and can become a topic often discussed on social media or online news. This issue becomes biased if it is presented by prioritizing one party. The issue of illegal mining is complex and controversial because it is related to the socio-economic impact on society, which generally contradicts ethics and morals (Espin & Perz, 2021). Although mining governance policies in Indonesia are starting to move towards environmental sustainability (Akhmaddhian et al., 2023), political and cultural power relations make violating or regulating small-scale mining complicated (Asori et al., 2023). Illegal mining activities open up job opportunities and can meet economic needs despite unstable income (Maulida et al., 2022). Illegal mining activities have implications for the Sustainable Development Goals (SDGs). Positive impacts appear in the SDGs related to economic activities and poverty, while negative impacts appear in categories related to health and the environment (Laing & Moonsammy, 2021). The research results also report that children are involved in illegal gold mining and dropped out of school (Azumah et al., 2020).

Before empirical testing is carried out in the field, experts validate the instrument. Aiken's V index indicates that the instrument developed is suitable for measuring the extent to which the items in the instrument represent components in the overall content area of the object to be measured and the extent to which the items reflect the behavioral traits to be measured (Baharuddin et al., 2020; Nunnally & Bernstein, 1994). Experts provide suggestions and recommendations for improving the instrument so that the instrument can be used to measure the desired variable. Expert agreement on indicators of critical reasoning regarding online socio-scientific issues has four dimensions: evaluating SSI information, SSI complexity, assessing the credibility of information sources, and multiperspective. Based on Table 2, the instrument for evaluating information is

based on comparing the content of SSI information with external sources. Students are asked to assess appropriate and inappropriate information and provide reasons for appropriateness and inappropriateness based on reliable external sources (Keshavarz, 2021). Assessment of the credibility of SSI information shows whether the source website is trustworthy, accompanied by reasons from various factors. Marttunen et.al. (2021) also indicates that assessing the credibility of information sources is assessing each source and identifying the main position of the source and the supporting reasons. Meanwhile, the items for SSI complexity are arranged through reasoning that connects cause and effect, interrelationships, or pros and cons in the illegal mining problem. Furthermore, the items for taking the SSI multiperspective provide alternative actions and solutions that stakeholders should propose based on the illegal mining problem.

Based on Table 3, the GFI value obtained is 0.94, exceeding the proposed cut-off value and indicating that the instrument model fits the proposed basic model (Goretzko et al., 2023). Likewise, the RMSEA value is 0.045, which is smaller than 0.08; Chi-Square/df 1.29, which is smaller than 2; probability (p-value) 0.098 which is greater than 0.05; Comparative Fit Index (CFI) 0 .99 which is greater than 0.90, and Adjusted Goodness of Fit Index (AGFI) 0.89 which is smaller than 0.90, is included in the marginal fit category. However, overall, the instrument model fits. Construct validity is achieved when the instrument construct model meets the fit index conditions (Hu & Bentler, 1999). Next, empirical tests are carried out in the field at three high schools. The analysis results show that the 12 instrument items have loading factor values that meet the minimum criteria of 0.5 in the range of 0.5-0.8 (Figure 1). Factor loadings indicate how well an item is related to its factor. Apart from that, factor loading also shows that the items contained in one factor differ from those in others. This analysis shows four dimensions of critical reasoning based on socio-scientific issues.

The construct reliability value represents internal consistency with a value > 0.7 (Table 5). The research results show that the four variables observed in the online socio-scientific issue-based critical reasoning test instrument have the following construct reliability coefficients: 0.78, 0.77, 0.80, and 0.72. Thus, each instrument variable is reliable for measuring students' critical reasoning. According to Retnawati (2016a), construct reliability is the consistency of the variables, which are the latent constructs to be tested. Based on the CR value, the instrument has a high level of consistency when measurements are carried out using this instrument. CR demonstrates better instrument reliability and provides a robust reliability measure in research (Rosli et al., 2021).

The results of convergent validity analysis based on AVE values meet the minimum criteria in the following three dimensions: identifying SSI complexity, evaluating SSI information, and assessing the credibility of SSI information sources. However, the AVE value has not reached the minimum value in the multiperspective dimension (Table 5). An AVE value below 0.5 indicates that the latent construct variance for each item indicator is lower than the error variance (Ridwan et al., 2023). As a result, instrument items on multiperspective dimensions are less valid for measuring each observed variable. AVE measures the amount of Variance a construct captures in terms of the Variance due to the measurement error (Moreira, 2020). The overall percentage of AVE in the other three dimensions is above 50%, indicating good convergent validity. The AVE values agree with the index estimates, justifying the choice of variables that make up the construct (Valentini & Damásio, 2016; dos Santos & Cirillo, 2021).

The advantages of this online socio-scientific issue-based critical reasoning instrument are related explicitly to socio-scientific issues from online news sources and the solutions offered from online sources' evaluation results. The instrument provides a context for students to reason critically about online SSI. This instrument contributes to the availability of measuring tools for critical reasoning skills as one of the skills of the 21st century. This research has limitations in the context used, the illegal mining context. In addition, the research instruments of construct validity and reliability test only use first-order CFA with a correlation factor model.

CONCLUSION

Critical reasoning instruments based on socio-scientific issues have valid and reliable characteristics, so they can be used to measure. The instrument consists of 12 items that assess the dimensions of critical reasoning based on socio-scientific issues that meet the content validity of expert judgment, construct validity, convergent validity, and construct reliability. The socio-scientific issue-based critical reasoning instrument developed is suitable for use as a learning evaluation tool. This instrument can observe students' critical reasoning profiles on online socio-scientific issues.

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