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Explanatory Factor Analysis of Critical Thinking Instrument for Elementary Students

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Abstract: One of the main challenges in primary education is the low critical thinking skills of students during the learning process, which has a major impact on their academic achievement as well as their social and emotional development. This study aims to analyze the structure of the instrument factors for measuring critical thinking ability, which is developed based on four main dimensions: analytical ability, evaluation ability, inference ability, and problem-solving skills in elementary school students. This study uses a quantitative approach with a survey design involving 240 elementary school students. Data analysis was carried out through Explanatory Factor Analysis (EFA). The findings show that the four dimensions of critical thinking have significant factor weight, adequate convergent validity, and high construct reliability, as well as SRMR values that have a match with empirical data. The model created can describe well and in context how critical thinking works as a whole. This instrument is relevant for academic research as well as a diagnostic tool for teachers in designing responsive learning. These findings contribute significantly to improving the quality of basic education through a comprehensive and effective evaluation of students' critical thinking skills.

Keywords: critical thinking; elementary school; problem solving abilities.

INTRODUCTION

The changing times which are increasingly rapid in terms of development require a renewal in the education system, especially in the development of critical thinking competencies. This ability is very important to be instilled from an early age, especially at the elementary school (SD) level, because it is the foundation for students to deal with the complexity of information in today's digital and global era. Critical thinkers generally go through a series of stages in their thinking process, starting from formulating problems, formulating arguments, applying deductive and inductive reasoning, conducting evaluations, and making decisions to then act (Jufri, 2013). This ability also not only supports aspects related to academic achievement, but also equips students with important life skills to be able to face problems in the future. In a complex and dynamic information era, students are expected to be able to analyze, evaluate, and infer related information from the existence of information received logically and reflectively. Learning in schools should train students to be able to use their abilities and skills in searching, processing, and assessing the information

received critically (Susanti et al., 2019). In elementary education, critical thinking skills help students understand the material while forming a logical, structured, and reflective mindset in dealing with everyday problems (Ennis, 2011).

Although important, the development and measurement of critical thinking skills in elementary school students is still constrained, especially due to the lack of valid and reliable instruments in the Indonesian context. Many of the measuring tools adopted from abroad have not been culturally and contextually adapted, thus risking producing inaccurate data and hindering the development of critical thinking skills effectively. This raises the question: to what extent are these instruments able to reflect the critical thinking skills of elementary school students with different social, cognitive, and curricular backgrounds? The lack of conceptual agreement in defining and operationalizing critical thinking indicators for children's age also exacerbates this situation (Norris, S.P., and Ennis, 1989). In some cases, critical thinking measurements often overlap with other basic cognitive measurements such as understanding and applying concepts, making it difficult to conduct an in-depth analysis of true critical thinking abilities.

This problem is important to be studied seriously because its consequences have a direct impact on the quality of education. If the instrument used is inaccurate or invalid, then the data obtained from the assessment results cannot be relied on for decision-making, both in the context of classroom learning and macro education policies. Without adequate validity and reliability, assessments of students' critical thinking skills can be misleading, cause bias, and even hinder the process of students' intellectual development. This is where the development and testing of factors analysis-based instruments comes in, which can statistically evaluate how the items are related to each other and whether they reflect a valid criticalmult thinking construct structure.

Several previous studies have attempted to develop instruments to measure critical thinking skills in elementary school students. For example, (Amini, 2023) developed an observational instrument in the form of a questionnaire that was tested for validity using Aiken's V coefficient and reliability using Cronbach's Alpha, with results showing that the instrument was valid and reliable. Similarly, (Astiwi et al., 2020) developed an instrument for assessing critical thinking skills in PPKn subjects, with a content validity result of 1.00 and reliability of 0.84. However, there are still gaps in research related to in-depth explanatory factor analysis to ensure that the instrument actually measures the complex dimensions of critical thinking.

Most previous studies have tended to focus on testing the validity of the content and reliability of the instrument in general, without the application of exploratory factor analysis (EFA) which aims to uncover and confirm the latent structure of the instrument used. In fact, the application of factor analysis has a crucial role in the development of psychometric instruments, because it allows researchers to evaluate the extent to which each indicator or question item really represents the theoretical construct in question. Without this analysis, the accuracy and accuracy of the measuring tool in representing the dimensions of critical thinking ability can be doubted. Therefore, the integration of factor analysis approaches is an important step to ensure the validity of the construct, as well as guarantee that the instrument actually measures what it is supposed to measure.

A review of the literature shows that critical thinking is a high-level cognitive process that involves the ability to analyze, evaluate, and synthesize information (Paul & Linda, 2014). These abilities do not develop naturally, but require stimulation through appropriate learning and assessment. In the context of elementary school-age children, critical thinking needs to be translated into a form that is appropriate to their stage of cognitive development, such as the ability to compare, identify cause and effect, make simple inferences, and develop arguments based on concrete evidence (King, A., Goodson, L., & Rohani, 1998). Therefore,

the development of measurement instruments cannot be done carelessly, but must be based on the theory of child developmental psychology, cognitive learning theory, and modern measurement principles.

In the process of developing instruments in the fields of psychology and education, there are two fundamental aspects that need to be considered, namely validity and reliability. Validity refers to the extent to which an instrument is able to measure constructs or concepts that should be measured precisely, while reliability refers to the level of consistency of measurement results when performed at different times and situations. In other words, a valid and reliable instrument is a prerequisite for obtaining accurate and reliable data (Creswell & Creswell, 2018). One statistical approach that can be used to test the validity of constructs is Exploratory Factor Analysis (EFA). With EFA, researchers can identify the latent structure of the instrument item set, evaluate the interconnectedness between the items, and determine whether the constructed construct reflects the theoretical dimension of critical thinking ability.

However, in practice, it is still rare to conduct research that seriously applies exploratory factor analysis to critical thinking instruments for children. Even in some instrument development studies, analysis is often limited to content validity tests through expert judgment and reliability tests with Cronbach Alpha, without exploring the possible structure of factors from empirical data. This shows that there is a gap between the empirical approach that should be the standard in the development of instruments and the still conventional testing practices. Therefore, explanatory factor analysis (EFA) is relevant and important to produce instruments that are truly reliable scientifically and applicatively.

The balance between pure and applied aspects in this study is also consistently maintained. In terms of pure aspects, this research contributes to strengthening the theory of measurement and construct validity in the context of basic education, especially critical thinking skills. Meanwhile, from the applied side, the results of this research can be used directly by teachers, principals, and curriculum developers as a basis for designing critical thinking assessments that are more in accordance with the characteristics of elementary school students. In other words, this research not only adds to the scientific treasures, but also contributes significantly to the improvement of educational practices in the field.

Based on this background, this study aims to analyze the factor structure of the critical thinking ability instrument designed for elementary school students. In particular, this study aims to identify latent dimensions of critical thinking skills, test the validity of the instrument's constructs through exploratory factor analysis, and measure its reliability with appropriate statistical approaches. The results of this study are expected to contribute to the development of valid, reliable, and contextual assessment instruments for basic education in Indonesia.

METHODS

This study uses a quantitative approach with an exploratory survey method to analyze the validity and reliability of the construct of the instrument for measuring the critical thinking ability of elementary school students. This survey method can be used to obtain data from the intended population location which is carried out in a relatively short time and supports to measure statistical analysis in depth (Sugiyono, 2013). In addition, surveys have been found to be a suitable instrument to be applied in educational contests, because they are able to assess students' diverse perceptions of students' learning experiences in the classroom. This research was conducted using an instrument in the form of a closed questionnaire consisting of 35 statements. These statements are developed based on four main aspects of critical thinking, namely analytical skills (9 items), evaluation ability (8 items),

inference ability (9 items), and problem solving (9 items). Each statement was compiled using a 4-point Likert scale with a rating range from "Strongly Disagree" (1) to "Strongly Agree" (4). The instruments were compiled in an offline questionnaire format using a paper print form, in order to reach participants optimally.

The population in this study consists of elementary school students at the upper middle class level (grades IV–VI) in the Cirebon area, West Java. The selection of this level is based on the consideration of the cognitive development of students who at that stage have shown more complex thinking skills, so that it is possible to measure the critical thinking aspect. The research sample amounted to 240 students obtained through quota sampling techniques, with the distribution as follows: class IV (38%), class V (33%), and class VI (29%). Samples were taken from several public elementary schools to ensure the diversity of institutional backgrounds and increase data representativeness. The justification for selecting respondents is based on the relevance of the role of students as the main subject in the learning process, as well as as a group that is the target of developing critical thinking skills in the basic education curriculum. Data collection was carried out for two weeks by filling out questionnaires directly at school. Before use, the instrument has gone through a content validity process by basic education experts to ensure the suitability of the indicators used with the dimensions of critical thinking skills measured. All stages of data collection are carried out by paying attention to the principles of research ethics, including obtaining approval from the school, maintaining the confidentiality of respondents' personal data, and ensuring that student participation takes place voluntarily and free from pressure from any party.

Table 1. Critical Thinking: Aspect and Indicators

Aspect	Indicators	Question Item
Analytical Skills	*Able to identify problems in a social phenomenon.*	*P1* *P2* *P3*
	Analyze information objectively.	*P4* *P5* *P6*
	Relate academic concepts to relevant facts.	*P7* *P8* *P9*
Evaluation Ability	*Assess the accuracy andrelevance of the relevance of information.*	*P10* *P11* *P12*
	Identifying in an argument	*P13* *P14* *P15*
	Use empirical evidence to support the opinions expressed.	*P16* *P17*
Inference Ability	*Draw conclusions based on the available data.*	*P18* *P19* *P20*

	Predict the impact or consequences of a phenomenon.	*P21* *P22* *P23*
	Determine the solution based on the evidence that has been reviewed.	*P24* *P25* *P26*

Aspect	Indicators	Question Item
Problem Solving Abilities	*Develope alternative solution to a problem.*	*P27* *P28* *P29*
	Evaluate the effectiveness of the proposed solution.	*P30* *P31* *P32*
	Implement the solution in a real context.	*P33* *P34* *P35*

For the analysis of the validity and reliability of the construct, SmartPLS software version 4 was used, which is a software based on Partial Least Square Structural Equation Modeling (PLS-SEM). Validity analysis is done through convergent validity types. The validity of the convergence is determined based on the loading factor value for each indicator, which is required to be more than 0.70 and the Average Variance Extracted (AVE) value for each construct that must exceed 0.50 (Hair et al., 2020)

Meanwhile, the reliability test was carried out with reference to two main indicators, namely Cronbach's Alpha and Composite Reliability (CR). The required Cronbach's Alpha value is > 0.70, which indicates that each construct has good internal consistency. Similarly, the accepted Composite Reliability value must be more than 0.70, as an indicator that the construct has adequate combined reliability (Hair et al., 2020). Model suitability is evaluated using the Standardized Root Mean Square Residual (SRMR) index at or below 0.08 indicating an acceptable fit level. Therefore, if the SRMR value in this analysis is ≤ 0.08, then the model can be declared to have a good match with the empirical data (Kline, 2023). The data from filling out the questionnaire is input into Microsoft Excel, then imported into SmartPLS for analysis. The analysis procedure is carried out in stages starting from measurement modeling (outer model) to testing validity and reliability.

The materials and equipment used in this study consist of: computer or laptop devices that have the SmartPLS 4 application installed, printers and paper to print questionnaires, and Microsoft Excel as an aid in initial data processing. This research procedure starts from the preparation of indicators based on the critical thinking literature (Facione, 2011), content validation by experts, questionnaire distribution, data collection, and data processing and analysis using SmartPLS. This study is designed to be repeatable with similar parameters and steps to obtain comparable results.

RESULT AND DISCUSSION

Exploratory Factor Analysis (EFA) is carried out to identify and test the latent structure of critical thinking constructs consisting of four main aspects: analytical skills, evaluation ability, inference ability, and problem solving abilities. The process of the EFA is

carried out in stages, starting from modeling measurements, validity, reliability, to testing the suitability of the model.

Table 2. Standardized Factor Loadings for the Critical Thinking Model

Items	**Code**	**Factors Loading**
I can identify problems in a story or event.	*P1*	*.966*
I can predict what might happen in an event.	*P2*	*.897*
I rarely know what to do when I see problems around me.	*P3*	*.977*
I always check whether information is true or not.	*P4*	*.823*
I can recognize when news is dishonest or unfair.	*P5*	*.921*
I have difficulty understanding information from teachers or friends.	*P6*	*.930*
I often ignore information that contradicts my views.	*P7*	*.970*
I can relate lessons to events happening around me.	*P8*	*.949*
I can use my knowledge to solve real-world problems.	*P9*	*.936*
I rarely use school knowledge to help my friends.	*P10*	*.926*
I can distinguish between true and false information.	*P11*	*.945*
I can make conclusions from the information I have learned.	*P12*	*.947*
I rarely check if the information I receive comes from a trustworthy source.	*P13*	*.826*
I can give strong reasons for my opinions.	*P14*	*.872*
I can explain why I agree or disagree with something.	*P15*	*.907*
I find it difficult to identify facts in my friend's opinion.	*P16*	*.943*
Items	***Code***	***Factors Loading***
I can identify flaws in an argument or opinion.	*P17*	*.945*
I can look for alternative ideas if the first solution fails.	*P18*	*.889*

I struggle to explain my opinion clearly without solid evidence.	*P19*	*.862*
I can identify causes and effects of an event.	*P20*	*.896*
I can find the right solution to a problem.	*P21*	*.883*
I have difficulty identifying causes and effects in an event.	*P22*	*.932*
I can recognize patterns in a story or event.	*P23*	*.919*
I can understand hidden meanings in a text or story.	*P24*	*.891*
I always consider various possibilities before making a decision.	*P25*	*.883*
I can determine whether a solution is effective or not.	*P26*	*.778*
I can construct logical arguments.	*P27*	*.939*
I often fail to ensure whether a solution is effective or not.	*P28*	*.833*
I can compare two different ideas or opinions.	*P29*	*.875*
I can think from multiple perspectives.	*P30*	*.862*
I enjoy exploring things more deeply.	*P31*	*.913*
I enjoy discussing various topics.	*P32*	*.889*
I can relate the information I learned with my own experiences.	*P33*	*.867*
I can think objectively without being influenced by emotions.	*P34*	*.901*
I rarely rephrase information in my own words.	*P35*	*.885*

In factor analysis, factor loading shows how strongly an item represents the factor being measured. The high loading value reflects a great contribution to the construct. In general, the ≥ value of 0.90 is classified as very strong, while 0.70–0.89 is considered strong and worth defending. Meanwhile, a value below 0.70 is considered weak and cannot be maintained. Preliminary Exploratory Factor Analysis (EFA) shows that everything is at a threshold above the 0.7 average. Of the 35 questions, there is an item that has the lowest value, which is 0.778 and has an item that has the highest value, which is 0.977. On 35 questions that are stated as appropriate and valid questions and can be distributed in 4 Aspects. This process ensures that only indicators that have values above the threshold limit of 0.7 can be used to measure critical thinking constructs.

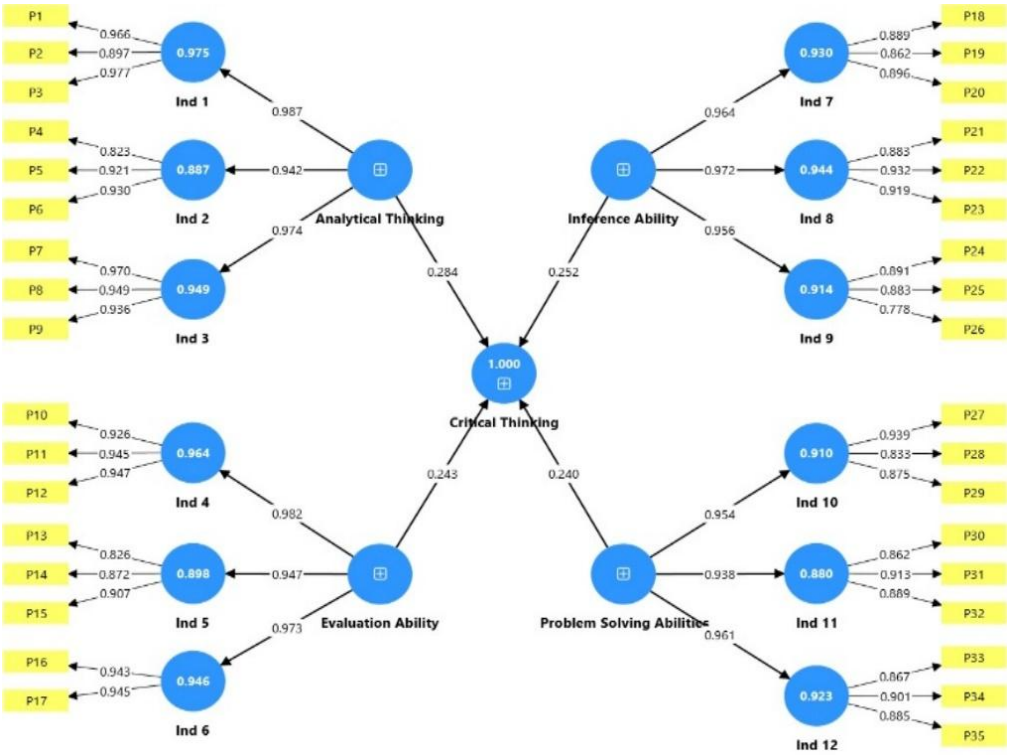

Figure 1. *Final Exploratory Factor Analysis Model of Critical Thinking Comprising*

Figure 1 of the EFA's model a, which consists of 4 aspects and 12 indicators containing 35 questions, shows a stable and consistent structure of factors. This model shows that the relationship between 4 aspects of critical thinking construction, each supported by relevant indicators. This model provides a solid starting basis for showing that the four aspects of critical thinking are indeed conceptually and empirically distinguishable in the context of elementary school students.

Table 3. Reliability and Convergent Validity of the Constructs

Aspect	Cronbach's alpha	CR	AVE
Analytical Thinking	.970	.975	.812
Evaluation Ability	.960	.966	.783
Inference Ability	.952	.959	.724
Problem Solving Abilities	.948	.956	.708

All constructs showed Cronbachh's alpha and CR ≥ 0.70 and AVE ≥ 0.50, indicating that all four constructs met the requirements for internal reliability and convergent validity. In practice, this signifies that the instrument has the ability to measure the dimensions of critical thinking with precision and precision. Therefore, empirical evidence corroborates the hypothesis that the items in each dimension are consistent and authentic representations of their respective theoretical constructs.

Table 4. Goodness-of-Fit Indices for the EFA Model

Fit Indices	Value	Cut-off Criteria	Interpretation
SRMR	.074	≤ 0.08	Good Fit
d_ULS	31,694	-	Good Fit

The results of the goodness-conformity analysis showed that all model suitability indices met the specified criteria, which showed that the EFA model of 4 critical thinking constructs (analytical skills, evaluation ability, inference ability, and problem solving abilities) showed optimal conformity with the data. Optimal models accordingly support structural validity, and these instruments are suitable for use in further research and for diagnostic or evaluative purposes in the context of basic education. In general, these results provide an early indication that the model has a sufficient degree of conformity to the empirical data.

The ability to think critically is a skill that is needed by students today to become the superior generation in global and future competition (Jamaluddin et al., 2020). In learning, critical thinking is seen as a multidimensional competency that involves cognitive, meta-cognitive, and affective aspects (Duron et al., 2006). Development of critical thinking skills not only done in learning only, but it must also be supported by An assessment instrument that reflects critical thinking skills. Critical thinking requires practice, one of which is the habit of working on problems that develop critical thinking skills (Kartimi & Liliasari, 2012). An approach that integrates these various dimensions allows students not only to absorb information passively, but also to play an active role as reflective thinkers who are emotionally and intellectually involved in the learning process. Thus, the development of critical thinking in elementary school students not only supports academic achievement, but also equips them with essential 21st-century life skills. Learning in schools must strive to form a critical mindset for students. That way, students will be able to appear confident and always try to provide the best solution to every problem that arises.

Success in adapting the instrument to primary school contexts suggests that modern psychometric approaches can be used to ensure the conceptual validity of such measures, even when applied to younger populations. These findings suggest that the critical thinking skills observed at the elementary level can be considered consistent with the theoretical frameworks used at higher education levels, depending on the application of appropriate linguistic and cultural adjustments. This instrument has the capacity to function as a conventional monitoring tool, to assess the existence of critical thinking skills in learning and reflected in daily life that is able to help student involvement from time to time, or as an evaluative instrument of learning policies that have been implemented. The reliability and validity of this tool support its use in two distinct yet interconnected domains. First, it is suitable for academic research purposes. Second, it can be incorporated into daily educational practices.

As a result, a deeper understanding of critical thinking will facilitate the implementation of more adaptive teaching strategies that are responsive to the overall needs of students. These results provide a solid foundation for educators and policymakers to develop comprehensive learning interventions. This research emphasizes an in-depth understanding of critical thinking as the basis of adaptive and continuous learning strategies, with instruments used to monitor student engagement longitudinally. Meanwhile, Amini's research focuses more on the development of observation instruments in the form of questionnaires that are tested for validity using Aiken's V coefficient and Alpha Cronbach reliability, without achieving the application of the instrument in the context of developing learning strategies. Thus, this research goes further in the practical application and long-term functionality of the instrument in the educational environment. In addition, these instruments can be used on an ongoing basis to monitor the dynamics of student engagement over time.

CONCLUSION

The results of this study show that instruments designed to measure critical thinking, which include the dimensions of analytical skills, evaluation ability, inference ability, and problem solving abilities, show valid and reliable quality when used in the context of elementary school. These findings confirm that critical thinking is not a single concept, but a multidimensional construct that complements each other in reflecting the ability of critical thinking as a whole in the learning process. The validity of the model is confirmed through the analysis of EFA, supporting the use of the instrument as an accurate diagnostic tool in the context of basic education. This research makes an important contribution to the development of more adaptive learning evaluations by emphasizing the importance of measuring and understanding critical thinking skills from various aspects. However, this study has limitations, mainly because the scope of observation is still limited to a few specific elementary schools, so the results cannot be generalized widely. The observational approach applied also does not fully record the dynamics of learning in depth, especially related to contextual factors such as teachers' teaching methods and student characteristics.

For future research development, it is recommended that the scope of the study be expanded to include more socially and geographically diverse populations. In addition, the use of a mixed methods approach can be considered to further explore the relationship between cognitive aspects and learning context in the development of critical thinking skills. Further research can also be focused on testing these instruments in problem-solving-based learning scenarios or inquiry approaches, in order to strengthen their external validity and practical application

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