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Assessing Higher-Order thinking skills: Development and content validation of a Domain-Specific test in business mathematics

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Abstract

Critical and creative thinking skills are essential for Business Mathematics students because they support effective problem-solving and decision-making. This study aimed to develop and validate a test instrument to measure these skills in the context of Business Mathematics learning. The instrument was developed using the PLOMP model, with a focus on the assessment phase, and expert validation was conducted by five specialists in mathematics education and evaluation. Data were analyzed using the Content Validity Ratio (CVR) and Content Validity Index (CVI), where all 8 critical thinking and 8 creative thinking items achieved perfect scores of 1.00. Construct validity testing using Pearson Product-Moment correlation indicated that all items met the required criteria with r_calculated>r_table. Reliability testing also showed high internal consistency with Cronbach's Alpha values of α=0.883and α=0.817. These results confirm that the instrument is valid, reliable, and feasible for further implementation.

Keywords: Critical thinking, Creative thinking, Content validity, Business mathematics, CVR, CVI

Introduction

Higher-order thinking skills, such as critical and creative thinking, are essential competencies for addressing the challenges of the 21st century (Herlinawati et al., 2024; Nurhayati et al., 2024; Partono et al., 2021; Supena et al., 2021; Yazar Soyadı, 2015). These skills encompass logical reasoning, complex problem solving, analytical decision-making, and the ability to generate original ideas. International organizations such as the OECD (Ramsden, 2020) and the World Economic Forum (WEF, 2023) emphasize that higher-order thinking skills are a fundamental pillar in preparing adaptive, innovative human resources capable of responding to dynamic global changes.

The rapid and data-driven development of the global business environment demands advanced analytical skills and the ability to model complex situations. In this context, mathematics plays a strategic role because it fosters systematic thinking, precision in reasoning, and the ability to model and evaluate real-world situations (Anggoro et al., 2024; Çakıroğlu & Yıldırım, 2024). Mathematical modeling in real-life contexts has been shown to stimulate higher-order thinking processes, particularly in understanding relationships among variables, making assumptions, and making analysis-based decisions (Suharta & Astawa, 2024). In line with this, higher education in Indonesia, through the Indonesian National Qualifications Framework (KKNI), stipulates that bachelor's graduates must demonstrate deep disciplinary mastery and be able to apply their knowledge critically, creatively, and responsibly in professional and social contexts (Herlinawati et al., 2024).

Despite the widespread recognition of the importance of developing critical and creative thinking skills, the assessment of these skills still faces significant challenges. Many assessment instruments place greater emphasis on learning outcomes and fail to capture the underlying thinking processes reflected in students' responses (K. Agustini et al., 2021; Puger et al., 2024; Suryawan et al., 2023). Ideally, the assessment of higher-order thinking skills (HOTS) should be developed using contextual, real-life scenarios rather than routine or procedural questions (Ayu et al., 2024; Santyasa et al., 2019). High-quality HOTS instruments should present authentic problems that require modeling, decision-making, and conceptual generalization processes (Paramita et al., 2024; Suharta & Astawa,

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2024).

Numerous studies indicate that innovative instructional media and approaches play a crucial role in stimulating higher-order thinking skills. Project, case, and problem-based learning approaches integrated with digital technologies such as gamification and interactive online learning—have been shown to enhance students' cognitive engagement (Suartama et al., 2023; Tegeh et al., 2022). Blended learning (Istri et al., 2023), as well as flipped learning and quantum flipped learning models, also contribute positively to the development of students' critical and creative thinking skills (Ketut Agustini et al., 2022; Ekayana et al., 2024; Santyasa et al., 2021; Tegeh et al., 2022).

Furthermore, the use of digital content designed based on cognitive theories—such as the Cognitive Theory of Multimedia Learning (CTML)—can help students process information more effectively and deeply (Sudarma & Sukmana, 2021; Sudatha et al., 2021). Appropriate visual and textual message design also facilitates students' analytical and reflective processes (Sudarma et al., 2015). Moreover, the application of adaptive digital systems, such as multiple intelligence diagnostic applications, has the potential to support differentiated learning and optimize learning outcomes through digital content tailored to learners' individual characteristics (Sudarma et al., 2025).

Within this context, HOTS assessment items should be developed in alignment with instructional approaches that promote exploration, reflection, and active student engagement. Assessment practices must also adapt to digital media that align with the characteristics and preferences of today's generation (Sari et al., 2024; Wayan Marti et al., 2023). However, in practice, many existing instruments remain overly general, insufficiently contextualized, and not specifically designed for the field of business mathematics.

In the development of psychometric instruments, content validity represents the most fundamental initial stage, as it determines the extent to which test items accurately represent the intended construct. Without strong content validity, measurement results risk producing misleading and unreliable interpretations (Sudarmika et al., 2022). Several studies have shown that critical and creative thinking instruments used in higher education (Hu & Bi, 2025; Hutting et al., 2025; Zhou et al., 2023; Zohoorian et al., 2023) are generally not specifically designed for the context of business mathematics, thereby limiting their ability to reflect the unique characteristics of problem solving and decision-making in this domain. Consequently, the development of contextualized, relevant, and content-validated instruments for business mathematics is urgently needed, both for learning evaluation purposes and as a foundation for curriculum and pedagogical improvement.

Content validity assessment in this study was conducted using two complementary quantitative approaches: The Content Validity Ratio (CVR) and the Content Validity Index (CVI). CVR is used to determine the extent to which experts judge each item as essential to the construct being measured, yielding a quantitative proportion that reflects item importance (Romero Jeldres et al., 2023). Meanwhile, CVI assesses the level of agreement among experts at both the item level (I-CVI) and the scale level (S-CVI) (Hutting et al., 2025; Rezaei et al., 2023). The combined use of these methods provides an objective quantitative foundation for content validation while still incorporating expert judgment. Numerous international studies have demonstrated the effectiveness of CVR and CVI in developing valid and reliable assessment instruments (Abbasi-Sosfadi et al., 2025; Hutting et al., 2025; Kermani et al., 2024; Rezaei et al., 2023). Nevertheless, these methods also have limitations, including sensitivity to the number of experts and potential subjectivity in scale interpretation. Therefore, in this study, the application of CVR and CVI was carried out cautiously, accompanied by transparent and systematic documentation of expert judgments.

Review of earlier research

In the era of information and technological disruption, higher-order thinking skills are a major asset in higher education, including in the domain of Business Mathematics. Critical and creative thinking skills are two essential components in addressing the complexity of real-world business problems and data-driven decision-making. Empirical studies indicate that learning approaches integrating projects, problem solving, and blended digital environments can effectively foster students'

scientific creativity and higher-order thinking skills (Warpala et al., 2025). However, the measurement of these two skills has not been fully accommodated in higher education assessments, particularly in contexts that integrate quantitative reasoning, business logic, and creative problem solving (Darma et al., 2018). Therefore, it is crucial to develop test instruments that are not only content-valid but also relevant to the specific needs of the Business Mathematics discipline (Anggoro et al., 2024; Zhou et al., 2023).

In fact, students' critical thinking skills are essential for meeting the challenges of the 21st century (Basri et al., 2019; Harjo et al., 2019; Hidayatullah et al., 2021; Santyasa et al., 2018; Suryawan et al., 2023). Critical thinking can be defined as the ability to analyze, evaluate, and synthesize information logically before drawing conclusions. This definition is rooted in the framework proposed by Facione (1990), which emphasizes six core skills: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Furthermore, Ennis (1991; 2011) emphasized that critical thinking also involves a dispositional tendency to think rationally and reflectively. In mathematics learning, strategies such as cognitive conflict supported by e-service learning have been shown to be effective in strengthening conceptual understanding and reducing misconceptions, thereby supporting the development of students' critical thinking skills (Parwati & Suharta, 2020).

Meanwhile, creative thinking refers to the ability to generate novel, flexible, and original ideas in problem solving. Recent research suggests that critical and creative thinking should not be viewed as separate competencies, but rather as complementary processes within complex cognitive activity. The critical–creative thinking model describes a cyclical process in which creative thinking generates innovative ideas, which are then refined and evaluated through critical thinking. In the context of Business Mathematics, this integration is reflected in the analytical processing of quantitative data followed by the formulation of adaptive and innovative business strategies. Previous studies on assessment development have shown that instruments grounded in contextual and culturally relevant frameworks are more effective in capturing students' character, reasoning, and thinking processes (Arnyana et al., 2017).

Most existing critical and creative thinking instruments have been developed for general education or primary and secondary school contexts. Only a limited number of studies have specifically designed assessment instruments that consider the unique scientific characteristics of Business Mathematics, which require strong quantitative reasoning combined with strategic decision-making skills. Research in economics and STEM education highlights that context-based instrument development yields higher validity, as it aligns assessment tasks with students' learning environments and disciplinary demands.

Content validation is a crucial stage in instrument development, as it ensures that test items accurately represent the constructs being measured. One of the most widely used validation approaches is the Lawshe model (LAWSHE, 1975), which employs the Content Validity Ratio (CVR), followed by refinements introduced by Lynn through the Content Validity Index (CVI). Validation is conducted through expert judgment involving subject-matter and measurement experts, and CVR and CVI values are used to determine the relevance, clarity, and representativeness of test items.

Based on the literature review, it is evident that there is an urgent need to develop an assessment instrument for critical and creative thinking skills that is specifically tailored to the context of Business Mathematics. Existing instruments do not sufficiently capture the characteristics of students who engage with numerical data and dynamic business problems. Moreover, the integration of critical and creative thinking within a single assessment instrument remains relatively underexplored. This study is expected to contribute to filling this gap, both theoretically and practically, by providing a validated and contextually relevant measurement tool.

Method

Research design: This study uses a research and development approach that focuses on the process of designing, compiling, and validating the contents of critical and creative thinking skills test instruments in the business mathematics domain. The development steps begin with an in-depth theoretical study to

formulate the constructs and indicators of the skills to be measured. Based on these indicators, questions are compiled which are then validated through expert judgment techniques by experts in the field of mathematics education and learning evaluation. This validation aims to assess the suitability between the items and the constructs being measured, as well as to ensure the relevance and context of the questions are in accordance with the characteristics of Business Mathematics. The results of the validation process are used to revise and refine the items so that they have editorial clarity, content accuracy, and readiness to be tested empirically in the next stage.

Instrument development

The development model used in this study refers to the PLOMP model (Plomp & Nieveen, 2013), which consists of three main phases: (1) preliminary research, (2) prototyping phase, and (3) assessment phase. The PLOMP model was selected because it provides a systematic and iterative framework for developing educational products that are contextual, valid, and suitable for implementation in real learning settings. This model is widely applied within the design research paradigm, which emphasizes continuous refinement through cycles of analysis, design, evaluation, and revision to ensure both theoretical soundness and practical relevance (Suharta & Sudiarta, 2022). The description of each phase is explained as follows:

Preliminary research

This stage includes literature study activities to identify concepts, dimensions, and indicators of critical thinking and creative thinking, as well as needs analysis based on the curriculum of the Business Mathematics study program. In addition, identification of student characteristics and the context of learning business mathematics at the higher education level is also carried out.

Prototyping phase

At this stage, based on the results of the initial investigation, the researcher designed 8 critical thinking skills test questions and 8 creative thinking skills test questions in the form of descriptions developed by referring to indicators of critical and creative thinking skills in the context of business case studies. The question design aims to explore students' skills in analyzing quantitative information and developing creative solutions to applicable problems in the business world.

Assessment phase

The evaluation stage focuses on the validation process of the instrument content by experts. Five experts who have competence in the fields of mathematics education, assessment instrument development, and business mathematics are involved as validators. The analysis techniques used to evaluate the validity of the content include calculating the Content Validity Ratio (CVR) and Content Validity Index (CVI).

Participants

The participants in this study were five expert judges who were selected purposively based on certain criteria, namely: (1) having expertise in the field of mathematics education or educational assessment, (2) having more than five years of experience in developing learning evaluation instruments, and (3) being active in academic activities and scientific publications. The experts were asked to provide an assessment of each question item in terms of relevance to the indicators, clarity of the question wording, and suitability of the context to the field of Business Mathematics.

Data Analysis Techniques

Content Validity Ratio (CVR)

CVR is used to measure the level of agreement of experts on the essentiality of each test item. The calculation of the CVR value is based on the formula developed by Lawshe (LAWSHE, 1975):

$$CVR = \frac{n_e - \left(\frac{N}{2}\right)}{\left(\frac{N}{2}\right)} \quad \ldots \ldots\ldots\ldots\ldots\ldots (1)$$

Description:

n_e : number of experts stating that the item is "essential"

N : total number of experts (5 people)

CVR values range from -1.00 to 1.00. For five experts, the minimum acceptable CVR value is 0.99. A high CVR value indicates that the item is considered important and relevant by the experts.

Content Validity Index (CVI)

CVI is used to measure the proportion of expert agreement on item relevance using a rating scale: 0=Not relevant, 1=Relevant. Item CVI is calculated as the proportion of the number of experts who give a score of 0 or 1 to the total number of experts. Meanwhile, the overall CVI value (S-CVI/Ave) is obtained from the average of all item CVIs.

Table 1. Interpretation of CVI values

Range of CVI Values	Validity Category
0.80-1.00	Valid High
< 0.80	Needs Revision

Construct validity

Construct validity was empirically tested to ensure that each item accurately measures the intended theoretical constructs of critical and creative thinking skills. The analysis was conducted using the Pearson Product Moment correlation technique in SPSS version 26. The correlation value of each item was compared to the critical value $r_{table} = 0.361$at a 5 percent significance level with a sample size of 30 students.

The results indicate that all items from both instruments obtained $r_{calculated}$values greater than r_{table}. Therefore, all items were confirmed to be construct valid because they significantly contributed to the measurement of critical and creative thinking skills.

Instrument reliability

The reliability of the instrument was evaluated using Cronbach's Alpha, which measures the internal consistency among the items. The analysis showed that the critical thinking skills test obtained a reliability coefficient of $\alpha = 0.883$, while the creative thinking skills test obtained a reliability coefficient of $\alpha = 0.817$. Both coefficients exceed the threshold of $\alpha > 0.80$, indicating a very high level of reliability.

These results demonstrate that all items in the instruments are consistent and stable in measuring the intended constructs, confirming that the instruments are reliable for use in this research.

Results: The content validation process of 8 critical thinking skills test items and 8 creative thinking skills test items was conducted by five experts using the Content Validity Ratio (CVR) and Content Validity Index (CVI) methods. All experts assessed that each item was included in the "essential" category with a CVR value of 1.00. This shows full agreement among experts regarding the importance of each item in measuring the constructs of critical and creative thinking in the context of Business Mathematics.

Similarly, the CVI calculation for each item produces a score of 1.00, which means that all experts give a score of 1 (relevant) to each item. The overall CVI value (S-CVI/Ave) also shows a perfect number, which is 1.00.

Table 2. CVR and CVI Values of each item

No	Item Question	CVR	CVI	Validity Category
Critical Thinking Skills Test				
1	Question 1	1.00	1.00	valid
2	Question 2	1.00	1.00	valid
3	Question 3	1.00	1.00	valid
4	Question 4	1.00	1.00	valid
5	Question 5	1.00	1.00	valid
6	Question 6	1.00	1.00	valid
7	Question 7	1.00	1.00	valid
8	Question 8	1.00	1.00	valid
Creative Thinking Skills Test				
1	Question 1	1.00	1.00	valid
2	Question 2	1.00	1.00	valid
3	Question 3	1.00	1.00	valid
4	Question 4	1.00	1.00	valid
5	Question 5	1.00	1.00	valid
6	Question 6	1.00	1.00	valid
7	Question 7	1.00	1.00	valid
8	Question 8	1.00	1.00	valid

All questions meet the minimum threshold values for CVR and CVI, so it can be concluded that the instrument has met quantitative content validity. Next, construct validity and reliability were carried out for the critical thinking skills test instruments.

Construct validity was empirically tested using SPSS version 26 through the Pearson Product Moment

correlation technique, correlating each item score with the total test score. The validity criteria were determined using a critical value of $r_{table} = 0.361$at $n = 30$and $\alpha = 0.05$. All items were declared valid because the calculated correlation values ($r_{calculated}$)exceeded the critical value (r_{table}).

Table 3. Results of the validity of the critical thinking skills test

Item	r_{table}	$r_{calculated}$	Interpretation
P1	0.361	0.691	valid
P2	0.361	0.710	valid
P3	0.361	0.723	valid
P4	0.361	0.737	valid
P5	0.361	0.721	valid
P6	0.361	0.755	valid
P7	0.361	0.797	valid
P8	0.361	0.843	valid

Reliability was then examined using Cronbach's Alpha, which resulted in a coefficient of $\alpha = 0.883$. This value falls under the category of very high reliability ($\alpha > 0.80$), indicating excellent internal consistency among test items.

Thus, the critical thinking skills test is considered highly valid (content and construct) and reliable, making it appropriate for use in this study.

Next, construct validity and reliability were carried out for the creative thinking skills test instrument. This instrument was designed to measure four dimensions of creative thinking: fluency, originality, elaboration, and flexibility. Construct validity testing employed the same Pearson correlation procedure in SPSS version 26. All items met validity requirements because their $r_{calculated}$values were greater than the r_{table}

Table 4. Results of the validity of the creative thinking skills test

Item	r_{table}	$r_{calculated}$	Interpretation
P1	0.361	0,570	Valid
P2	0.361	0,472	Valid
P3	0.361	0,551	Valid
P4	0.361	0,727	Valid
P5	0.361	0,671	Valid
P6	0.361	0,789	Valid
P7	0.361	0,724	Valid
P8	0.361	0,824	Valid

The reliability test obtained a Cronbach's Alpha value of $\alpha = 0.817$, which indicates very high reliability and excellent internal consistency. Therefore, the creative thinking skills test is considered highly valid (content and construct) and reliable, and is feasible to be used in evaluating students' creative thinking skills.

Discussion

Content validity is a key dimension in the development of measurement instruments, as it determines the extent to which the items in a test reflect the full domain of the construct being measured. In this context, the constructs of critical and creative thinking refer to students' abilities to analyse information, evaluate arguments, generate solutions, and develop innovative ideas while solving contextual Business Mathematics problems.

The high CVR and CVI values obtained for all test items indicate a very strong level of agreement among the experts regarding the relevance and essentiality of each item. A perfect CVR score of 1.00 confirms that each expert classified every item as essential for measuring the intended construct. This reinforces the scientific legitimacy of the test as a content-valid measurement tool. An important strength of this instrument is the integration of real Business Mathematics cases into the question design, which facilitates the application of higher-order cognitive processes in authentic contexts. Such contextualization is highly relevant for Business Mathematics students who must develop data-driven decision-making skills and quantitative reasoning aligned with real economic scenarios. Therefore, embedding business case studies within the assessment enhances its ecological validity and increases students' opportunities to transfer knowledge to practice.

In addition, the use of both CVR and CVI provides a triangulation approach in content validation, strengthening the rigor of the evaluation process. CVR offers a strong quantitative justification for the essentiality of items, while CVI provides more detailed evidence regarding clarity, appropriateness, and relevance. The involvement of experts from mathematics, mathematics education, and educational evaluation also ensures compliance with both content accuracy and psychometric standards, supporting the development of an instrument that is

theoretically sound and practically usable across diverse educational settings.

Construct validity further supports the robustness of the instrument. The results of the Pearson Product Moment correlation analysis showed that all items in both the critical and creative thinking tests had correlation coefficients higher than the critical value $r_{table} = 0.361$. This suggests that each item significantly contributes to measuring the intended constructs and is not influenced by irrelevant variance. In other words, students' scores on individual items are aligned with their overall performance, confirming that the items are accurate indicators of the respective cognitive abilities. This finding aligns with empirical validation principles which emphasize that item scores must demonstrate strong associations with the total construct score in order to establish construct validity.

Instrument reliability also showed excellent results. Based on Cronbach's Alpha analysis, both instruments demonstrated very high internal consistency coefficients, with $\alpha = 0.883$for the critical thinking test and $\alpha = 0.817$for the creative thinking test. These values exceed the commonly accepted threshold of $\alpha > 0.80$, indicating that the items consistently measure the same constructs and produce stable results across administrations. High reliability also suggests that measurement errors are minimal and that the instrument can be used confidently to assess students' abilities in various classroom or research settings.

Overall, these findings support existing literature emphasizing that the development of high-quality assessment instruments must incorporate systematic validation procedures that align theory, empirical evidence, and psychometric standards.

The integration of contextual business problems, expert validation through CVR and CVI, and strong construct validity and reliability outcomes confirms that the developed test instruments are both scientifically rigorous and pedagogically meaningful. Consequently, the instrument is highly feasible for use in evaluating improvements in critical and creative thinking skills among Digital Business students within higher education environments.

Conclusions

This study successfully developed and validated a test instrument for measuring critical and creative thinking skills in the Business Mathematics study program using the PLOMP development model. The results of content validation by five experts showed perfect CVR and CVI scores of 1.00, confirming that all items are essential and highly relevant to the constructs being measured. Empirical testing also demonstrated strong construct validity, where all items obtained correlation coefficients greater than $r_{table} = 0.361$. Reliability analysis further showed high internal consistency, with Cronbach's Alpha values of $\alpha = 0.883$for the critical thinking test and $\alpha = 0.817$for the creative thinking test. These findings prove that the developed instrument is valid and reliable, and therefore suitable for use in subsequent implementation stages to assess students' higher-order thinking skills in Business Mathematics.

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