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Development of Ethnomathematics-Based Test Instrument to Measure Critical Thinking Ability

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Abstract

In an effort to improve one's critical thinking skills through mathematics, of course, an instrument or special material is needed to measure critical thinking skills, one of which is through an ethnomathematics-based test instrument. This research is research and development (R&D), which involves developing test instruments with the formative research model (Tessmer). This development goes through two stages, namely preliminary and self-evaluation stages. The research was conducted on 4th-semester students who had studied mathematical economics. Validation sheets, tests, and questionnaires were used to collect data. The data collected were analysed using question validity analysis, student and lecturer response analysis, and test quality analysis, including reliability, difficulty level, and differentiability. At the same time, the critical thinking skills of students will be analysed descriptively. The results of this development obtained ethnomathematics-based test instruments that meet the criteria for validity, reliability, differentiability, difficulty level, and practicality according to standards. Thus, ethnomathematics-based test instruments are feasible to use to measure students' critical thinking skills.

Keywords: Critical thinking, Ethnomathematics, Test Instrument, Tessmer

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INTRODUCTION

Critical thinking has become a crucial element in recent decades. According to Barnett (1997), critical thinking is the defining identity of universities in the West, and it can shape students into 'critical citizens'. Pettersson (2020) revealed that critical thinking must be given a central role in the education system. This is to support reflective thinking (Dewey, 1933; Scheffler, 1973; Siegel, 1988). Although there are many diverse definitions regarding critical thinking, according to Moore (2013), critical thinking involves a variety of skills, practices, values, and dispositions that encourage deep questioning and reflectivity. Meanwhile, according to Liu et al. (2016), The definitions offered by various frameworks in higher education and the workforce share some common features. For example, most frameworks have emphasised skills such as evaluating evidence, analysing arguments, inductive and deductive reasoning, identifying assumptions and hypotheses, drawing conclusions, extrapolating inferences and understanding implications. Facione (1990) and Halpern (2014) revealed that critical thinking includes analysis, reasoning, problem-solving, argumentation, and evaluation of information.

However, the reality in the field is that the level of critical thinking skills of Indonesian students often has not reached their intended potential (Pramasdyahsari, Setyawati, Aini, & Nusuki, 2023). In 2022, Indonesia's PISA score in mathematics

showed a figure of 366, a significant decrease compared to the score in 2018, which reached 279 (OECD, 2023; OECD, 2018). Low math scores on PISA measurements in Indonesia are closely related to students' low critical thinking skills. This is because students still have difficulty solving mathematics problems, which emphasises the skills of formulating and interpreting a problem. These skills are needed to develop the right math problem-solving strategy (Rahayu & Alyani, 2020). In addition, research by Evendi et al. (2022) also revealed that students' critical thinking skills are still relatively low or in the non-critical category. One of the triggers for this low ability is the unhabit of students in solving critical thinking problems. Teaching methods that tend to focus more on memorisation and application of formulas without encouraging analytical thinking are one of the main causes of low critical thinking skills among students. Chikiwa & Schäfer (2018) revealed that one way to improve critical thinking skills is to ask appropriate and formulated questions at the right cognitive level in mathematics teaching and learning.

In an effort to improve critical thinking skills, ethnomathematical approaches emerged as an interesting solution. Research on ethnomathematics has also been widely documented by experts so far using diverse perspectives. Prahmana and D'Ambrosio (2020) indicate that Yogyakarta Batik uses the concept of geometry transformation in the making of Yogyakarta's unique Batik motif. Besides that, each motif or pattern also contains local values. These, namely moral, historical, and philosophical values, can be felt, reflected, and applied in daily life, such as values that teach leadership, good deeds, and so on. Mania and Alam (2021) show that the ethnomathematical approach is interesting, can overcome students' boredom in learning mathematics, and can preserve Indonesian culture. Research Shahbari & Daher (2020) the main results indicated that the students succeeded in constructing the concepts of congruence and congruent triangles via the ethnomathematics learning process. In addition, the students succeeded in arriving at and formulating the three congruence theorems. Moreover, findings obtained from the questionnaires indicated that the students improved their proving processes as a result of ethnomathematics-based learning. Furthermore, paired sample t-tests indicated significant differences between the students' mean scores before and after the learning process. Exploratory study (2019), the first section of our paper, presented how seven elementary teachers explored the mathematics of Talavera tiles as a culturally responsive context for their students, who recognised the tiles in their homes and communities. In the second half of the paper, we extended the discussions from the professional development workshop to present ways that teachers might address transformational geometry and symmetry with the Talavera tiles. The designs of Talavera tiles can offer multiple opportunities to help students develop a deeper and broader understanding of mathematics in ways that connect to the cultural artefacts they might see in their homes and communities.

In the past decade, research on the development of ethnomathematics-based test instruments has long attracted the attention of world experts (Aini et al., 2022; Dasaprawira & Susanti, 2019; Rawani et al., 2019; Yansen et al., 2019; Nizar et al., 2018; Oktiningrum et al., 2016). Aini et al. (2022) developed a PISA model test using the context of historic buildings. This study produced a similar PISA in the context of building space and shape to the context of historical buildings in Karawang, which has a potential effect on students' interest in PISA-like questions, as well as students' ability to understand and answer PISA-like questions. Moreover, Susanti (2019) developed a PISA-type test using the context of Bangka (Tanjung Kalian Lighthouse). The results of the study show that the problems developed have a ptosensory effect on communication skills, representation, mathematics, reasoning, arguments, and formulating strategies to solve problems. Rawani et al. (2019) developed a PISA-type test using the context of Taekwondo at the Asian Games. Based on the analysis of students' answers, the questions

developed showed a potential effect on basic mathematical skills, including reasoning and argumentation skills. Yansen et al. (2019) developed PISA-type questions using the context of football games at the Asian Games. This research produces questions that have a potential effect on students' mathematical literacy skills. Students' mathematical literacy skills that emerged during the research were communication, reasoning and argumentation, and designing strategies for problem-solving. (Nizar et al., 2018) developed a PISA-type test using the context of football and table tennis games at the Asian Games. The answers of the 33 students involved in the field test showed that the questions had a potential effect on communication and representation skills. Finally, Oktiningrum et al. (2016) developed a PISA-type test using the context of Indonesian heritage and culture. The results of the study show that the problems developed have the potential to have an impact on students' mathematical literacy by activating the indicators of each basic mathematical ability.

Although there have been several previous studies, there is still a research gap in the context of the development of ethnomathematics-based test instruments. This is related to the limited ethnomathematics-based tests that focus on developing critical thinking skills. The tests developed by the researchers have previously covered diverse contexts, such as historic buildings, football games, table tennis, taekwondo, and Indonesia's cultural heritage. However, empirical evidence reporting the potential impact of ethnomath-based tests on critical thinking skills is limited. Therefore, more specific and explicit follow-up research is needed to direct the focus on developing ethnomathematics test instruments that can significantly facilitate critical thinking skills and indirectly improve students' critical thinking skills.

Therefore, in order to fill the gaps and limitations of previous research, this study aims to develop ethnomathematics-based test instruments to measure critical thinking skills. Specifically, this study asks several questions. First, what are the characteristics of ethnomathematics-based test instruments? Second, how is the quality of the developed test instruments reviewed from the perspective of validity, reliability, level of difficulty, differentiation, and practicality of ethnomathematics-based test items? Third, how is the level of students' critical thinking skills measured using ethnomathematics-based test instruments? Thus, this research is expected to contribute both empirically and conceptually. Empirically, this research produces questions that can measure students' critical thinking skills and can be used widely. Furthermore, conceptually, this research is expected to contribute to the use of ethnomathematics-based assessments in the independent curriculum and be able to preserve Indonesian culture.

METHODS

The method section must be able to explain the research method used, including how the procedure is implemented. Research tools, materials, media or instruments must be well described. If there is a statistical formula used as part of the research method, it is better not to write a formula that is already generally accepted. This type of research is Research and Development (R&D). The Research and Development used in this study refers to the Tessmer model (1993), which includes the preliminary stage or preparation stage and the formative evaluation stage. The preparatory stage includes an in-depth literature review related to the development of test instruments from various references and previous research, as well as an in-depth analysis related to ethnomathematical practices in marriage ceremonies in the Bugis tribe. The formative evaluation stages include self-evaluation, expert review, one-to-one evaluation, small group evaluation, and field test stage.

The self-evaluation stages include curriculum analysis of economic mathematics course achievements, student analysis, materials and design. Furthermore, the formative evaluation stage includes (1) the expert review stage and the expert validation stage involving three experts. Two of them are math experts, and the other is an education evaluation expert. The two mathematics experts function to assess the content of ethnomathematics-based tests that contain the Bugis marriage culture and four indicators of critical thinking skills, such as interpretation, analysis, evaluation, and inference. Educational evaluation experts assess the difficulty level of the tests created. Next, the researcher analysed the validity of the test based on the experts' assessment. After the revision, prototype I was produced, which is a valid test instrument. (2) The one-to-one stage is an individual test stage conducted on three people to identify deficiencies through suggestions and inputs given by test subjects. Products that have been revised at this stage will produce prototype II. (3) The small group stage is a small-scale group trial stage consisting of 6 people to evaluate the product that has been developed. The results of the revision from this stage then produced prototype III. Furthermore, the results of the revision of prototype III were tested in the field so that quality test instruments were produced.

The design of the test instrument test in the form of a description question in the mathematics of economics course is described in the Tessmer development flow chart in Figure 1.

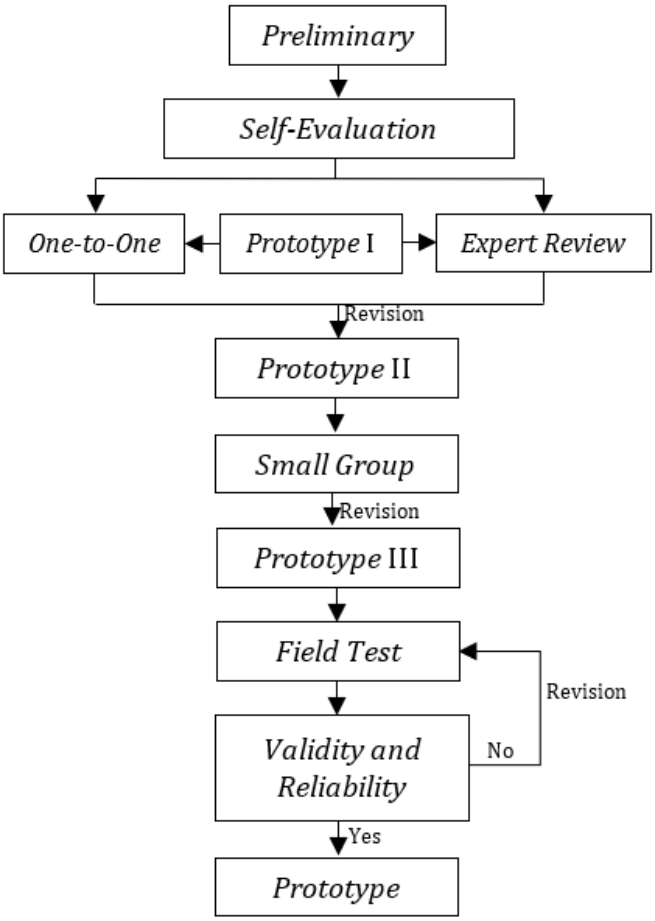

Figure 1. Test Design

The test subjects in this study involved 28 people who were fifth-semester students of the Islamic Economics Study Program, with 13 males and 15 females. Furthermore, the instruments used in this study are validation sheets to measure validity based on experts, tests to determine the level of students' critical thinking skills, and questionnaires to find out students' responses to instruments.

The collected data were analysed using content validity analysis, student response analysis, and test quality analysis, which includes reliability, difficulty level and differentiability. Meanwhile, students' critical thinking skills will be analysed descriptively.

RESULTS & DISCUSSION

Results

There are four characteristics of the developed test instrument. First, ethnomathematics-based tests use the context of the Bugis tribal marriage culture, such as madduta (official proposal), mappettu ada (agreement or agreement between the two parties), mappaisseng (giving news), mappacci (girlfriend's night), cemme pasili (special bathing tradition), mabbarazanji (reading the book of al-barzanji), mappenre botting (escorting the groom to the bride's house to carry out the marriage contract), Mapparola (a return visit by the bride). In addition, the context of the questions used also includes important components in the marriage culture of the Bugis tribe, such as sompa (dowry or dowry), dui paenre (delivery money), pattenre' ada or passio (binding, usually in the form of a ring), waju tokko (traditional clothes for Bugis women), and lipa' sabbe (woven sarong). These various contexts are then associated with mathematical content or, specifically, economic mathematical content.

Second, the test consisted of five main material topics, namely sets, matrices, systems of linear equations, application of functions in mathematics, and series. The ethnomathematics contexts in the five materials are described in Table 1.

Table 1. Ethnomathematical Context on Economic Mathematics Content

Content	Context
Set	The colour of *waju tokko* (traditional clothes of Bugis women), *mabbarazanji* (reading of the book *of al barzanji*), *lipa sabbe* (woven sarong), *mapparola* (a return visit from the female side to the male side)
Matrix	The amount of *sompa* (dowry), *dui paenre* (delivery money), bridesmaids (2 *passeppi,* 1 *balibotting,* 3 *pattiwi cere',* 2 *indo' pasusu*)
Linear Equation System	The traditional ceremony *of mappacci* (girlfriend's night), *mappenre botting* (escorting the groom to the bride's house to carry out the marriage contract), *jatas tutu'* (Bugis traditional clothes for men), *waju tokko* (Bugis traditional clothes for women), cemme pasili *procession (special bathing tradition*)
Application of Functions in Mathematics	Processed dishes at the Bugis tribal wedding party, *mappettu ada* (agreement of both parties), *pattenre' ada* or *passio* (binding), *sompa* (dowry)
Series	Madduta procession (official proposal), *mappaisseng* (giving news), *dui menre* (delivery money)

Third, the test is in the form of multiple choice, equipped with a question grid as a guide for compiling questions, answer keys and scoring guidelines. Fourth, the test contains four indicators of critical thinking ability so that it can measure students' critical thinking skills.

Lipa sabbe or woven sarong is one of the components of clothing that is paired with *waju tokko* (the traditional attire for Bugis women) during the *mapparola* procession, a return visit from the bride's family to the groom's family as part of the Bugis wedding ceremony. *Lipa sabbe* has several types of motifs or patterns, each with its distinctive meaning. The wide variety of motifs leads to differences of opinion among Pak Ahmad's family members. There are 20 people who like the *balo renni* motif, 18 people who like the *balo lobang* motif, and 25 people who like the *balo bombang* motif. In addition, there are 15 people who like both *balo renni* and *balo lobang*, 18 people who like both *balo renni* and *balo bombang*, and 20 people who like both *balo lobang* and *balo bombang*. If the total number of family members expressing their opinions is 50, then the number of family members who like all three motifs is ...

A. 40
B. 42
C. 32
D. 35
E. 38

Figure 2. A snippet of the Set Content Test

The results of the Expert Review, which was analysed using the Content Validity Ratio (CVR) method and as a whole were estimated using the Content Validity Index (CVI), showed that of the 35 question items, it supported the validity of the test and the average score of the CVI of all question items was 1. Therefore, *prototype one* is considered valid.

Validation in the one-to-one group was carried out with three students. The results of the analysis of one-to-one student responses to ethnomathematics-based test instruments can be seen in Table 2.

Table 2. Results of the One-to-One Student Response Questionnaire

Indicator	Percentage (%)
Content Quality	88.89
Linguistics	88.89
Highlights	79.17
Facilities	87.50
Average	**86.11**

Based on the comments from subjects one to one, it can be concluded that there are still several things that need to be improved, including consistency in writing the narrative of questions that are in accordance with General Guidelines for Indonesian Spelling rules, for example, the use of italics that must be adjusted to the rules. The revision resulted in prototype II. Prototype II was then given to a small group of 6

students. The results of the analysis of the response of small-group students to ethnomathematics-based test instruments can be seen in Table 3.

Table 3. Results of the Small Group Student Response Questionnaire

Indicator	Percentage (%)
Content Quality	88.89
Linguistics	83.33
Highlights	89.58
Facilities	87.50
Average	**87.32**

Based on student comments, the average commented on the time needed to complete the test, which was considered to be lacking. The results of this revision produced prototype III, which was then tested at the field test stage. The results of the analysis of the response of field test students to ethnomathematics-based test instruments can be seen in Table 4.

Table 4. Results of the Field Test Student Response Questionnaire

Indicator	Percentage (%)
Content Quality	84.82
Linguistics	80.95
Highlights	83.48
Facilities	89.73
Average	**84.74**

Based on the analysis of student responses at the field test stage, an average score of 84.74% was obtained. The score is included in the interpretation criteria with the category "Very Good".

Furthermore, the researcher conducted a reliability test based on the results of the student test at the field test stage. Based on the results of the student's work, the level of reliability of the test that has been developed can be calculated.

Table 5. Reliability Test

Parameter	Parameter Values				
	Package A	Package B	Package C	Package D	Package E
Number of Score Variances per Item	1.67	1.68	1.65	1.72	1.69
Varians Total	4.35	4.73	4.40	4.64	4.43
Number of Question Items	7	7	7	7	7
Reliability Coefficient Cronbach's Alpha	0.71	0.75	0.72	0.73	0.72
Information	**High**	**High**	**High**	**High**	**High**

Based on Table 5, it was obtained that the reliability of ethnomathematics-based test instruments for Package A, package B, package C, package D, and Package E is included in the criteria with the "High" reliability level category. Therefore, the test instrument is declared reliable.

The analysis of the level of difficulty (LD) was also obtained from the data of student test results at the field test stage. The following are the results of the analysis of

the difficulty level of ethnomathematics-based test instruments.

Table 6. Difficulty Test

Question Items	Package A		Package B		Package C		Package D		Package E	
	LD	Category	LD	Category	LD	Category	LD	Category	LD	Category
1	0.60	Medium	0.53	Medium	0.60	Medium	0.60	Medium	0.60	Medium
2	0.67	Medium	0.60	Medium	0.64	Medium	0.53	Medium	0.46	Medium
3	0.60	Medium	0.64	Medium	0.67	Medium	0.46	Medium	0.57	Medium
4	0.60	Medium	0.64	Medium	0.64	Medium	0.53	Medium	0.57	Medium
5	0.60	Medium	0.57	Medium	0.53	Medium	0.53	Medium	0.39	Medium
6	0.50	Medium	0.53	Medium	0.57	Medium	0.57	Medium	0.64	Medium
7	0.46	Medium	0.57	Medium	0.46	Medium	0.42	Medium	0.42	Medium
Average	**0.57**	**Medium**	**0.58**	**Medium**	**0.58**	**Medium**	**0.52**	**Medium**	**0.52**	**Medium**
Average Total						**0.52**				

Based on Table 6, it was found that the test instruments of Package A, package B, package C, package D, and Package E for all items had a difficulty level in the "Medium" category or the difficulty interval of 0.30 – 0.70. Overall, the question item has an average difficulty level of 0.52 and is in the "Medium category.

The results of the analysis of the difference (D) of the test instrument questions were obtained from the data from the results of the field test to students, which can be seen in Table 7.

Table 7. Difference Test

Question Items	Package A		Package B		Package C		Package D		Package E	
	D	Category	D	Category	D	Kategori	D	Category	D	Category
1	0.50	Very Good	0.50	Very Good	0.35	Good	0.50	Very Good	0.50	Very Good
2	0.50	Very Good	0.64	Very Good	0.57	Very Good	0.64	Very Good	0.50	Very Good
3	0.64	Very Good	0.42	Good	0.35	Good	0.35	Good	0.71	Very Good
4	0.35	Good	0.42	Good	0.57	Very Good	0.50	Very Good	0.42	Good
5	0.50	Very Good	0.57	Very Good	0.64	Very Good	0.35	Good	0.35	Good
6	0.57	Very Good	0.64	Very Good	0.57	Very Good	0.57	Very Good	0.42	Good
7	0.50	Very Good	0.71	Very Good	0.78	Very Good	0.71	Very Good	0.71	Very Good
Average	**0.50**	**Very Good**	**0.55**	**Very Good**	**0.54**	**Very Good**	**0.51**	**Very Good**	**0.51**	**Very Good**

Based on Table 7, it was found that the test instrument had two categories of question differentiation levels, namely the "Good" and "Very Good" categories. The average question items developed are in the "Very Good" category.

Furthermore, the test result data to measure students' critical thinking skills were evaluated based on the final score obtained when working on ethnomathematics-based test questions in the economic mathematics course. The results of the test instrument trial for 28 students can be seen in Table 8.

Table 8. Test Result Analysis

Package	Average	Category
A	58	Good Enough
B	59	Good Enough
C	59	Good Enough
D	53	Good Enough
E	53	Good Enough

Based on the descriptive analysis in Table 8, information was obtained that the average score of students' critical thinking skills was in the good enough category. The results of the trial at the field test stage produced two important things, namely the quality of ethnomathematics-based test instruments developed and also the critical thinking ability of students in the Economic Mathematics course. The analysis of critical thinking skills aims to classify the value of students' critical thinking skills into five categories, namely very good, good, good enough, not good, and very bad. Based on the results of data analysis, it was found that the average critical thinking ability of students in each test package was in the category of good enough.

Discussion

Critical thinking skills are a complex set of thinking skills recognised as one of the essential educational goals at all levels of education. Critical thinking is a way of making reasonable decisions or judgments about a particular claim, statement, or phenomenon (Chikiwa & Schäfer, 2018). This skill is considered one of the most crucial skills and dispositions, not only in the context of higher education but also in everyday life situations and the professional sphere of the individual for career planning and development. Furthermore, critical thinking skills are skills that individuals facing global challenges must develop, so it is considered an important topic for individual success in teaching and learning in the 21st century (Arsyad & Lestari, 2023; Carmichael & Farrel, 2012; Evendi et al., 2022; Irwanto et al., 2019; Marthaliakirana et al., 2022; Yang, 2012). Critical thinking skills are important, and they require the measurement of these abilities at the individual level, one of which is for university students. It aims to identify the extent to which students have developed their critical thinking skills, as well as provide an in-depth evaluative basis for their ability to analyse, evaluate, and formulate solutions to complex problems in a variety of academic and everyday contexts. As expressed by Irwanto et al. (2019), educators need to teach and evaluate the level of critical thinking skills of students from an early age.

Quality test instruments are needed to measure students' critical thinking skills. Therefore, this research focuses on the development of ethnomathematics-based tests that can be used to measure critical thinking skills. The ethnomathematics used refers to the context of the Bugis wedding culture. Fouze & Amit (2018b) reveal that cultural values, traditions, and symbols are embodied in the life of every society. Therefore, culture occupies a very important place in human life and society, influencing the economy and social, religious, and educational activities. Cultural values also influence education in general and mathematics education in particular; this is then known as ethnomathematics (Molly, 2016; Umbara et al., 2021). Mathematics and culture will be an interesting scientific context, as students will learn mathematics based on cultures that they understand and are relevant to daily life (Hamidah, Kusuma, & Auliana, 2024). The use of ethnomathematical context can make a great contribution to the learning process of students, so ethnomathematics can be a means to improve students' mathematical achievement (Fouze & Amit, 2018a). The findings revealed that students who were taught using ethnomathematical approaches had higher retention and higher average achievement scores than those taught using conventional approaches (Sunzuma & Maharaj, 2019). The ethnomathematical approach, taking into account the cultural context in formulating the questions on the test, provides an additional dimension that is meaningful in evaluating students' critical thinking skills. This not only improves the quality of evaluation implementation but also creates space for the development of critical thinking skills that are more contextual and related to students' daily lives.

The results of this study show that ethnomathematics-based test instruments have good quality in measuring students' critical thinking skills in economic mathematics courses. This research is in line with the research of Aini et al. (2023), who developed a PjBL STEM-based mathematical critical thinking test instrument using a valid and reliable ethnomathematical approach. Research by Kamid et al. (2021) produced a set of HOTS questions based on Jambi's culture that were valid and practical. Another study by Sukmawati et al. (2022) developed a mathematical literacy test from the perspective of multiple linguistic bits of intelligence, multiple logical-mathematical bits of intelligence, multiple visual-spatial bits of intelligence, and multiple bodily-kinesthetic bits of intelligence based on Javanese cultural ethnomathematics have met the criteria for valid questions to be used as an instrument for evaluating mathematical literacy in perspective multiple intelligences. Research by Qomariyah (2023) also develops ethnomathematics-based test instruments to train students' problem-solving skills that are valid, practical, and effectively applied in learning. Thus, ethnomathematics-based test instruments can be used to construct and measure students' critical thinking skills.

In their research, Richardo et al. (2018) also showed that ethnomathematics-based questions can measure students' critical thinking skills in contrast to Risdiyanti and Sulisworo (2021) and Tania et al. (2022), who takes a different approach by developing ethnomathematics-based books to improve students' critical thinking skills. Although the approaches are different, both show that the ethnomathematical context can be an effective foundation for building and improving students' critical thinking skills. This is because ethnomathematics makes mathematics more relevant and meaningful for students (Shahbari & Daher, 2020). Thus, the results of this study provide an in-depth understanding of the relevance and potential of ethnomathematics-based test instruments in measuring and building students' critical thinking skills in various mathematics learning contexts.

CONCLUSION

Based on the research results, the ethnomathematics-based test instrument that has been developed has four main characteristics. First, it uses the cultural context of Bugis marriage as its background. Second, the test covers five main material topics, namely sets, matrices, systems of linear equations, applications of functions in mathematics, and series. Third, the test is in the form of multiple choice and is equipped with a grid of questions, answer keys, and scoring guidelines. Fourth, the test contains four indicators of critical thinking skills designed to measure students' critical thinking skills. This ethnomathematics-based test instrument has been proven to be of good quality in terms of validity, reliability, difficulty level, differentiating power, and practicality. This instrument is effectively used to measure students' critical thinking skills in economic mathematics courses. In addition, the measurement results show that the average critical thinking skills of students are in the good enough category. Overall, this instrument is relevant and effective in measuring and improving critical thinking skills in the context of local culture. Further research can develop teaching materials or learning media based on ethnomathematics to develop students' critical thinking skills. In addition, ethnomathematics can, of course, also be used in other courses.

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