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Development of a Scientific Literacy Test Instrument to Identify Students' Understanding of Concepts and Misconceptions in Colloidal Systems Material

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Abstract

Literacy is one of the skills that need to be considered in the 21st century. This study aims to develop a literacy test instrument to determine students' understanding of concepts and misconceptions on colloidal material using a valid three-tier multiple choice test instrument based on expert validation and Rasch analysis. The research method used is 4D (Define, Design, Development, and Desimination). Research data collection techniques through observation, tests, interviews, and questionnaires. The results of Rach's analysis showed a value of 0.75 (sufficient). The quality of the developed instrument resulted in 13 valid questions. The level of difficulty obtained is 3 points of the easy category, 7 points of the medium category, 4 points of the difficult category, and 6 points of the very easy category. The highest concept understanding of students in the submaterial understanding solutions, colloids, and suspensions with a percentage of 77% and the highest misconception of students in the submaterial of categorizing experimental designs involving colloidal principles with a percentage of 38%. The results of the recapitulation of the response questionnaire obtained by 91% of students gave affirmative responses to the instrument developed. Based on the results of the study, the developed test instruments are feasible for the analysis of students' understanding of concepts and misconceptions.

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INTRODUCTION

21st-century skills have become a major focus in today's education. These skills form the foundation of science learning, which is still not being effectively delivered in schools (Astuti et al., 2014). The *Merdeka Belajar* curriculum was introduced to prepare students for global competition in the 21st century. Competencies in this era require individuals to be innovative and creative so they can adapt quickly (Indarta et al., 2022). 21st-century skills are often referred to as the 4Cs: Communication, Collaboration, Critical Thinking, and Creativity. Both teachers and students must understand these skills to create effective education. The 4Cs serve as a key component in supporting government policies, particularly the *Merdeka Belajar* program (Marna & Hayati, 2022). One of the most crucial skills for students in this era to properly apply scientific knowledge is literacy.

In the 21st century, students are no longer expected to simply listen and memorize material; instead, they are positioned as the center of learning to develop their thinking, knowledge, and skills (Rifa Hanifa Mardhiyah et al., 2021). Human intelligence is assessed through three domains:

cognitive, psychomotor, and affective (Sukma & Sihes, 2016). Scientific literacy in chemistry helps students understand natural phenomena and human activities from a chemical perspective, based on what they have learned in school (Adawiyah & Wisudawati, 2017). The goal is to encourage students to utilize their surroundings and nature to gain knowledge through scientific literacy concepts. Students learn by observing natural events and social occurrences, which are referred to as scientific and socio-cultural contexts.

Indonesia ranks among the lowest in the PISA (Programme for International Student Assessment) rankings. In the reading category, Indonesia is ranked 75th out of 80 countries, placing it among the bottom six. Indonesia's PISA scores are concerning, as the country has never exceeded the ideal benchmark score of 500 (Kelana & Pratama, 2019). Research by Odja and Payu (2014) also highlights that from 2003 to 2012, Indonesian students' literacy skills remained in the low category based on PISA study reports. The test results indicate that most Indonesian students are still at a level where they can only suggest appropriate sources of information and identify quantities in an experiment.

Teachers always strive to help students understand the material presented during lessons, but not all students fully grasp and absorb the information. This gap leads to differences in conceptual understanding between teachers and students (Syahrul, 2015). Such differences are often referred to as misconceptions. Various factors contribute to misconceptions, including students' prior knowledge, teachers, learning materials, and instructional methods (Suparno, 2013). One of the instruments that can identify students' misconceptions in colloid topics is a diagnostic multiple-choice test. These diagnostic test designs are structured to analyze students' basic conceptual understanding in a direct and measurable way, allowing educators to assess how well students have mastered the material taught in class (Bayrak, 2013). The Three-Tier Multiple Choice test is a valid and efficient tool for large student samples. It helps analyze students' reasoning, distinguish misconceptions in specific topics, and estimate the prevalence of misconceptions (Ade Monita & Suharto, 2016). By using the Three-Tier Multiple Choice test, teachers can quickly identify students' conceptual weaknesses and use the results as a basis for improving future learning processes.

To ensure that an instrument is suitable for use, several analyses must be conducted. This study employs the Rasch model as the analytical method. The Rasch model is a one-parameter logistic measurement model (Rusilowati, 2018). The quality of test items must be verified through validity, reliability, difficulty level, and discriminating power (Son, 2019). A test is considered reliable if the observed scores have a high correlation with the actual scores (Allen & Yen, 1979). To determine the quality of test items, this study utilizes the Rasch model, which offers several advantages, including the ability to identify response errors, detect missing data scores, assess ability beyond just correct answers, and recognize guessing patterns in responses (Sumintono & Widhiarso,

2014). An instrument is considered valid and reliable if it accurately measures what it is intended to measure (Creswell, 2014).

Colloids are one of the topics taught in grade XI. Jayanti (2020) states that colloid concepts are contextual, meaning they are closely related to real-life situations encountered by students. While colloidal systems are relevant to daily life, some of their concepts are abstract, making them difficult for students to understand (Utama, 2018).

The research problem formulated in this study includes determining the feasibility, validity, and reliability of the developed instrument, analyzing students' conceptual understanding and misconceptions, and gathering teachers' and students' responses regarding the developed instrument. The objective of this study is to develop a literacy test instrument to assess students' conceptual understanding and misconceptions in colloid topics using a validated *Three-Tier Multiple Choice* test, based on expert validation and Rasch analysis.

METHODS

This research is a type of *Research and Development* (R&D) study that follows the 4D development model (*Define, Design, Develop, and Disseminate*). The study was conducted at SMA Negeri 2 Salatiga, involving different groups of students at various stages. A small-scale trial was conducted with 20 students from grade XI MIPA 5, followed by a large-scale trial with 33 students from grade XI MIPA 4. For the implementation stage, 60 students from grade XI MIPA 1 and XI MIPA 2 participated. Data collection methods included observations, tests, interviews, and questionnaires. The data analysis involved expert validation for both test and non-test instruments, along with item analysis using the Rasch model. This analysis was used to determine the reliability, validity, item fit, item difficulty (*item measure*), individual ability level (*person fit*), and *scalogram* analysis.

This study utilizes a *Three-Tier Multiple Choice* test instrument based on reading literacy. The test data is analyzed by examining students' responses at the first, second, and third tiers. Students' understanding and misconceptions are evaluated based on the patterns of answer combinations, as outlined in Table 1.

Table 1. Score Categories in Three-Tier

Category	Answer Type			Score
	Answer	Reason	Confidence	
Conceptual Understanding	Correct	Correct	Confident	5
Guessing	Correct	Correct	Not Confident	4
Partial Understanding	Correct	Incorrect	Not Confident	3
	Incorrect	Correct	Not Confident	
Not Understanding	Incorrect	Incorrect	Not Confident	1
Positive Misconception	Incorrect	Correct	Confident	2
Negatif	Correct	Incorrect	Confident	2

Misconception				
Full Misconception	Incorrect	Incorrect	Confident	0

The combination of answers serves as the basis for analyzing students' misconceptions. The analysis of each test item is conducted using the following formula:

$$\% = \frac{The\ Number\ of\ Students\ who\ experience\ the\ pattern\ criteria\ according\ to\ the\ combination\ answer}{Overall\ score}$$

The initial step of this research is the define stage. This stage involves conducting observations, analyzing problems, and determining the product to be developed. The data collected in this phase includes the senior high school chemistry syllabus, the grade XI chemistry textbook based on the 2013 curriculum, guidelines for instrument development, research journals supporting the development, and observation results from SMA Negeri 2 Salatiga.

The design stage is carried out to develop the test instrument and other supporting instruments, such as questionnaires. The development stage consists of three phases: small-scale trials, large-scale trials, and implementation testing. Before testing, the test instrument is first validated by experts to ensure its feasibility. The validation process assesses the quality of the product. The trials also include analysis using the Rasch model to determine the validity, reliability, discriminating power, and difficulty level of the test items. Finally, the dissemination stage is conducted to distribute and communicate the developed test instrument

RESULT AND DISCUSSION

Instrument Feasibility

The test instrument is first validated before being administered to students. Validation is conducted to assess the adequacy and appropriateness of the interpretations made from the assessment (Linn & Gronlund, 1995). Expert validation is carried out based on content, construct, and language aspects. The validated instruments include the *Three-Tier Multiple Choice* test and the student response questionnaire. The results of the test instrument validation can be seen in Table 2.

Table 2. Test Instrument Validation Results

No	Total Score	Category
1	22	Can be used with revisions
2	27	Can be used without revisions
3	26	Can be used without revisions
Average	25	Can be used with revisions

The student response questionnaire is validated by experts before being used in the study. The validation sheet for the response questionnaire consists of 10 statement aspects. The results of the response questionnaire validation are presented in Table 3.

Table 3. Test Response Questionnaire Validation Results

No	Total score	Category
1	32	Can be used without revisions
2	36	Can be used without revisions
3	33	Can be used without revisions
Average	33,67	Can be used without revisions

Based on this data, the test instrument has been proven to be feasible, so it can be used for testing. The resulting test instrument was refined based on suggestions and input from the three validators.

Validity and Reliability with Rasch Model Analysis

This study aims to identify students' conceptual understanding and misconceptions using a Three-Tier Multiple Choice diagnostic test instrument. The research was conducted in three stages: Small-Scale Trial, Large-Scale Trial, and Implementation Testing. The reliability of the Rasch model is assessed through person reliability, item reliability, and Cronbach's alpha (KR-20) (Sumintono & Widhiarso, 2014). The test results were analyzed using the Rasch model. The reliability analysis results can be seen in Table 4.

Table 4. Results of Reliability and Quality of Question Items

	Small Scale Trials	Large Scale Trials	Implementation
Person Reliability	0,58 (Weak)	0.67 (fair)	0,71 (fair)
Item Reliability	0,69 (fair)	0.91 (excellent)	0,94 (excellent)
Alpha Cronbach	0,69 (weak)	0,73 (fair)	0,75 (fair)

Level of Appropriateness of Question Items

Item Fit Order is used to determine the validity of each test item. If an item does not fit, it indicates that students may have misconceptions about the given question (Wigati & Ali, 2021). The criteria for assessing item difficulty based on Boone et al. (2014) are as follows:

a. Outfit Mean Square (MNSQ) value: $0.5 < MNSQ < 1.5$

b. Outfit Z-Standard (ZSTD) value: $-0.2 < ZSTD < 0.2$

c. Point Measure Correlation (Pt Measure Corr) value: $0.4 <$ Pt Measure Corr < 0.85

If an item does not meet the MNSQ and Pt Measure Corr criteria but meets the ZSTD criteria, it is still considered fit or valid. The Item Fit Order analysis results can be seen in Table 5..

Table 5. Results of Analysis Item Fit Order

Test Stage	Valid	Not Valid
Small Scale Trials	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 17, 18, 19	1, 13, 14, 16, 20
Large Scale Trials	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20	19
Implementation	2, 3, 4, 5, 6, 7, 10, 12, 13, 14, 16, 17, 19	1, 8, 9, 11, 15, 18, 20

Level of Difficulty of Question Items

Item measure indicates the difficulty level of each test item. The difficulty level is determined based on the logit value of the test items in the measure column. The results of the Item Measure analysis can be seen in Table 6.

Table 6. Results of Analysis item measure

Test Stage	Very Hard	Hard	moderate	Easy
Small Scale Trials	2, 8, 15, 17	1, 9, 14, 13, 20, 16, 11	19, 3, 10, 18	4, 5, 12, 7, 6
Large Scale Trials	1, 8, 9, 19, 16	18, 3, 5, 10	11, 17, 4, 20,15, 13, 6, 14	2, 12, 7
Implementation	20, 11, 17, 9,18, 8	10, 19, 1, 15	19, 5, 12, 4, 3, 6, 14	7, 13, 2

Student Conformity Level

Student response patterns that do not align with expected outcomes can be detected using the Rasch model through Person Fit Order. This refers to inconsistencies in students' answers based on their ability levels. The criteria for identifying inconsistencies in item difficulty, according to Boone et al. (2014), are as follows:

a. Outfit Mean Square (MNSQ) value: $0.5 < MNSQ < 1.5$

b. Outfit Z-Standard (ZSTD) value: $-0.2 < ZSTD < 0.2$

c. Point Measure Correlation (Pt Measure Corr) value: $0.4 <$ Pt Measure Corr < 0.85

The results of Person Fit Order differ from Item Fit Order. In Person Fit Order, if a student's ZSTD value meets the criteria but MNSQ and Pt Measure Corr do not, the student is classified as not fit. The results of the Person Fit Order analysis can be seen in Table 7.

Table 7. Results of Analisys Person Fit Order

Test Stage	Fit	Not Fit
Small Scale Trials	01L, 19L, 17L, 09l, 18L, 02P, 15L, 20L, 16P, 14P, 11P, 12P, 03P, 05P, 06P,13P, 08P, 07L	04L, 10L
Large Scale Trials	01L, 02P, 03L, 06L, 07L, 08L, 10P, 11L, 12L, 13P, 14L, 15P, 16P, 18P, 19L, 20P, 21P, 22P, 23P, 25P, 27P, 28P, 29P, 30P, 31P, 32P, 33P	04L, 05L, 09L, 17L, 24P, 26P
Implementation	08P, 64P, 04L, 17L, 33L, 10P, 38P 46P, 20P, 30P, 49P, 16L, 11L, 31P, 12L, 27P, 07L, 25P, 05P, 03L, 18L, 29L, 01L, 51L, 50L, 45L, 02P, 06P 09L, 19P, 22P, 23P, 28P, 3P, 36L, 40P, 53L, 54P, 55P, 56P, 65P, 21P, 37L, 14L, 43P, 57L, 35L, 59P, 24P, 26P, 42L	15P, 39P, 48P, 63P, 34L, 47P, 13P, 44L, 41L, 62P, 52L, 61P, 60L, 58L

Student Ability Level

Person Measure indicates the ability level of students and is used to assess their competence in answering test questions. The results of the *Person Measure* analysis can be seen in Table 8.

Table 8. Results of Analisys Person Measure

Test Stage	High	Moderate	Low
Small Scale Trials	18L, 06L, 13P, 03P, 17L, 01L, 14P	12P, 08P, 02P	05P, 16P, 09L, 10L, 20L, 11P, 07L,19L, 15L, 04L
Large Scale Trials	27P, 08L, 33P, 06L, 12L, 30P, 31P, 20P 25P, 29P, 07L, 18P, 28P, 32P, 02P, 21P, 09L, 16P, 19L	11L, 14L, 10P, 13P, 23P, 26P	22P, 24L, 04L, 17L 05L, 01L, 15P, 03L
Implementation	16L, 18L, 20P, 26L, 08P, 14L, 09L, 13P, 15P, 43P, 05P, 02P, 29L, 27P, 30P, 32P, 45L, 01L, 06P, 07L, 22P, 25P, 42L, 24P, 04L, 17L, 21P, 33L, 03L, 12L, 23P 28P, 51L 10P, 38P, 46P	41L, 47P	44L, 31P, 34L, 57L, 58L, 35L, 36L, 49P, 65P, 19P, 56P, 63P, 52L, 60L, 61P, 37L, 62P. 39P, 50L,54P, 48P, 64P, 53L, 40P,55P

Profile of Student Concept Understanding and Misconceptions

The developed *Three-Tier Multiple Choice* test instrument consists of 20 questions, each with three levels. The first level (*Tier 1*) consists of a standard multiple-choice question, the second level (*Tier 2*) requires students to select a reason for their answer in *Tier 1*, also in a multiple-choice format, and the third level (*Tier 3*) assesses students' confidence in their answers from *Tier 1* and *Tier 2*. Based on the written test results, there is a possibility of misconceptions occurring across all subtopics. The categories of students' knowledge based on the written test can be seen in Table 9.

Table 9. Student Knowledge Categories Based on Test Results

Question items	PK		Mnb		KPK		TPK		Mp		Mn		M	
	Jml	%	Jml	%	Jml	%	Jml	%	Jml	%	Jml	%	Jml	%
1	21	32%	0	0%	14	22%	3	5%	21	32%	1	2%	5	8%
2	50	77%	7	11%	1	2%	1	2%	5	8%	1	2%	0	0%
3	39	60%	3	5%	3	5%	5	8%	5	8%	3	5%	7	11%
4	35	54%	0	0%	8	12%	2	3%	1	2%	16	25%	3	5%
5	37	57%	1	2%	5	8%	5	8%	1	2%	9	14%	7	11%
6	38	58%	6	9%	6	9%	2	3%	2	3%	3	5%	8	12%
7	34	52%	9	12%	8	12%	2	3%	1	2%	10	15%	1	2%
8	10	15%	1	11%	7	11%	3	5%	24	37%	5	8%	15	23%
9	1	2%	1	20%	13	20%	8	12%	1	2%	37	57%	4	6%
10	18	28%	2	3%	2	3%	11	17%	4	6%	22	34%	6	9%
11	0	0%	4	6%	6	9%	8	12%	1	2%	42	65%	4	6%
12	34	52%	1	2%	13	20%	2	3%	2	3%	5	8%	8	12%
13	33	51%	11	17%	8	12%	2	3%	9	14%	2	3%	0	0%
14	40	62%	2	3%	9	14%	8	12%	4	6%	0	0%	2	3%
15	15	23%	10	15%	12	18%	0	0%	20	31%	5	8%	3	5%
16	30	46%	3	5%	15	23%	9	14%	0	0%	2	3%	6	9%
17	9	14%	1	2%	6	9%	10	15%	22	33%	24	37%	13	20%

18	11	17%	13	20%	2	3%	11	17%	1	2%	5	8%	22	34%
19	24	37%	3	5%	5	8%	16	25%	0	0%	4	6%	13	20%
20	10	15%	7	11%	1	2%	18	28%	3	5%	1	2%	25	38%

Table 9 shows that question number 2 is the most well-understood by students, as it has the highest percentage in the conceptual understanding category. In contrast, question number 20 has the highest percentage in the full misconception category, indicating that it is the most misunderstood by students.

Student Questionnaire Responses to Instruments

The response questionnaire aims to assess students' reactions to the test instrument they have completed. Students fill out the questionnaire after finishing the test. The response questionnaire consists of 10 questions with four response options. The reliability results can be seen in Table 10.

Table 10. Student Response Questionnaire Reliability Results

	Small Scale Trials	**Large Scale Trials**	**Implementation**
Responden	20 students	33 students	65 students
Reliability	0,91 (very good)	0.74 (good)	0,84 (very good)

The results of the student response questionnaire show that 33% of students rated the instrument as *very good*, 58% rated it as *good*, 8% gave a *fair* response, and 1% rated it as *poor*. The summary of these results can be seen in Figure 1.

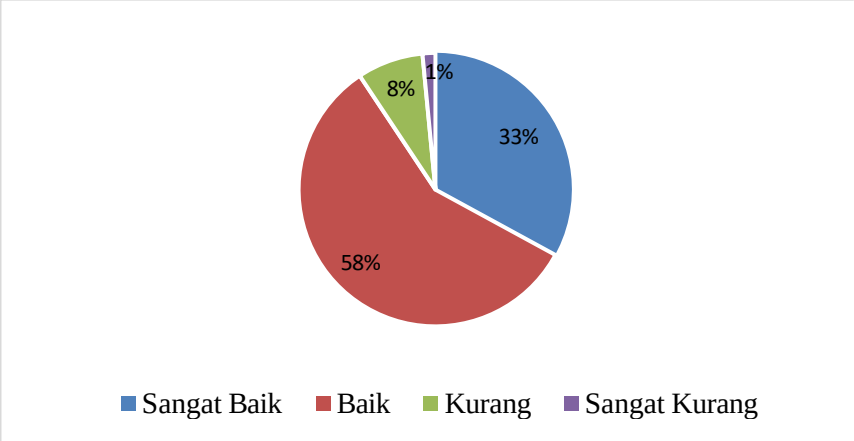

Figure 1. Results of Student Response Questionnaire Recapitulation

Based on the summary of the student response questionnaire, it can be concluded that students gave a positive response to the developed instrument, as the majority rated it as *good*. This indicates that the developed instrument is suitable for assessing students' conceptual understanding and misconceptions in colloid topics

CONCLUSION

The developed test instrument consists of 3 questions categorized as easy, 7 questions categorized as moderate, 4 questions categorized as difficult, and 6 questions categorized as easy. The reliability analysis using the Rasch model shows a Cronbach's Alpha value of 0.75, which falls into the moderate category. This indicates that the test instrument is suitable for use. Based on the diagnostic test results, 77% of students demonstrated conceptual understanding in colloid topics, particularly in identifying types of solutions, colloids, and suspensions. However, the highest misconception rate, at 38%, was found in the application of colloid principles in daily life. Additionally, student responses to the test instrument were overwhelmingly positive, with 91% of students expressing a favorable response.

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