TOSLS: Development, Implementation, and Quality Analysis of an Instrument for Assessing Scientific Literacy

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Abstract

The research aimed to develop an appropriate cognitive assessment for scientific literacy to measure science education students' abilities to identify learning strengths and weaknesses. This research used the R & D method. The normality test and a one-sample t-test was conducted. The specific topic covered in the research is fermented material. The study participants are science education students at a public university in Surabaya, Indonesia. The results indicated that the percentage of question difficulty levels, with 11.11% categorized as difficult and 44.44% categorized as easy. The analysis of test item discrimination reveals that 66.67% fall into the very good category, 11.11% into the good category, and 22.22% into the bad category. The one-sample t-test is conducted, yielding a significance value of 0.0314. Based on the obtained data, with 0.314 > 0.05, the null hypothesis (Ho) is accepted. This implies that the TOSLS instrument influences assessing students' level of scientific literacy ability. The findings of this study serve as a reference and best practice for tertiary institutions seeking to evaluate students' scientific literacy abilities.

Keywords: Assessment, Fermentation, Scientific Literacy, Student

INTRODUCTION

The provided passage highlights the significance of scientific literacy, which refers to an individual's capacity to comprehend, interpret, and utilize scientific information daily (David *et al*., 2022). Strong scientific literacy skills are crucial in today's complex and advanced era, particularly in the fields of science and technology (Allum *et al*., 2018). However, the assessment of students' scientific literacy skills in Indonesia, carried out by the Program for International Student Assessment (PISA), indicates that students' scientific literacy abilities in Indonesia are categorized as very low. Data from 2018 reveal that Indonesia ranked 74th out of 79 countries participating in the PISA test 2018 (OECD, 2019). This positioning indicates that Indonesia's scientific literacy performance is considerably lower than other participating countries because students are not accustomed to working on science literacy-based questions (Jufrida *et al*., 2019). Indonesian students' abilities are limited to utilizing scientific knowledge to solve a few problems at a lower cognitive level (Shafer et al., 2019). However, they need help to apply their scientific knowledge to more complex problems at a higher cognitive level, partly because they rarely practice science literacy-based questions (Cahyana *et al*., 2019).

Furthermore, additional research highlights the weaknesses of Indonesian students in literacy science, particularly in identifying, comprehending, and applying fundamental scientific knowledge in everyday situations (Hawa *et al*., 2018). These findings illustrate the existing challenges and areas that require improving science education in Indonesia to enhance students' scientific literacy skills (Ismail *et al.*, 2017). This information highlights the need for efforts to improve students' scientific literacy skills in Indonesia. Improving students' ability to identify, understand, and apply scientific knowledge is an important aspect of helping them become more skilled at solving problems and participating in everyday life, which is increasingly connected to science and technology. This ability is a component of ability that must be possessed for a high level of scientific literacy (Kayumova *et al.*, 2016). As the next generation, students must have good scientific literacy skills to keep up with the developments in science and technology that continue to develop (Valladares, 2021). Scientific literacy tests for students can help measure the extent to which they understand science and technology concepts and can apply them in everyday life (Septiani *et al.*,

2019). The results of scientific literacy tests can also help detect weaknesses in science and technology education in tertiary institutions and assist educators in designing more effective teaching methods (National Science Board, 2018). In addition, scientific literacy tests can also assist educational institutions and the government in evaluating the success of implemented science and technology education programs (Sjöström *et al.*, 2020).

According to Gormally et al. (2012), two key aspects must be considered when measuring scientific literacy skills. The first aspect is understanding investigative methods that lead to scientific knowledge. This involves the individual's comprehension and application of scientific concepts, such as hypotheses, variables, and research methods used in scientific inquiry. The second aspect is organizing, analyzing, and interpreting quantitative data and scientific information. This includes the individual's capacity to effectively arrange, analyze, critically evaluate, and connect quantitative data and scientific information to relevant scientific concepts. These two aspects hold great importance in scientific literacy skills as individuals who excel can comprehend and critically evaluate scientific information, enabling them to make informed decisions based on that information. Cognitive assessment is useful for measuring students' scientific literacy abilities (Zalfaghari *et al*., 2016). In scientific literacy, cognitive assessment is utilized to measure cognitive abilities related to scientific concepts, understanding of investigative methods, analysis and interpretation of data, and the ability to draw conclusions based on existing scientific evidence. Recent research indicates that the results of cognitive assessment can provide an accurate representation of students' scientific literacy abilities.

These findings indicate deficiencies in various aspects of scientific literacy in the cognitive domain, particularly in the first two aspects, which were classified as low. It is crucial to encourage students to learn with natural science content to explore their ideas about science and seek evidence to support or challenge their scientific thinking (according to opinions). This approach to learning differs from the traditional method where the teacher imparts scientific ideas as facts to be memorized, and practical work is only utilized to illustrate scientific relationships, laws, and theories. Analysis of scientific literacy in students can provide an understanding of the effectiveness of science education at the tertiary level (Jagger *et al.*, 2017). By assessing

scientific literacy skills, we can identify weaknesses and strengths in science teaching and learning and direct improvement and development of a better curriculum (Putri *et al*., 2022).

Therefore, it is necessary to develop appropriate scientific literacy assessment instruments to measure the scientific literacy ability of students in the Science Education S1 study program to identify weaknesses and strengths in learning. Realizing the importance of this problem, the writer is interested in researching this matter. Thus, the research results can provide useful information and recommendations for developing students' scientific literacy learning and skills.

METHOD

This study adopted a simplified approach R n D based on Sugiyono (2013), consisting of three main stages: preliminary study, development study, and evaluation. The preliminary study is conducted to gather initial information about scientific literacy evaluation instruments through literature research, policy studies, and preliminary data collection. The development study involves designing the initial product and the evaluation instrument. The evaluation phase is the final stage, where the instrument undergoes extensive testing to gather data on its validity, difficulty level, differentiability, and feasibility as a scientific literacy evaluation instrument (Krapp *et al.*, 2011). The study focuses on 29 science education students at Surabaya State University, and the chosen topic is fermented material. Fermented material is material in biochemist lessons. The evaluation results are utilized to improve the instrument, aiming to create a more effective and accurate evaluation tool. The data obtained from student exam scores are analyzed using a normality test, and a one-sample t-test is conducted to examine the impact of the TOSLS (Test of Scientific Literacy Skills) question instrument on assessing the level of students' scientific literacy abilities (Jackson, S. L, 2015).

RESULTS AND DISCUSSION

Scientific literacy refers to the ability to utilize scientific knowledge, pose relevant questions, and draw evidence-based conclusions to comprehend and make informed decisions regarding the natural world and its changes caused by human activities (Ardianto, 2016). Developing evaluation instruments based on scientific literacy is crucial in assessing students' literacy abilities, particularly in science. Cognitive assessment is a process that aims to measure and evaluate an individual's cognitive abilities, including their scientific literacy skills. The primary objective of cognitive

assessment is to gauge the extent to which individuals understand scientific concepts, can apply scientific knowledge in practical situations, and possess critical and analytical thinking abilities related to science.

Through cognitive assessment, students can be presented with various tasks or questions that assess their understanding of scientific concepts, ability to analyze scientific data and information, and logical and critical thinking skills within science. The Test of Scientific Literacy Skills (TOSLS) is an evaluation instrument designed to measure an individual's scientific literacy abilities, as shown in Table 1. This test assesses an individual's understanding of scientific concepts, their critical thinking skills in the context of science, and their capacity to apply scientific knowledge in everyday life situations. The development of the TOSLS test has been discussed by Gormally *et al*. (2012).

Table 1. Overview of TOLS Test Development

No	Overview
1	An examination of existing literature on instruments was conducted to identify scientific literacy skills.
2	A faculty survey was conducted better to understand the components and scope of scientific literacy skills.
3	A pilot assessment was developed and administered to assess the identified scientific literacy skills.
4	Following the pilot assessment, the assessment was carefully revised based on item analyses and feedback obtained from student interviews
5	To further validate the assessment instrument, additional student interviews and evaluations by biology faculty were conducted
6	The finalized assessment instrument was evaluated to assess its item difficulty, item discrimination, and reliability
7	The administered assessment instrument was implemented in multiple contexts to demonstrate its utility and effectiveness in measuring scientific literacy skills.

The scientific literacy indicators used in this study are based on the two aspects of scientific literacy developed by Gormally *et al*. (2012). These two aspects are measured as follows: Understanding of investigative methods that lead to scientific knowledge Indicator 1 is that Students can explain the meaning of fermentation through explanations, questions and answers, and discussions. Indicator 2: Students can identify the components of the fermentation process through explanations, questions and answers, and diagrams. Indicator 3 Students can analyze the process of fermentation by applying scientific investigation methods to present daily problems. Organizing, analyzing, and interpreting quantitative data and scientific information Indicator

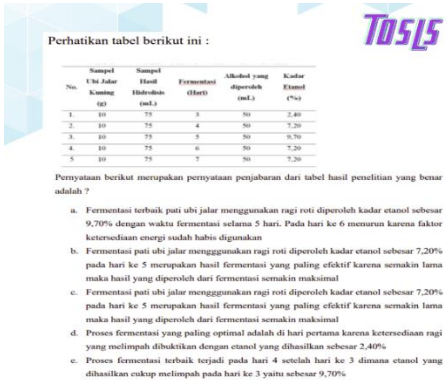
4: Students can analyze the linkages of the fermentation process in everyday life as a form of alternative energy application, demonstrating an understanding of the interaction between science, technology, and society. Indicator 5: Students can communicate the results of discussions about applying the fermentation process as an alternative energy in everyday life, showing an understanding of the interaction between science, technology, and society.

These indicators are aligned with the learning objectives set for the semester lectures. They aim to assess students' abilities in applying scientific literacy, such as knowledge, thinking, investigation, and understanding of the interaction between science, technology, and society in the context of the fermentation process. By using these indicators in Table 2, the cognitive assessment instruments developed in this study are designed to measure students' scientific literacy skills effectively and align with the specific learning objectives established for the course.

Table 2. Scientific Literacy Indicators

Component	Indicator	No	Question Form
Understand the methods of inquiry that lead to scientific knowledge	Identify valid scientific arguments	1	Multiple choice
	Evaluate the validity of the source	2	Multiple choice
	Evaluate the use and misuse of scientific information	3	Multiple choice
	Understanding the elements of research design and how to explain scientific findings and conclusions	4	Multiple choice
Organize, analyze, and interpret quantitative data and scientific information	Create a graphical representation of the data	5	Multiple choice
	Read and interpret graphical representations of data	6	Multiple choice
	Solve problems using numeracy skills	7	Multiple choice
	Understand and interpret basic statistics	8	Multiple choice
	Justify conclusions, predictions, and conclusions based on quantitative data	9	Multiple choice

The test instrument was successfully developed and adapted to the scientific literacy indicators. When preparing multiple-choice test instruments, some things to consider are that they must be in accordance with the objectives to be achieved and not have double meaning (Widyawati *et al.*, 2022). The Figure 1 and Figure 2 show the results of the development of the problem instrument according to the indicators of scientific literacy.



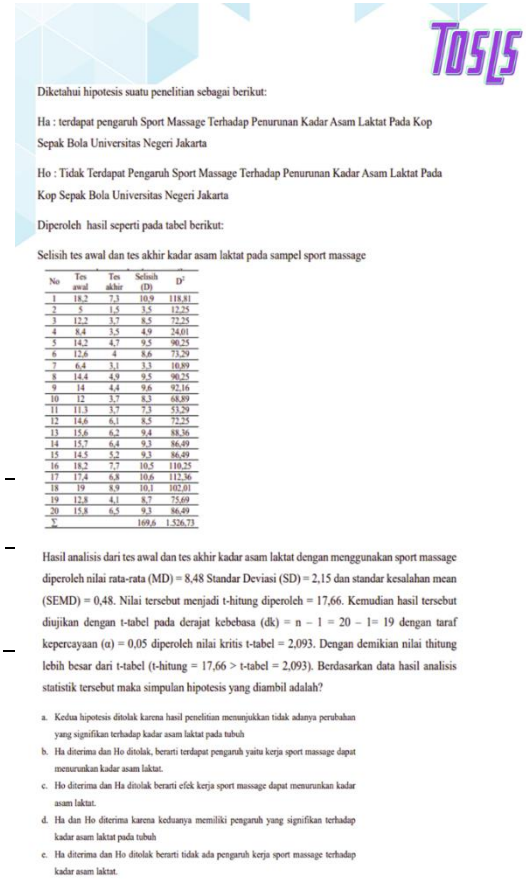
Perhatikan tabel berikut ini :

No.	Sampel Ubi Jalar Kuning (g)	Sampel Hasil Hidrolisis (mL)	Fermentasi (Hari)	Alkohol yang diperoleh (mL)	Kadar Etanol (%)
1.	10	75	3	50	2,40
2.	10	75	4	50	7,20
3.	10	75	5	50	9,70
4.	10	75	6	50	7,20
5.	10	75	7	50	7,20

Pernyataan berikut merupakan pernyataan penjabaran dari tabel hasil penelitian yang benar adalah ?

a. Fermentasi terbaik pati ubi jalar menggunakan ragi roti diperoleh kadar etanol sebesar 9,70% dengan waktu fermentasi selama 5 hari. Pada hari ke 6 menurun karena faktor ketersediaan energi sudah habis digunakan
b. Fermentasi pati ubi jalar mengggunakan ragi roti diperoleh kadar etanol sebesar 7,20% pada hari ke 5 merupakan hasil fermentasi yang paling efektif karena semakin lama maka hasil yang diperoleh dari fermentasi semakin maksimal
c. Fermentasi pati ubi jalar mengggunakan ragi roti diperoleh kadar etanol sebesar 7,20% pada hari ke 5 merupakan hasil fermentasi yang paling efektif karena semakin lama maka hasil yang diperoleh dari fermentasi semakin maksimal
d. Proses fermentasi yang paling optimal adalah di hari pertama karena ketersediaan ragi yang melimpah dibuktikan dengan etanol yang dihasilkan sebesar 2,40%
e. Proses fermentasi terbaik terjadi pada hari 4 setelah hari ke 3 dimana etanol yang dihasilkan cukup melimpah pada hari ke 3 yaitu sebesar 9,70%

Figure 1. Question 6



Diketahui hipotesis suatu penelitian sebagai berikut:

Ha : terdapat pengaruh Sport Massage Terhadap Penurunan Kadar Asam Laktat Pada Kop Sepak Bola Universitas Negeri Jakarta

Ho : Tidak Terdapat Pengaruh Sport Massage Terhadap Penurunan Kadar Asam Laktat Pada Kop Sepak Bola Universitas Negeri Jakarta

Diperoleh hasil seperti pada tabel berikut:

Selisih tes awal dan tes akhir kadar asam laktat pada sampel sport massage

No	Tes awal	Tes akhir	Selisih (D)	D^2
1	18,2	7,3	10,9	118,81
2	5	1,5	3,5	12,25
3	12,2	3,7	8,5	72,25
4	8,4	3,5	4,9	24,01
5	14,2	4,7	9,5	90,25
6	12,6	4	8,6	73,29
7	6,4	3,1	10,89	
8	14,4	4,9	9,5	90,25
9	14	4,4	9,6	92,16
10	12	3,7	8,3	68,89
11	11,3	3,7	7,3	53,29
12	14,6	6,1	8,5	72,25
13	15,6	6,2	9,4	88,36
14	15,7	6,4	9,3	86,49
15	14,5	5,2	9,3	86,49
16	18,2	7,7	10,5	110,25
17	17,4	6,8	10,6	112,36
18	19	8,9	10,1	102,01
19	12,8	4,1	8,7	75,69
20	15,8	6,5	9,3	86,49
Σ			169,6	1.526,73

Hasil analisis dari tes awal dan tes akhir kadar asam laktat dengan menggunakan sport massage diperoleh nilai rata-rata (MD) = 8,48 Standar Deviasi (SD) = 2,15 dan standar kesalahan mean (SEMD) = 0,48. Nilai tersebut menjadi t-hitung diperoleh = 17,66. Kemudian hasil tersebut diujikan dengan t-tabel pada derajat kebebasa (dk) = n – 1 = 20 – 1= 19 dengan taraf kepercayaan (α) = 0,05 diperoleh nilai kritis t-tabel = 2,093. Dengan demikian nilai thitung lebih besar dari t-tabel (t-hitung = 17,66 > t-tabel = 2,093). Berdasarkan data hasil analisis statistik tersebut maka simpulan hipotesis yang diambil adalah?

a. Kedua hipotesis ditolak karena hasil penelitian menunjukkan tidak adanya perubahan yang signifikan terhadap kadar asam laktat pada tubuh
b. Ha diterima dan Ho ditolak, berarti terdapat pengaruh yaitu kerja sport massage dapat menurunkan kadar asam laktat.
c. Ho diterima dan Ha ditolak berarti efek kerja sport massage dapat menurunkan kadar asam laktat.
d. Ha dan Ho diterima karena keduanya memiliki pengaruh yang signifikan terhadap kadar asam laktat pada tubuh
e. Ha diterima dan Ho ditolak berarti tidak ada pengaruh kerja sport massage terhadap kadar asam laktat.

Figure 2. Question 7

Once the questions have been developed based on the scientific literacy indicators, the next step is to analyze the characteristics of the items. Analyzing item characteristics involves conducting item difficulty tests and item discrimination tests. The item difficulty test calculates the percentage of test takers who answered each question correctly. The difficulty level of the items is determined based on predetermined criteria, which typically include the following ranges: (0.000 - 0.244) for difficult items, (0.245 - 0.744) for moderate items, and (0.745 - 1.000) for easy items (Nani, 2014). The data on the difficulty level of the questions is presented in the Table 3. Table 3 likely includes the item number, the percentage of test takers who answered correctly, and each item's corresponding difficulty level category. Analyzing the difficulty level of the questions provides insights into the level of challenge posed by the items and helps determine their appropriateness for assessing students' scientific literacy abilities. It allows researchers to identify items that are too difficult or too easy and make necessary adjustments to improve the overall quality and balance of the assessment instrument in Table 3.

Table 3. Difficulty Level of Items

Questions number	Difficulty Level
1,4,6,7	Currently
2,5,8,9	Easy
3	Hard

The obtained proportion of difficulty levels for the questions was 11.11% difficult, 44.44% moderate, and 44.44% easy. However, these proportions must align with the ideal difficulty level distribution

recommended by Arifin (2009), which suggests 25% difficult, 50% moderate, and 25% easy questions. The analysis of the difficulty level of the items revealed that many students faced challenges in answering certain items. This indicates that the difficulty level of some items was not ideal, and adjustments may be needed to improve the balance and appropriateness of the assessment instrument. To gain insights into the factors influencing the results of the item difficulty level analysis, data from the student response questionnaire were collected and analyzed. The questionnaire likely included items related to students' perception of the clarity of the questions, their familiarity with the topic, and their overall experience in answering the items (Shepard *et al*., 2018). By identifying and considering these factors, researchers can gain a better understanding of the reasons behind the observed difficulty levels and make informed decisions on how to improve the items and ensure a more accurate assessment of students' scientific literacy abilities in Table 4.

Table 4. Student responses to the instrument

Variable	Student Responses	Percentage
Feasibility of the instrument of the TOSLS indicator test	Pictures/diagrams and data serve as a stimulus to help answer questions	70%
	Allocation of time to working on the problem	70%
Writing grammar and language on the instrument questions	Sentences used by the rules of language and easy to understand	85%
	There are no typos	80%
	Sentences do not contain SARA	100%
Understanding of the topic material presented in the questions	The material for the test is by the scope of the fermented material	100%
	There are other reference sources as additional information obtained by students	90%

Based on the Table 4 given by the students, it is illustrated that the aspects that affect the questions' difficulty level are the instrument questions' feasibility variables. Student tests respond. Pictures/diagrams and data serve as a stimulus in helping answer questions, and a time allocation that is too short can affect students' answering questions. According to Arikunto, good questions in 2019 are questions that are relatively easy and easy. Questions in the medium category can be stored in the question bank. Meanwhile, there are three

possibilities for questions in the difficult or easy categories: discarding, revising, or saving and reusing as part of a mix of test questions (Sudijono, 2015).

After calculating the difficulty level of the items, a test for differential power is carried out so that the categories of questions with the criteria for differentiating items can be identified as follows: 0.395 – 1.000 very good categories; 0.295 - 0.394 good category, 0.195 - 0.294 moderate category, -0.00 - 0.194 bad category (Nani, 2014). Data from the analysis of the criteria for discriminating power of questions is presented in Table 5.

Table 5. The discriminating power of the items

Question Items	Category
1,4,6,7,8,9	Very good
2	Good
3,5	Bad

The analysis of the test questions reveals that 66.67% of the questions fall into the very good category, 11.11% in the good category, and 22.22% in the bad category based on the proportion of different test questions. According to Fitriatun Sukanti (2016), questions with poor discriminating power are often difficult questions that students guess the answers to or very easy questions that students answer correctly with little thought.Further analysis of the data indicates that the questions categorized as bad or very bad in discriminating power exhibited difficulty levels that varied between difficult and easy. This finding aligns with the research conducted by Ratnawati *et al.* (2020), which suggests that questions categorized as bad may be the result of students answering quickly and incorrectly or being influenced by the stimuli provided in the questions that lead them to choose the correct answer. Based on the analysis, it is recommended that items 3 and 5 be deemed not suitable for use in the assessment. However, if there is a desire to include them, revisions should be made based on the analysis of the responses provided by the students. This will help ensure the validity and reliability of the assessment instrument.

The analysis of student test results using the TOSLS instrument involved applying the standardized residual Shapiro-Wilk normality test to assess the normal distribution of the data. The Shapiro-Wilk test helps determine whether the data follows a normal distribution. A significance value (Sig.) less than 0.05 indicates non-normal distribution, while a significance value greater than 0.05 suggests normal distribution. In this study, the Shapiro-Wilk normality test yielded a significance value of 0.111, indicating that the data is normally distributed as 0.111 > 0.05. Therefore, the analysis proceeded to the one-sample t-test. The purpose of the one-sample t-test was to

investigate the influence of the TOSLS instrument on students' scientific literacy levels. Decisions for the one-sample t-test were based on the significance value (Sig.) obtained from SPSS. If the significance value is less than 0.05, the null hypothesis (Ho) is rejected, and the alternative hypothesis (Ha) is accepted. Conversely, if the significance value exceeds 0.05, Ho is accepted, and Ha is rejected. This study's significance value obtained from the one-sample t-test was 0.0314. Since 0.0314 < 0.05, the null hypothesis (Ho) is accepted, indicating an influence of the TOSLS instrument in assessing students' scientific literacy abilities. The results of this study provide valuable insights and can serve as a reference and best practice for tertiary institutions seeking to assess and identify students' scientific literacy abilities.

CONCLUSION

Based on the results, it was found that item numbers 3 and 5 were not suitable for use, and revision was needed so that they could be used as instruments for student scientific literacy questions. The use of the TOSLS cognitive instrument has an effect on measuring the level of students' scientific literacy skills in fermented material.

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