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Development of a critical thinking skills assessment instrument for students on diffusion and osmosis subject

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ABSTRACT

Critical thinking is a crucial 21st-century skill that enables students to analyze information, evaluate arguments, and make logical decisions. However, assessments in Biology education often focus more on factual knowledge rather than higher-order thinking skills. This research aimed to develop an assessment instrument for measuring students' critical thinking skills in diffusion and osmosis. This study used the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The research was conducted with 46 students from the XI MIPA class at MA Nurul Huda Munjul. The assessment instrument consists of multiple-choice questions designed to evaluate six components of critical thinking: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Validation results indicate that 20 out of 24 test items are valid, while four require revision or replacement. Reliability testing using the split-half method shows a coefficient of 0.672, which falls into the moderate reliability category and is still acceptable for educational assessment purposes. The developed instrument provides teachers with a tool to evaluate students' critical thinking skills better and tailor their teaching strategies accordingly. This study contributes to improving Biology education by promoting a more contextual and problem-solving-based approach to assessment.

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Critical thinking skills, Instrument development, Osmosis diffusion

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INTRODUCTION

Critical thinking ability is one of the 21st-century skills that is very important for students facing global challenges (Wayudi et al., 2020). This skill involves analyzing information, evaluating arguments, and making decisions based on logical evidence. In the context of learning, critical thinking skills are one of the main targets that must be developed through practical learning and assessment approaches (Wangsa et al., 2021).

Diffusion and Osmosis materials in biology subjects offer an excellent opportunity to train critical thinking skills. The concepts in this material are abstract and require a deep understanding, thorough analysis, and practical application in diverse contexts, including everyday biological phenomena and laboratory experiments (Yulianti, 2019). However, the reality in the field shows that assessing students' critical thinking skills is often not optimally integrated with learning this material. Most assessments still focus on aspects of factual and conceptual knowledge without

providing sufficient space to measure students' abilities at a higher level (Subhan, 2022), such as analyzing, evaluating, and applying the concepts of diffusion and osmosis critically.

Assessment instruments are needed to measure cognitive learning outcomes and direct students to think critically to develop more relevant learning. The instrument should be designed by considering contextual and problem-based approaches that can facilitate students in understanding the relevance of diffusion and osmosis concepts to real life (Samawati & Rahayu, 2021). However, empirical studies on developing critical thinking skills assessment instruments on Diffusion and Osmosis material are still limited. This creates a gap between the need to develop students' critical thinking skills and the available evaluation tools. Therefore, this study aims to develop an assessment instrument that is valid, reliable, and able to comprehensively measure students' critical thinking skills on Diffusion and Osmosis material.

This study aimed to develop an instrument for assessing students' critical thinking skills on diffusion and osmosis material to produce a valid and reliable instrument. This research is expected to significantly improve the quality of biology learning, especially in assessment. With the developed instrument, teachers can more easily identify the level of critical thinking skills of students so that they can design more effective learning interventions following the needs of students. In addition, this research supports the implementation of the independent curriculum, which emphasizes contextual learning and character strengthening through the development of critical thinking skills.

METHOD

The research method used is Research and Development (R&D) with a development model, the ADDIE model. This model uses five stages of development: analysis, design, development, implementation, and evaluation (Kurnia et al., 2019). The components of critical thinking skills used in this study are interpretation, evaluation analysis, inference, explanation, and regulation in the form of multiple choice questions with four items of questions related to diffusion and osmosis of two items each. The study population was MA Nurul Huda Munjul students, with a sample of all students of class XI MIPA, a class that studies diffusion and osmosis material based on the 2013 curriculum with 46 students. The analysis used expert validation, construction, and reliability techniques. Expert validation uses a checklist sheet, construct validity analysis uses Pearson analysis, and reliability uses Split Half Method analysis.

Analysis is carried out to determine learning needs and identify problems. The analysis stage aims to identify problems that occur to students during the learning process. Things done at the analysis stage are (1) syllabus analysis, including core competencies, essential competencies, indicators of competency achievement, and subject matter; (2) analyzing learning resources. At this stage, several things must be considered, namely, availability, suitability, and ease of use; (3) analysis of student needs to find out the needs and problems of students in the learning process. Based on the results of the following analysis, the design stage of the critical thinking skills assessment instrument was carried out. At this stage, a question grid was prepared based on aspects of critical thinking skills and diffusion and osmosis materials.

After the design stage, the next is the development stage. At this stage, the assessment instrument in the form of multiple choice questions began to be developed according to the results

of the analysis and design stages. After completion of the development, the question of the assessment instrument was validated by the Biology teacher. Content validation of the question is a step to assess whether the question design is sufficiently feasible to use before the next stage is carried out, namely the question trial. Revision of questions is done after content validation has been completed. The question can be declared valid if the results of the content validation assessment have reached the valid category following the predetermined content validation criteria. If the results are not yet valid, revisions will be made according to the suggestions and input from the validator. The aim is to refine the weaknesses of the assessment instrument question further.

The fourth stage is implementation. At this stage, the question has been declared valid by both validators. This is a limited trial stage, carried out simply by testing all students of class XI MIPA MA Nurul Huda Munjul, which is 46 students. The results of this implementation were analyzed for construct validity and reliability through the SPSS application. Construct validity using Pearson analysis and reliability analysis using Split Half Method analysis. Then the last stage is the evaluation stage. In this final stage, improvements (revisions) are made after obtaining data from the construct validity and instrument reliability analysis and receiving suggestions, comments, and input from students and validators.

RESULTS AND DISCUSSION

The test instrument was developed to assess students' critical thinking skills on diffusion and osmosis materials. It includes six critical thinking components, each consisting of two questions on diffusion material and two on osmosis material, so the total number of questions is 24. The critical thinking assessment uses the form of multiple-choice questions with five answer options (Kurnia, 2021).

The first thing that was done in developing this test instrument, just like the science process skills assessment instrument, was the development of the instrument grid. After the instrument grids were developed, expert validation was conducted. The validation results showed that all items were valid. The next step was to design the draft instrument, and after that, the test instrument was tested. After testing, the next step is data analysis, both construct validity analysis using Pearson analysis and reliability using Split Half Method analysis due to interval data (Subhaktiyasa, 2024). Table 1 shows the results of the two studies.

From the data of the contract validity analysis table above, it is obtained that of the 24 multiple choice questions tested to 46 students, 20 items exceed the r table (0.297), so the items are valid to be used as an instrument for assessing students' critical thinking skills on diffusion and osmosis material. The four items, namely question numbers 1, 10, 16, and 24, need to be corrected or replaced because they have a significance value of less than 0.297. The value below the r table of the question instrument must be changed or replaced (Rahmi & Nurlizawati, 2023). From the results obtained, assessment activities are a part that cannot be ignored and separated from education and learning. Assessment is the process of collecting and processing information to determine the size of the achievement of student learning outcomes (Permendikbud RI No. 23 of 2016). Assessment of Learning Outcomes from teachers can be said to be information gathering or evidence-based activities about students can achieve competencies (knowledge attitudes, skills) in learning that are

carried out based on plans that are made and carried out systematically, both when participating in learning activities and afterward (Permendikbud RI No. 53 of 2015). Learning assessment is the process of facilitating students in giving values based on the results of measurements used as benchmarks with the quality of value indicators that educators have prepared (Akbar, 2013).

Table 1. Analysis of the validity of the construct of the question instrument

No	Components of Critical Thinking Skills	Material	No Question	Construct Validity Value	Validity Criteria	Information
1.	Interpretation	Osmosis	1	0,234	invalid	questions changed/replaced
			2	0,426	valid	questions can be used
		Diffusion	3	0,428	valid	questions can be used
			4	0,496	valid	questions can be used
2.	Analysis	Osmosis	5	0,488	valid	questions can be used
			6	0,367	valid	questions can be used
		Diffusion	7	0,583	valid	questions can be used
			8	0,523	valid	questions can be used
3.	Evaluation	Osmosis	9	0,438	valid	questions can be used
			10	-0,058	invalid	questions changed/replaced
		Diffusion	11	0,519	valid	questions can be used
			12	0,555	valid	questions can be used
4.	Inference	Osmosis	13	0,434	valid	questions can be used
			14	0,524	valid	questions can be used
		Diffusion	15	0,552	valid	questions can be used
			16	-0,266	invalid	questions changed/replaced
5	Explanation	Osmosis	17	0,487	valid	questions can be used
			18	0,335	valid	questions can be used
		Diffusion	19	0,367	valid	questions can be used
			20	0,598	valid	questions can be used
6	Regulation	Osmosis	21	0,416	valid	questions can be used
			22	0,416	valid	questions can be used
		Diffusion	23	0,381	valid	questions can be used
			24	0,088	invalid	questions changed/replaced

Educators' assessment of learning outcomes, namely teachers, is done using assessment instruments that have been prepared with appropriate parameters (Permendikbud RI No. 53 of 2015). So, in an assessment, collecting data on students' achievements is necessary, and this is called

an instrument. Assessment instruments cannot be separated from evaluation activities. Evaluation is one of the tools with parameters that educators use to carry out evaluation activities in learning and when seeking information from the results of students' learning activities (Arikunto, 2013).

Assessment of student learning outcomes is more often carried out through tests. A test is a series of questions in the form of a question sentence statement, exercise, or physical performance that can be used as a reference in determining information on the parameters of aspects of skills, knowledge, or other abilities individuals or groups possess (Nurrochmah, 2016). A test tool is called good if it has criteria including (1) reliability, (2) validity, (3) objectivity, (4) economical or minimal cost, (5) the existence of norms, (6) has clear instructions on how to do it, and (6) there are educational values in it (Winarno, 2004). Meanwhile, in Permendikbud RI No. 23 of 2016 article 5, the principles of assessing learning outcomes include: (1) valid, (2) objective, (3) reliable, (4) coherent, (5) transparent, (6) integration and continuity, (7) organized, (8) has reference criteria, (9) accountable. Thus, it can be said that assessing learning outcomes must start from the affective, psychomotor, and cognitive domains. In addition, in making assessment instruments, it is necessary to have the criteria and principles specified in the theory and juridical basis to have good validity, reliability, and objectivity.

Test instrument development is used in measuring cognitive and psychomotor abilities. Because the cognitive and psychomotor aspects that are assessed are different, the development procedure is also different. The guidelines for developing cognitive tests, according to Wiyono & Sunarni (2009) include: (1) Determination of test objectives, (2) Preparation of test grids, (3) Writing questions, (4) Review and revision of questions, (5) Test-analysis of questions-assembly of questions, (6) Presentation or implementation of tests, (7) Processing of test results, (8) Reporting, (9) Utilization of test results. These steps can be simplified into three steps: test planning, test construction, and try-out and technical analysis (Wiyono & Sunarni, 2009).

The data follows the theory that items with a correlation value below the *r* table do not meet the validity criteria and must be corrected or replaced to be more representative in measuring the expected competencies (Arikunto, 2013). Instrument validity refers to the extent to which an instrument is able to measure what should be measured. If an invalid instrument is invalid, the results do not accurately reflect the student's ability and risk giving inappropriate conclusions (Subhaktiyasa, 2024).

Reliability Statistics

Cronbach's Alpha	Part 1	Value	.687
		N of Items	12[a]
	Part 2	Value	.576
		N of Items	12[b]
	Total N of Items		24
Correlation Between Forms			.510
Spearman-Brown Coefficient	Equal Length		.676
	Unequal Length		.676
Guttman Split-Half Coefficient			.672

a. The items are: SOAL1, SOAL2, SOAL3, SOAL4, SOAL5, SOAL6, SOAL7, SOAL8, SOAL9, SOAL10, SOAL11, SOAL12.

b. The items are: SOAL13, SOAL14, SOAL15, SOAL16, SOAL17, SOAL18, SOAL19, SOAL20, SOAL21, SOAL22, SOAL23, SOAL24.

Figure 1. Analysis of the reality of the question instrument (source: SPSS)

According to Ndiung & Jediut (2020), reliability refers to the consistency of the results given by a measurement instrument in various conditions or at different times, where an instrument with high reliability indicates that the measurement results are reliable and not easily affected by outside factors. The following are the results of the instrument reliability analysis.

Based on Figure 1, the reliability analysis of the student critical thinking skills assessment instrument above obtained the Split Half Method coefficient value of 0.672, which when compared to the table of question instrument reliability criteria below, found that 0.672 is included in the range $0.40 < r \leq 0.70$ which means this question has moderate reliability, and the reliability value is considered fixed if it meets the minimum value of 0.60 (Jumini et al, 2023), so this question can be used as an instrument for assessing critical thinking skills on diffusion and osmosis material. According to Ristianti & Fathurrochman (2020), as detailed in Table 2, reliability in the range of 0.70 to 0.90 is categorized as high, while values above 0.90 are considered very high. Thus, although the reliability value of 0.672 is still in the medium category, this instrument can still be used with the possibility of minor revisions to improve its reliability.

Table 2. Criteria for the reliability of question instruments

No	Reliability	Criterion
1	$r \leq 0.20$	Very low reliability
2	$0.20 < r \leq 0.40$	Low reliability
3	$0.40 < r \leq 0.70$	Medium reliability
4	$0.70 < r \leq 0.90$	High reliability
5	$0.90 < r \leq 1.00$	Very high reliability

(Source: Ristianti & Fathurrochman, 2020)

According to Gayatri (2004), reliability can be improved by increasing the number of items. In addition, Hopkins (1998) emphasized that the reliability of an instrument can be improved by conducting repeated trials and eliminating items that have a low correlation to the total score.

Evaluation instruments include attitude, knowledge, and skills (Mustafa & Roesdiyanto, 2021). Teachers must assess students' knowledge, skills, and attitudes at the end of learning. Therefore, the role of instruments is crucial in collecting student learning outcomes to determine the extent to which learning targets can be achieved.

21st-century skills are a set of knowledge, skills, and characters considered necessary in education (Moyer et al., 2016). This aligns with the opinion (Tindowen et al., 2017) that 21st-century skills are education's top priority skills or attributes. From this perspective, education needs to consider critical thinking (Facione, 1990). The ability to think critically mathematically is something that every individual must own to carry out the process (Syafril et al., 2020). Critical thinking has a significant function in education, where critical thinking can be applied in all aspects of knowledge and daily life (Rogovaya et al., 2019).

Critical thinking is a thought characterized by an idea, problem, or event before accepting, formulating an opinion, or giving a conclusion (Colley et al., 2012). Meanwhile, according to (Ennis, 1996), critical thinking is a reflective process in determining a reason for evaluating questions. (Bowel & Kemp, 2010) explained that students who think critically have reasons for making conclusions. The purpose of critical thinking is appropriate decision-making so as not to bear a

consequence (Facione, 2015). Critical thinking is divided into two parts, namely, skills and dispositions (Facione, 1995). The characteristics of critical thinking include being active and informative, open-minded and fair, doubtful in making decisions, and independent (Butterworth & Thwaites, 2013).

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Table 3. Components of Critical Thinking Skills

No.	Component Critical Thinking	Explanation
1.	Interpretation	Understanding and expressing the meaning or meaning of different experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures, or criteria. Interpretation includes the sub-ability of categorization, deciphering meaning, and clarifying meaning.
2.	Analysis	Identifying the intent and relationship between statements, questions, concepts, descriptions, or other forms that express beliefs, judgments, experiences, reasons, information, or opinions. The sub-ability of analysis is to test views and detect and analyze reasons.
3.	Evaluation	Assessing the credibility of a statement describing a person's perceptions, experiences, situations, judgments, beliefs, or opinions and examining the logical strength of the relationship between two or more statements, descriptions, questions, or other forms of representation. The evaluation sub-ability is to estimate/establish a statement or reason
4.	Inference	Identifying and obtaining the elements needed to conclude, form a conjecture or hypothesis, consider relevant information, and develop consequences following data, statements, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, and other forms of representation. The sub-ability of inference is to ask for facts/information/evidence, estimate alternatives, and describe conclusions
5.	Explanation	An ability to present the results of a person's assessment convincingly and coherently. The explanatory sub-ability is to establish results, present procedures, show reasons
6.	Regulation	Self-regulation or self-awareness to monitor cognitive activity, the elements used in the activity, and the results developed, primarily through the use of skills in analyzing, evaluating a person's inferential assessment with a view through asking questions, confirming, validating, or correcting the results of a person's assessment. The sub-ability of self-regulation is self-testing/examination and self-correction.

Diffusion is the flow or movement of a substance in a solvent from a high-concentration part to a low-concentration part. At the same time, osmosis is the movement of water through a selectively permeable membrane from a thinner to a more concentrated part (Irnaningtyas, 2017). According to Mindariati (2021), adding sugar to a fresh liquid is a simple example of a diffusion event. An example of an osmosis event is a potato placed in salt water. The speed of diffusion is determined by the amount of substance available, the speed of kinetic motion, and the number of gaps in the cell membrane. This simple diffusion can occur in two ways: through gaps in the double lipid layer, especially if the diffusing material is lipid soluble, and through slippery channels in some transport proteins.

Wahyudi (2021) states that osmotic pressure is a colligative property, which means that this property depends on the solute's concentration, not the solute's nature. Factors that affect the occurrence of osmosis in living cells are the solute size: the more solute, the faster the osmosis event will occur. Because solutes have osmotic pressure that serves to break the solvent moving through a semipermeable membrane, membrane thickness: the thicker a membrane will inhibit the occurrence of osmosis. Because it can cause more difficulty for solutes to penetrate the membrane, surface area: The larger the surface area of a semipermeable membrane, the more water molecules can pass through the membrane in a given time. This is because a larger surface area provides a larger contact area for water diffusion, thereby increasing the rate of osmosis and the distance between the solvent and solute molecules. The distance between the solvent and solute molecules is closely related to the concentration gradient, osmotic pressure, and osmosis rate. In biological or experimental systems, the smaller the distance between solute molecules, the faster osmosis occurs because the concentration gradient is sharper. Conversely, more considerable distances tend to slow down the process of osmosis.

Thus, the instruments analyzed in this study have good validity for most questions and moderate reliability, which is still acceptable in educational research. However, to improve the quality of the instrument, it is necessary to revise invalid items and increase reliability by improving the questions' wording or rearranging some items to be more consistent in measuring students' critical thinking skills.

CONCLUSION

From the results of the validity and reliability test of the student critical thinking skills assessment instrument on diffusion and osmosis material, it is found that this instrument is considered valid and reliable with details of 24 items obtained, 20 valid items, and four items that need improvement or replacement because they have low validity values and reliable instruments are used. After all, they have moderate reliability and meet the minimum reliability value.

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