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Development of Authentic Assessment-Based Performance Assessment Tools on Buffer Solution Material

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ABSTRACT

This study aims to develop and evaluate a performance assessment tool based on authentic assessment on buffer solution material in chemistry learning in secondary schools. The study uses a research and development (R&D) approach with reference to the 4-D model which includes the define, design, develop, and disseminate stages. The developed product includes an assessment specification table, a performance assessment grid, analytical rubrics in the cognitive, affective, and psychomotor domains, student performance tasks, student activity sheets, and a learning implementation plan. The validity of the tool was determined through expert judgment and analyzed using the content validity coefficient, while the practicality and effectiveness were tested through a limited trial on 40 grade XI science students. The results showed that all components of the performance assessment tool met the criteria of validity (V = 0.89–1.00), practicality (average value of implementation T = 4.35), and effectiveness. The effectiveness of the tool is demonstrated by an increase in cognitive learning outcomes from 47.5% to 80%, the achievement of affective and psychomotor learning outcomes, which are predominantly in the good and very good categories, and a positive student response of 89.79%. These findings indicate that the developed performance assessment tool is capable of supporting comprehensive and authentic chemistry learning assessments and has the potential to improve the quality of student learning processes and outcomes.

Keywords: Performance Assessment; Authentic Assessment; Chemistry Education; Buffer Solution; Development

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INTRODUCTION

Assessment is an essential component of the educational process because it serves not only to measure learning outcomes but also as a feedback tool that guides learning improvements and pedagogical decision-making. In the 21st-century educational era, the focus of assessment has shifted from traditional assessments that only measure memory and the ability to recall information to assessments that assess higher-order thinking skills, problem-solving, and application skills relevant to real-world demands (Levy-Feldman, 2025).

The gap between current assessment practices and the needs of global education is widening as demands for 21st-century competencies increase. Recent research trends show a significant increase in studies exploring authentic assessment and performance assessment, particularly in STEM and science education, in response to the need to assess complex competencies such as collaboration, problem-solving, and creativity (performance assessment has increased in publications since 2021) while simultaneously bridging the gap

between learning and the practical application of knowledge (performance assessment, authentic assessment) (Vlachopoulos & Makri, 2024).

However, despite scientific needs and trends indicating increasing interest in more holistic and contextual authentic assessment, its implementation in learning practices, particularly in secondary school chemistry education, still faces several obstacles. Previous research has shown that teachers often struggle to design and implement valid, reliable, and practical performance assessment instruments, leading to the dominant use of traditional written tests that fail to comprehensively capture science process skills (Nawali et al., 2024).

Recent research indicates an increasing trend in the implementation of authentic assessment and performance assessment in chemistry education at all levels, from secondary school to higher education. A systematic review of the literature between 2015–2025 shows that authentic assessment in chemistry education is implemented through various forms, including performance assessment, projects, portfolios, and peer and self-assessment that integrate cognitive, affective, and psychomotor domains holistically, but faces practical challenges such as limited time, facilities, digital readiness, and educator training (authentic assessment in chemistry), (Pahriah, et al., 2025).

The study confirms that while the literature suggests that authentic assessment models can improve student engagement and learning outcomes, classroom practice still demonstrates a gap between theory and implementation. Teachers often face challenges in designing valid and reliable assessment instruments and effectively integrating three-domain assessment, particularly in complex chemistry learning materials such as buffer solutions, which require conceptual mastery as well as laboratory skills and higher-order thinking skills.

In chemistry learning, especially in topics with central concepts like buffer solutions, conceptual understanding alone is not enough; students also need to demonstrate science process skills such as designing experiments, observing chemical phenomena, and transferring knowledge to meaningful contextual situations. Unfortunately, the literature shows that existing assessment instruments often fail to capture students' actual performance in these contexts, and lack the integration of systematic and standardized assessment rubrics for the three domains: cognitive, affective, and psychomotor.

This gap between the demand for comprehensive, authentic assessment and its implementation in the classroom highlights the need for research that develops valid, practical, and effective performance assessment tools, particularly for complex chemistry materials such as buffer solutions. Such research not only fills the methodological gap in the chemistry education assessment literature but also provides empirical evidence relevant to current learning practices, particularly within the framework of assessment for learning, which emphasizes the integration of learning and assessment.

Thus, the need to develop a systematic, valid, practical, and effective performance assessment tool capable of measuring cognitive, affective, and psychomotor domains in an integrated manner and appropriate to the context of secondary chemistry learning is crucial. This development is also required to help teachers overcome the challenges of implementing authentic assessment identified in recent studies, thereby making a real contribution to improving the quality of chemistry learning and achieving 21st-century competencies.

METHOD

This study employed a research and development approach, aiming to produce an authentic assessment-based performance assessment tool for buffer solution materials. The R&D approach was chosen because it enabled researchers not only to produce educational products but also to empirically test their quality through indicators of validity, practicality, and effectiveness (Sugiyono, 2021).

The development model used is the 4-D model developed by Thiagarajan, Semmel, and Semmel, which includes four main stages: define, design, develop, and disseminate. This model is widely used in science education research because it is systematic, iterative, and oriented towards the quality of learning and assessment products (Branch, 2009).

The design phase focused on developing the initial design of the performance assessment instrument. Activities included developing an assessment specification table,

developing a performance assessment grid, designing assessment rubrics for the cognitive, affective, and psychomotor domains, and developing student performance tasks (TKS) and student activity sheets (LKS). All instruments were designed with reference to the principle of constructive alignment, namely the alignment between learning objectives, learning activities, and assessment strategies (Biggs & Tang, 2011).

The development phase aims to obtain a performance assessment tool that is suitable for use. Activities at this stage include expert validation and limited trials. Validation was conducted by two experts with expertise in chemistry education and learning evaluation to assess the suitability of the content, clarity of indicators, readability of the language, and the appropriateness of the assessment rubric. The validation results were used as the basis for revising the tool before field trials.

A limited trial was conducted to obtain empirical data on the practicality and effectiveness of the performance assessment tool. This stage is crucial to ensure that the developed tool is not only theoretically valid but also optimally applicable in real-life learning contexts (Fraenkel et al., 2019).The dissemination phase was conducted on a limited basis through socialization of the performance assessment tool to chemistry teachers. This phase aimed to obtain practical feedback and serve as an initial step in implementing the tool in a broader learning context. Limited dissemination was chosen considering the time and scope constraints of the development research (Thiagarajan et al., 1974).

Data analysis was conducted quantitatively and descriptively. The validity of the instrument was analyzed using a content validity coefficient based on expert assessment. Practicality was analyzed based on the performance assessment instrument's implementation score as observed by observers. Effectiveness was determined based on the completeness of learning outcomes, achievement in the affective and psychomotor domains, and positive student responses to the performance assessment instrument (Arikunto, 2019).

RESULT AND DISCUSSION

RESULT

This section presents the results of the development and testing of a performance assessment tool on buffer solution materials, including its validity, practicality, and effectiveness. The presentation of results is supported by quantitative data in the form of tables and statistical descriptions.

1. Validity of Performance Assessment Tools

The validity of the performance assessment tool was determined through the assessment of two experts in the field of chemistry education and learning evaluation. Validity analysis was conducted using the content validity coefficient. The validation results for all tool components are presented in Table 1.

Table 1. Validation results for all device components

Device Components	Content Validity Coefficient (V)	Category
Assessment specification table	0.89	Valid
Performance assessment grid	1.00	Very valid
Cognitive rubric	1.00	Very valid
Affective rubric	1.00	Very valid
Psychomotor rubric	1.00	Very valid
Student Performance Assignments (TKS)	1.00	Very valid
Student Activity Sheets (LKS)	1.00	Very valid
Lesson Implementation Plan (RPP)	1.00	Very valid

Based on Table 1, all components of the performance assessment tool have a content validity coefficient value of ≥ 0.75, indicating that the tool is in the valid to very valid category. This indicates that the indicators, rubrics, and instruments developed are in

accordance with the assessment objectives and characteristics of the buffer solution material, and are suitable for use in chemistry learning.

2. Practicality of Performance Assessment Tools

The practicality of the performance assessment tool was analyzed based on the results of observations of the tool's implementation by three observers during the learning process. The implementation score was calculated as the average value of the three observers' assessments and categorized based on the implementation interval.

Table 2. Results of Observations on the Implementation of Performance Assessment Tools

Observer	Average Implementation Score
Observer 1	4.30
Observer 2	4.40
Observer 3	4.35
Average (T)	**4.35**

Observation results show that the average value of the implementation of the performance assessment tool is T = 4.35, which is in the category of mostly implemented. This finding indicates that the performance assessment tool is easy to use by teachers and can be implemented consistently in the learning process, thus meeting the criteria of practicality.

3. Effectiveness of Performance Assessment Tools

The effectiveness of the performance assessment tool is analyzed based on three main indicators, namely the completion of cognitive learning outcomes, achievement of affective and psychomotor learning outcomes, and student responses.

3.1 Cognitive Learning Outcomes

Cognitive learning outcomes were analyzed based on student performance scores obtained from the TKS (Teaching Tasks), LKS (Learning Worksheets), and practicum reports. Learning completion was determined based on the Minimum Completion Criteria (KKM) of 70.

Table 3. Completion of Students' Cognitive Learning Outcomes

Value Category	Frequency	Percentage (%)
< 70 (Incomplete)	8	20.0
≥ 70 (Complete)	32	80.0
Total	**40**	**100**

Eighty percent of students achieved cognitive learning completion after implementing the performance assessment tool. This percentage meets the established effectiveness criteria, which requires a minimum of 80% of students achieving a score of 70 or greater.
In comparison, before the implementation of the performance assessment tool, the learning completion rate only reached 47.5%.

Table 4. Comparison of Learning Completion Before and After Treatment

Condition	Completion Percentage (%)
Before implementation	47.5
After implementation	80.0
Improvement	32.5

3.2 Affective Learning Outcomes

Affective learning outcomes are obtained through observation of students' attitudes during the learning and practical process using an affective assessment rubric.

Table 5. Achievement of Students' Affective Learning Outcomes

Value Range	Category	Frequency	Percentage (%)
90–100	Very good	10	25.0
70–89	Good	24	60.0
50–69	Enough	6	15.0
< 50	Not enough	0	0.0

As many as 85% of students were in the good and very good categories in the affective aspect. This indicates that the performance assessment tool was able to encourage positive student attitudes during the learning process and practical work.

3.3 Psychomotor Learning Outcomes

Psychomotor assessment is carried out based on students' skills in carrying out buffer solution practicums.

Table 6. Achievement of Students' Psychomotor Learning Outcomes

Category	Frequency	Percentage (%)
< 60 (Failed)	3	7.5
≥ 60 (Pass)	37	92.5
Total	**40**	**100**

A total of 92.5% of students achieved a passing grade on the psychomotor aspect. This finding indicates that the performance assessment tool is effective in measuring and improving students' practical skills.

4. Student Response to Performance Assessment Tools

Student responses to the performance assessment tool were analyzed using a four-level Likert scale questionnaire.

Table 7. Student Responses to Performance Assessment Tools

Response Categories	Percentage (%)
Positive response	89.79
Negative response	10.21

The majority of students (89.79%) responded positively to the developed performance assessment tool. This indicates that the tool is not only academically effective but also well-received by students.

Overall, the research results indicate that the developed performance assessment tool for buffer solution material meets the criteria of validity, practicality, and effectiveness. Improved learning outcomes, high levels of affective and psychomotor learning outcomes, and positive student responses indicate that this tool is suitable for use as an alternative authentic assessment in chemistry learning.

Discussion

The results of the study indicate that the authentic assessment-based performance assessment tool for buffer solutions meets the criteria of validity, practicality, and effectiveness. These findings reinforce the view that performance assessment is a relevant and strategic approach in chemistry learning, particularly for comprehensively measuring student competencies across the cognitive, affective, and psychomotor domains. High content validity across all components of the tool indicates that the indicators, rubrics, and instruments developed align with the learning objectives and the conceptual and procedural characteristics of chemistry material. These results align with research on the development of performance assessment instruments in science education, which emphasizes that expert judgment is a crucial step in ensuring the appropriateness of the content and measurability of the competencies being assessed (Hasibuan et al., 2023).

From a practical perspective, the device's implementation index, which falls into the "mostly implemented" category, indicates that the performance assessment tool can be implemented effectively in a real-life learning context. This finding is significant because one of the main criticisms of authentic assessment is the perception that it is difficult to implement and requires a high amount of time and workload for teachers. These findings support previous research suggesting that systematically designed performance assessment tools with clear rubrics can actually help teachers conduct assessments in a more structured and efficient manner (Windyariani et al., 2022; Nawali et al., 2024). Thus, the practicality of the tool is a key factor in bridging the gap between the theoretical demands of authentic assessment and its implementation in the classroom.

The effectiveness of the performance assessment tool is reflected in a 32.5% increase in students' cognitive learning outcomes after the tool's implementation. This increase indicates that students' active involvement in authentically assessed performance tasks and learning activities can foster a deeper understanding of chemical concepts. This finding is consistent with international research reporting that performance assessment can improve learning outcomes because students not only memorize concepts but also apply them in problem-solving contexts and practical activities (Vlachopoulos & Makri, 2024; Levy-Feldman, 2025). In the context of buffer solutions, performance assessment allows students to relate acid-base concepts to real-world phenomena, thus making learning more meaningful.

In addition to cognitive aspects, the achievement of affective and psychomotor learning outcomes, which were predominantly in the good and excellent categories, confirms the superiority of performance assessment over traditional assessments. Performance assessment provides space for observing students' scientific attitudes, cooperation, accuracy, and laboratory skills, which have not been accommodated in written tests. These results align with previous research that emphasized that the integration of affective and psychomotor rubrics in chemistry assessments contributes significantly to the development of students' science process skills and scientific attitudes (Munawwarah et al., 2024). These findings also support international literature stating that authentic assessment is an effective approach to assessing 21st-century competencies holistically (Darling-Hammond et al., 2020).

The nearly 90% positive student response to the performance assessment tool indicates a high level of acceptance of this assessment approach. These positive responses indicate that students perceive the assessment as fairer, more transparent, and more relevant to their learning activities. These results are consistent with research that reports that authentic assessment can increase student motivation and engagement because assessment criteria are clearly communicated through rubrics, enabling students to understand performance expectations (Hasanah et al., 2024). Thus, performance assessment serves not only as an evaluation tool but also as a means of assessing learning.

Overall, the results of this study confirm that the development of an authentic assessment-based performance assessment tool for buffer solutions is a relevant solution to overcome the limitations of conventional assessment practices in chemistry learning. This study's contribution is not only practical in providing a teacher-ready assessment tool, but also theoretical by enriching the study of the implementation of authentic assessment in secondary chemistry education. However, this study still has limitations in terms of subject

coverage and implementation scale, so further research is recommended to test the effectiveness of the tool in a more diverse school context and with more diverse student characteristics.

CONCLUSION

Based on the development process and limited trials conducted, the authentic assessment-based performance assessment tool for buffer solution material was proven to meet the criteria of validity, practicality, and effectiveness. The content validity of the tool was declared high based on expert assessment (V = 0.89–1.00), practicality was seen from the average implementation index T = 4.35 (category mostly implemented), and its effectiveness was reflected in the increase in students' cognitive completeness from 47.5% to 80% (an increase of 32.5%), the achievement of the affective and psychomotor domains which were mostly in the good–very good category, and a positive student response of 89.79%. Overall, the findings indicate that the developed tool is able to assess and simultaneously encourage more authentic and meaningful chemistry learning at the secondary level.

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