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Developing a Formative Assessment Based on Self-directed Learning Oriented Assessment (SLOA) for Circle Topics in Senior High School

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Abstract

The implementation of the Merdeka Curriculum emphasizes meaningful learning processes supported by appropriate assessment practices. In mathematics learning, formative assessment is essential for monitoring students' conceptual understanding and learning progress. However, existing practices remain predominantly teacher-centered and provide limited opportunities for students to engage in reflection and self-assessment, and studies integrating student-centered assessment approaches in senior high school mathematics are still limited. This study aims to develop a formative assessment based on Self-directed Learning Oriented Assessment (SLOA) for circle topics in senior high school that is valid, practical, and effective. SLOA is an assessment approach that promotes self-directed learning by integrating reflection, monitoring, and self-evaluation into the assessment process. This study employed a research and development approach using the ADDIE model. The study involved 26 grade XI students in one class at SMAN 7 Banjarmasin without a control group. The instruments included expert validation sheets, essay-type formative tests, self-assessment questionnaires, and a teacher practicality questionnaire. The results showed that the formative tests and self-assessment questionnaires were highly valid, with average scores of 3.50 and 3.46 on a 4-point scale. The practicality score reached 80%, categorized as very practical. Based on a minimum passing grade of 75 and a classical completeness criterion of 85%, the implementation results showed that 92% of students in the first test and 96% in the second test achieved mastery. These findings indicate that SLOA-based formative assessment is feasible and effective in supporting students' self-directed learning and provides practical implications for mathematics teachers in implementing more student-centered assessment practices.

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INTRODUCTION

The implementation of the Merdeka Curriculum emphasizes meaningful and student-centered learning supported by appropriate assessment practices. In mathematics education, assessment plays a crucial role not only in measuring students' cognitive achievement but also in monitoring learning progress and supporting conceptual understanding (Hamdi et al., 2022; Wahyudin et al., 2024). Mathematics, particularly geometry, requires deep conceptual understanding; therefore, evaluation practices should

help students recognize their level of mastery and learning difficulties. This is particularly important in circle topics, which involve interconnected concepts and are prone to misconceptions (Mailani et al., 2024).

Formative assessment is one of the key approaches promoted in the Merdeka Curriculum, as it provides continuous information during the learning process and allows teachers to adjust instructional strategies based on students' needs (Aminah & Mustamid, 2024; Magdalena et al., 2021; Sintawati & Rusmining, 2024). However, several studies indicate current practices remain predominantly teacher-centered and tend to reflect assessment of learning and assessment for learning, where students are positioned mainly as recipients of results rather than active participants (Lestari & Prasetyono, 2025; Shafii & Berger, 2025). In contrast, assessment as learning refers to an approach that engages students as active agents in reflecting on and evaluating their own learning processes. Such conditions limit students' opportunities to develop metacognitive awareness, which may hinder their ability to identify learning gaps, regulate their learning strategies, and build independent learning skills (Muamar et al., 2025; Ni'mah, 2025).

To overcome these limitations, an assessment approach that actively involves students in the evaluation process is required. One such approach is Self-directed Learning Oriented Assessment (SLOA), which is designed to support students' self-directed learning by integrating assessment with reflection, monitoring, and self-evaluation activities (Mentz & Lubbe, 2021). A key characteristic of SLOA is the systematic integration of self-assessment and reflection within the assessment process, enabling students to continuously monitor and regulate their learning. These features distinguish SLOA from conventional formative assessment, which often emphasizes teacher feedback without explicitly facilitating structured self-reflection. Through self-assessment, students are encouraged to develop awareness of their learning strategies, recognize conceptual misunderstandings, and plan improvements based on their self-identified strengths and weaknesses (Fitriyah et al., 2024; Yan et al., 2023). In this regard, SLOA aligns with the principles of assessment as learning (Sufyadi et al., 2021).

Previous studies have shown that SLOA-based formative assessment can support students' learning autonomy and engagement (Marvelia et al., 2025; Rohmah et al., 2021). However, most studies have been limited to elementary-level education or non-mathematics contexts. Even within mathematics education, the development of SLOA-based formative assessment at the senior high school level, particularly in geometry topics such as circles, remains very limited. Given that circle topics involve interconnected concepts that are prone to misconceptions, there is a need for an approach that not only measures learning outcomes but also facilitates students' reflection and conceptual awareness, making SLOA particularly relevant in this context.

Based on this gap, this study aims to develop a formative assessment based on SLOA for circle topics in senior high school that is valid, practical, and effective. The study contributes to the literature by developing an SLOA-based formative assessment that integrates self-assessment into mathematics learning on circle topics at the senior high school level, an area that has been rarely addressed in previous studies.

METHODS

This study employed a research and development (R&D) approach aimed at developing a formative assessment based on SLOA for circle topics in senior high school. The development process followed the ADDIE model, which consists of five stages: analysis, design, develop, implement, and evaluate (Branch, 2009). According to Mesra (2023), this ADDIE model provides a systematic and structured framework for developing educational products and evaluating their quality based on predefined criteria, as shown in Figure 1.

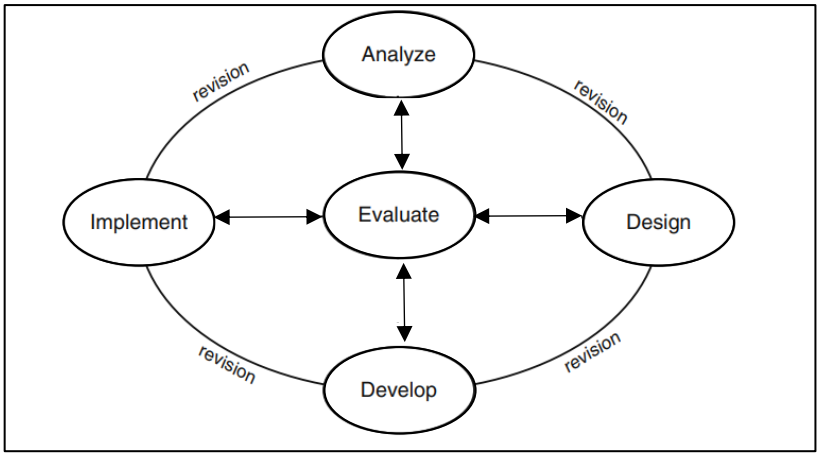

Figure 1 ADDIE model development stages

The research was conducted at SMAN 7 Banjarmasin. The participants consisted of 26 students from class XI.2, representing one intact class, who participated in the implementation stage of the developed formative assessment. The selection of the subjects was based on discussions with the mathematics teacher and consideration of students' heterogeneous abilities. The implementation was conducted in a single class without a control group. In addition, one mathematics teacher of class XI was involved as a practitioner to assess the practicality of the developed product. The implementation of the assessment was carried out by the researcher, while the teacher acted as an observer and evaluator of the product's practicality.

Several research instruments were used to collect data in this study. The instruments included (1) expert validation sheets, (2) formative test packages, (3) self-assessment questionnaires, and (4) a teacher practicality questionnaire. The expert validation sheets were used to evaluate the validity of the formative assessment and self-assessment questionnaire in terms of content, construction, and language. The formative tests consisted of two packages of essay-type questions designed based on the learning objectives of the circle topics. The first package consisted of three questions, covering arcs and chords concepts, while the second package consisted of two questions focusing on tangent concepts. Each formative test package was accompanied by a self-assessment questionnaire containing reflective statements that guided students to evaluate their understanding, learning process, and perceived achievement. The teacher practicality questionnaire was used to obtain feedback regarding the ease of use, clarity, and applicability of the developed assessment in classroom learning. All instruments were developed by the researcher and validated by two expert validators with expertise in mathematics education prior to implementation.

Data analysis in this study was conducted using descriptive quantitative techniques. The validity of the developed product was determined based on the average scores obtained from expert validation sheets. Each validator assessed the instruments based on several indicators, such as content, construction, and language, using a 4-point scale ranging from 1 (not valid) to 4 (very valid). The average validity score was calculated using the following formula.

$$VR = \frac{\sum_{i=1}^{n} \bar{V}}{n} \quad \ldots (1)$$

Notes:
VR: average validity score
$\bar{V}$: average score of each validator
n : number of validators

The validity criteria were categorized as Table 1 (Riyani et al., 2017).

Table 1 Guidelines for categorizing product validity

Interval Score	Validity Category
$3 \leq VR < 4$	Very Valid
$2 \leq VR < 3$	Valid
$1 \leq VR < 2$	Less Valid
$0 \leq VR < 1$	Not Valid

The practicality of the product was determined based on the teacher practicality questionnaire using the following formula.

$$Practicality(\%) = \frac{Obtained\ score}{Maximum\ score} \times 100\% \quad \ldots (2)$$

The practicality criteria were categorized as Table 2 (Rizky et al., 2019).

Table 2 Guidelines for categorizing product practicality

Percentage (%)	Category
80-100%	Very Practical
66-79%	Practical
56-65%	Fairly Practical
40-55%	Less Practical
30-39%	Not Practical

Meanwhile, effectiveness was measured based on students' learning mastery using formative tests. The product was considered effective if at least 85% of students achieved the minimum passing grade of 75. The minimum passing grade of 75 is the standard determined by SMAN 7 Banjarmasin for mathematics subjects. Meanwhile, the classical completeness criterion of 85% was adopted based on commonly used benchmarks in evaluating learning effectiveness in educational research (Mada et al., 2024). The percentage of students who obtained the minimum passing grade is calculated using the following formula (Suseno et al., 2021).

$$K = \frac{T}{T_1} \times 100\% \quad \ldots (3)$$

Notes:
K : percentage of learning mastery in a class
T : number of students achieving mastery
T_1: total number of students

The research procedures followed the ADDIE development stages. At the analysis stage, curriculum analysis, analysis of student characteristics, and material analysis were conducted. The design stage involved developing test blueprints and drafting formative assessment items and self-assessment instruments aligned with learning objectives. At the development stage, the assessment instruments were produced and validated by experts. The implementation stage involved administering the formative assessment and self-assessment to students in two learning sessions. Each session was conducted in 2 × 45 minutes. The first 45 minutes were used for instructional activities, followed by 40 minutes for students to complete the formative test and 5 minutes to complete the self-assessment questionnaire. Finally, the evaluation stage was conducted to review the validity, practicality, and effectiveness of the developed assessment and to identify potential improvements.

RESULTS AND DISCUSSION

The development of SLOA-based formative assessment for circle topics resulted in two formative test packages accompanied by self-assessment questionnaires. The first formative test consisted of three essay items covering arcs and chords, while the second consisted of two essay items focusing on tangents. The first self-assessment questionnaire contained 8 statements, while the second consisted of 7 statements.

At the analysis stage, students were found to experience difficulties in understanding the relationship between central and inscribed angles, as well as in solving problems involving tangents of circles. These findings served as the basis for determining the focus of the assessment instruments.

During the design stage, the formative tests and self-assessment questionnaires were developed based on the identified learning objectives and indicators. Each self-assessment questionnaire was aligned with the corresponding test package to guide students in reflecting on their understanding and problem-solving processes.

In the development stage, the instruments were validated by two experts in mathematics education. The validation results showed that the formative test obtained an average validity score of 3.50. The detailed validation results are presented in Table 3.

Table 3 Validity results of the developed formative test

Aspect	Indicator	Validator 1	Validator 2
Content	1	4	3
	2	4	3
	3	4	4
	4	4	4
	5	4	4
	6	3	1
Construction	1	4	4
	2	3	3
	3	3	2
Language	1	4	4
	2	3	4
	3	4	4
Total Score		44	40
Average Validator Score		3.67	3.34
Average Validity Score			3.5

Meanwhile, the self-assessment questionnaires obtained an average validity score of 3.46, as shown in Table 4.

Table 4 Validity results of the developed self-assessment questionnaire

Aspect	Indicator	Validator 1	Validator 2
Content	1	3	4
	2	4	4
	3	3	3
	4	3	4
Construction	1	4	4
	2	4	4
	3	3	3
	4	3	3
	5	3	3
	6	3	4
Language	1	3	4
	2	3	4
	3	4	4
	4	3	3
Total Score		46	51

Aspect	Indicator	Validator 1	Validator 2
Average Validator Score		3.28	3.46
Average Validity Score			3.46

Both instruments were categorized as highly valid, with minor revisions made to improve clarity and alignment between test items and self-assessment statements.

At the implementation stage, the instruments were administered in two classroom sessions. The teacher's evaluation indicated a practicality score of 80%, categorized as very practical.

The effectiveness analysis showed that 92% of students in the first formative test and 96% in the second formative test achieved the minimum passing grade, both exceeding the classical completeness criterion of 85%. These results indicate that most students successfully achieved mastery of the circle concepts assessed (Table 5).

Table 5 Formative test results

Student (PD)	Formative Test 1	Formative Test 2	Student (PD)	Formative Test 1	Formative Test 2
PD-01	100	95	**PD-14**	100	100
PD-02	100	97	**PD-15**	100	80
PD-03	100	80	**PD-16**	100	80
PD-04	97	95	**PD-17**	100	95
PD-05	100	80	**PD-18**	70*	95
PD-06	100	95	**PD-19**	100	100
PD-07	100	100	**PD-20**	100	95
PD-08	100	95	**PD-21**	100	100
PD-09	100	100	**PD-22**	100	95
PD-10	100	97	**PD-23**	100	95
PD-11	100	80	**PD-24**	70*	80
PD-12	100	70*	**PD-25**	100	95
PD-13	100	90	**PD-26**	100	95
Effectiveness of formative test 1			**92%**		
Effectiveness of formative test 2			**96%**		

*: students who have not achieved minimum passing grade (≤ 75)

Following the implementation, reflections were conducted based on the results of validity, practicality, and effectiveness. The evaluation identified strengths of the developed product, such as alignment with learning objectives and support for students' reflection through self-assessment.

The analysis of self-assessment results revealed variations in students' prediction accuracy. In the first self-assessment, most students were able to estimate their performance accurately. However, in the second self-assessment, the number of accurate predictions decreased, while overestimation increased (Table 6).

Table 6 Comparison of students' predicted scores and teacher scores

Self-assessment	**Frequency**			**Total**
	Lower (<)	**Match (=)**	**Higher (>)**	
Self-assessment 1	9	15	2	26
Self-assessment 2	8	4	14	26

Notes:
< : frequency of students' predicted scores lower than the teacher scores
= : frequency of students' predicted scores equal to teacher scores
> : frequency of students' predicted scores higher than the teacher scores

The distribution of students' confidence levels showed that all students reported being either confident or very confident in both assessments, indicating generally high levels of confidence in evaluating their performance (Figure 2).

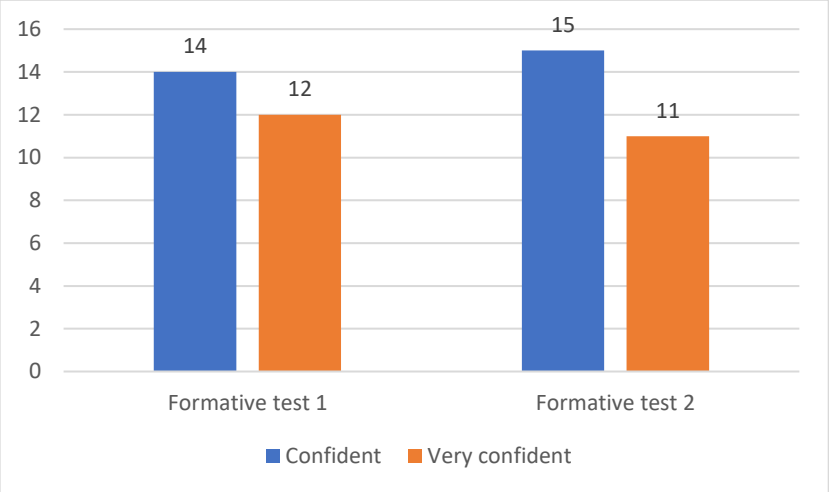

Figure 2 Students' confidence in score predictions

Individual cases further illustrate this pattern. For example, PD-18 indicated uncertainty in several concepts, particularly arcs, chords, and the relationship betweem central and inscribed angles (Figure 3).

No	Pertanyaan	Ya	Ragu-ragu	Tidak
1	Saya mampu mengidentifikasi unsur lingkaran dan menggunakannya dengan tepat untuk menyelesaikan soal.		√	
2	Saya memahami konsep busur lingkaran dan unsur-unsur yang berkaitan.			√
3	Saya dapat menjelaskan hubungan antara sudut pusat dan sudut keliling yang menghadap busur lingkaran yang sama.		√	
4	Saya dapat menggunakan hubungan antara sudut pusat dan sudut keliling untuk menyelesaikan soal dengan benar.		√	
5	Saya memahami konsep tali busur dan dapat menggambarkan hubungan antara unsur lingkaran lainnya dengan tali busur.		√	
6	Saya memahami dan mampu menggunakan rumus yang sesuai untuk menyelesaikan soal yang berkaitan dengan materi busur dan tali busur.	√		
7	Saya mengerjakan soal dengan langkah yang logis dan sistematis, serta sesuai dengan konsep yang telah dipelajari.	√		
8	Saya merasa percaya diri saat mengerjakan soal.		√	

Petunjuk: Jawablah pertanyaan di bawah ini dengan penuh pertimbangan.

1. Berapa perkiraan nilai tes formatif yang kamu peroleh (dalam skala 0 – 100)?
   Jawab: 80

2. Seberapa yakin kamu dengan nilai tersebut?

Sangat Yakin	Yakin	Kurang Yakin
√		

Figure 3 PD-18's self-assessment results

This was consistent with the formative test results, where errors were observed in solving related problems (Figure 4).

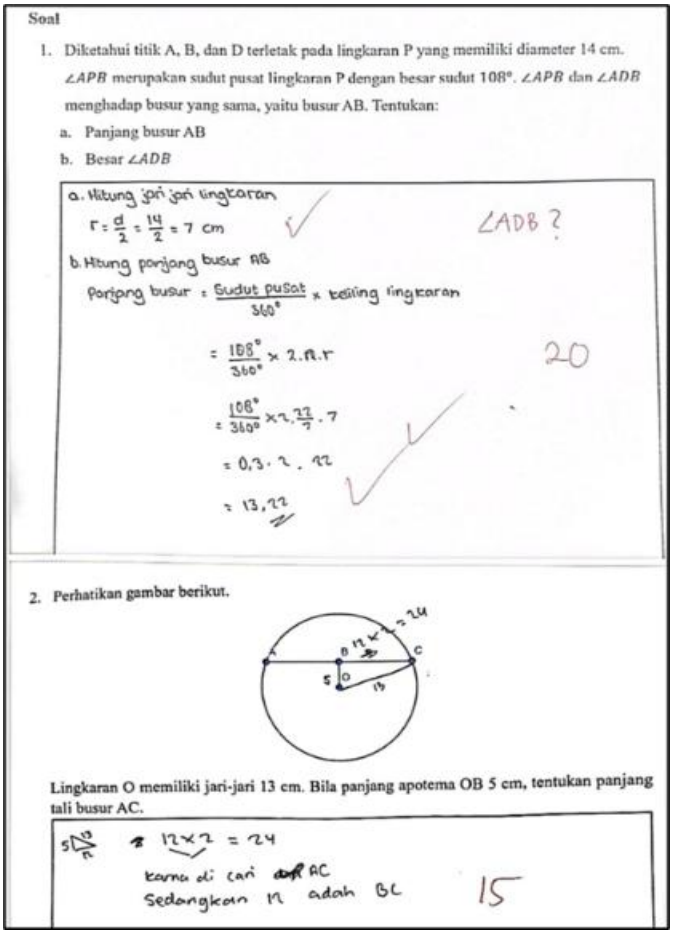

Figure 4 PD-18's formative test answers

However, the predicted score provided in the self-assessment did not correspond to the actual test score.

These findings indicate that the SLOA-based formative assessment developed through the ADDIE model meets the criteria of validity, practicality, and effectiveness. The high validity scores suggest that the instruments were well aligned with learning objectives and assessment indicators. This alignment is closely related to the analysis stage, which identified students' difficulties in key circle concepts and guided the development of appropriate assessment tasks.

The practicality result indicated that the developed assessment can be implemented effectively within classroom conditions. This suggests that integrating formative tests with self-assessment does not create excessive demands on instructional time and remains feasible for regular classroom use.

The effectiveness results demonstrate that most students were able to achieve mastery in circle topics. The high percentage of students reaching the minimum passing grade indicates that the integration of self-assessment may contribute to improved conceptual understanding and learning engagement.

In the first self-assessment, most students were able to estimate their performance accurately. However, in the second self-assessment, the number of accurate predictions decreased, while overestimation increased.

Beyond learning outcomes, the findings provide insight into students' self-assessment abilities. The increase in overestimation observed in the second assessment suggests the emergence of overconfidence, where students' confidence develops more rapidly than their

evaluative accuracy. This pattern is commonly observed in the early stages of metacognitive skill development.

This phenomenon can be explained through the concept of metacognitive awareness, particularly students' ability to monitor and evaluate their own learning processes. Students with limited metacognitive awareness tend to experience discrepancies between perceived and actual performance, leading to inaccurate self-assessment. This finding is consistent with previous studies indicating that self-assessment accuracy develops gradually and requires continuous practice (Yan et al., 2023).

The case of PD-18 further illustrates this issue, where awareness of learning difficulties was present but not accompanied by accurate performance prediction. This indicates that recognizing one's own difficulties does not automatically translate into accurate self-evaluation, highlighting a gap between metacognitive awareness and self-assessment accuracy.

Although most students demonstrated high confidence in their predictions, this confidence was not always aligned with accurate judgments. This finding supports previous research indicating that confidence does not necessarily reflect well-developed self-assessment skills (Dewi & Roshayanti, 2022).

The integration of self-assessment in this study aligns with the principles of assessment as learning, where students are actively involved in monitoring and evaluating their own learning processes (Mentz & Lubbe, 2021). The reflective statements in the self-assessment questionnaires supported students in identifying their strengths and weaknesses, thereby fostering greater awareness of their conceptual understanding. This is consistent with studies showing that self-assessment can enhance students' metacognitive awareness and promote self-directed learning (Huang, 2022).

Furthermore, the presence of students who were able to accurately predict their performance suggests that self-assessment skills can develop over time through repeated practice (Van der Linden et al., 2023). This finding extends previous research by applying SLOA-based formative assessment in senior high school mathematics, particularly on circle topics, which have received limited attention in prior studies.

However, these findings should be interpreted with caution due to the limited sample size and short duration of implementation. The study involved only one class without a control group, which may limit generalizability. In addition, the short implementation period restricted opportunities for follow-up activities such as remedial and enrichment (Lestari et al., 2022). Overall, the findings suggest that SLOA-based formative assessment not only meets the criteria of validity, practicality, and effectiveness but also has strong potential to promote students' metacognitive awareness and self-directed learning in mathematics classrooms.

CONCLUSION

This study developed a formative assessment based on SLOA for Circle topics in senior high school and examined its validity, practicality, and effectiveness. The results indicate that the developed formative assessment and self-assessment instruments were highly valid based on expert judgment, were considered very practical by the teacher, and met the effectiveness criteria based on students' mastery learning outcomes. These findings suggest that the developed product is feasible and appropriate for use in mathematics learning, particularly in geometry topics related to circles.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTION STATEMENT

KCP is responsible for the study's design, data collection, and data analysis. CFP and TH contributed to supervising the research process, reviewing the manuscript, and providing suggestions and constructive feedback to improve the quality of the study. ZBH contributed to reviewing the manuscript and providing suggestions for improving the quality and clarity of the article.

AI DISCLOSURE STATEMENT

The author used ChatGPT and Grammarly during the preparation of this paper for language polishing and translation. Additionally, Publish or Perish, Google Scholar, and Mendeley were used for literature searching and reference management. After using the tool/service, the author thoroughly reviewed and edited the content as needed and takes full responsibility for the content of the publication. The authors declare that this research was prepared, researched, written, and edited without the aid of artificial intelligence (AI) techniques.

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