

A Learning Analytics-Based Formative Assessment Framework for Supporting Students' Self-Regulated Learning

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History Article:

Received 09 16, 2026

Accepted 09 22, 2026

Published 09 23, 2026

ABSTRACT

The use of learning analytics in formative assessment has the potential to help students monitor and manage their learning process more effectively, but its application in supporting self-regulated learning remains limited. This study aims to analyze the effectiveness of a learning analytics-based formative assessment framework in improving students' self-regulated learning. A quantitative approach with a one-group pretest-posttest quasi-experimental design was used, involving 60 students selected through purposive sampling. Data were collected through a self-regulated learning questionnaire and student activity data from the Learning Management System, then analyzed using descriptive statistics and a paired-sample t-test. The results showed improvements in students' ability to plan, monitor, and evaluate their learning, associated with substantial pre-to-post SRL gains ($t = 18.42$; $p = 0.000$); however, the absence of a control group limits causal inference. These findings suggest that learning analytics-based formative assessment can support independent learning and may serve as a learning evaluation strategy in higher education. The framework offers a practical basis for using LMS activity data in formative feedback in higher education.

Keywords: Learning Analytics; Formative Assessment; Self-Regulated Learning; Digital Learning; Student

INTRODUCTION

Digital transformation in education has driven a paradigm shift from teacher-centered learning toward more adaptive, student-oriented learning. The development of learning technology, particularly the Learning Management System (LMS), generates various types of learning activity data that can be used to understand the student learning process in greater depth (Bessadok et al., 2023). These data include material access patterns, discussion activity, task completion, and assessment results, collectively known as learning analytics. In higher education, the use of learning analytics is increasingly important because institutions are required not only to improve academic achievement but also to develop students' ability to manage their learning process independently. According to Viberg et al. (2020), despite the widespread use of digital technology, most educational institutions still face challenges in converting learning data into meaningful information that supports learning decision-making.

Self-regulated learning (SRL) is one of the important competencies in modern learning, as students need to be able to set goals, choose learning strategies, monitor their understanding, and evaluate their own learning process. Alam and Mohanty (2024) explained that SRL is an active process in which individuals control cognitive, motivational, and behavioral aspects to achieve learning goals. In practice, low self-regulation ability remains a problem in digital-based learning because students often use technology merely as a medium to access information without reflecting on their learning progress. A study by Broadbent et al. (2023) shows that self-regulation skills are strongly related to success in online learning, yet many students still find it difficult to monitor and evaluate their learning independently.

Theoretically, SRL is a construct that has long been studied in educational psychology. Zimmerman (2000, 2002) developed a cyclical, three-phase model of SRL consisting of forethought (planning), performance (execution), and self-reflection. This model emphasizes that self-regulated learning is not merely a cognitive ability but a metacognitive process involving goal setting, self-monitoring, and continuous self-evaluation. In the context of digital learning, Panadero (2017) asserted that SRL can be facilitated through interventions that encourage students to actively monitor and evaluate their learning process, particularly when technology provides data that can serve as a basis for reflection.

One approach with the potential to strengthen SRL is learning analytics-based formative assessment. Formative assessment allows students to receive ongoing feedback on their learning progress, while learning analytics provide data-driven information that can be used to deliver more personalized learning interventions. Black and Wiliam (1998) and Nicol and Macfarlane-Dick (2006) emphasized that effective formative assessment functions not only as an evaluation tool but also as a mechanism to help students understand the gap between their actual performance and their learning goals, and to develop strategies for closing that gap. In the digital context, Siemens and Long (2011) explained that learning analytics can be used to understand learning behavior, predict performance, and provide personalized feedback. Scheel et al. (2022) stated that digital learning data can improve the quality of feedback and help students understand their weaknesses and competency development. In addition, Matcha et al. (2020) showed that learning analytics-based support can help improve students' metacognitive awareness through information about their learning patterns.

Nevertheless, most research still focuses on predicting learning outcomes or identifying at-risk students, while the use of learning analytics as a formative assessment framework for building self-regulation skills remains underdeveloped. Several studies have directly addressed the relationship between learning analytics and SRL, such as Chen (2024), who examined the effects of learning analytics-based feedback on SRL and academic achievement; Kleimola et al. (2025), who studied the promotion of SRL

through learning analytics in higher education; Sedrakyan et al. (2020), who designed a learning analytics dashboard to support learning regulation; and Alhazbi et al. (2024), who reviewed the use of learning analytics to measure SRL. However, these studies differ in focus and context. Chen (2024) and Kleimola et al. (2025) examined learning analytics-based interventions to support SRL, while Sedrakyan et al. (2020) focused on dashboard design for learning regulation, and Alhazbi et al. (2024) reviewed the use of learning analytics primarily to measure existing SRL. None of these studies, however, explicitly structures a formative assessment framework around Zimmerman's SRL phases and empirically tests its effectiveness through a quasi-experimental design, particularly within the Indonesian higher education context. Moreover, the research contexts are predominantly in countries whose higher education systems differ from that of Indonesia.

The novelty of this study lies in three main aspects. First, it develops and tests a learning analytics-based formative assessment framework that explicitly integrates Zimmerman's SRL phases (planning, monitoring, and evaluation) into the intervention structure, thereby not only measuring SRL but also building it through systematic instructional design. Second, this study is conducted in the context of Indonesian higher education, which has different student characteristics, learning culture, and technological infrastructure compared with the Western contexts in which most previous studies were conducted. Third, this study employs a quasi-experimental design with a one-group pretest-posttest model to empirically test the framework's effectiveness, providing quantitative evidence regarding changes in students' SRL abilities before and after the intervention. Accordingly, this study is expected to bridge the gap between technically oriented learning analytics research and psychologically oriented SRL research, as well as to provide practical contributions to the development of data-based assessment strategies in Indonesian higher education.

Based on this gap, the present study aims to analyze the effectiveness of a learning analytics-based formative assessment framework in supporting the improvement of students' self-regulated learning. This study specifically examines changes in students' self-regulation abilities (covering learning planning, learning strategies, monitoring of the learning process, and self-evaluation) before and after implementation of the framework. A quantitative approach with a quasi-experimental design was used to obtain empirical evidence on the effect of data-based formative assessment on the development of students' SRL in a digital learning environment.

Based on this purpose, the study proposes the hypothesis that applying a learning analytics-based formative assessment framework has a positive influence on improving students' self-regulated learning. This assumption rests on the premise that learning information obtained through digital activity data, formative feedback, and monitoring of learning progress can help students improve their ability to plan, monitor, and evaluate their learning process. Previous research has shown that learning analytics can provide indicators of learning behavior that support students' self-regulation processes in a digital learning environment (Alhazbi et al., 2024). In addition, learning analytics-based feedback has also been reported to increase student engagement and support the development of independent learning strategies (Chen, 2024). Accordingly, the hypothesis of this study states that there is a significant difference in students' level of self-regulated learning before and after the application of the learning analytics-based formative assessment framework, with post-treatment scores expected to be higher than pretreatment scores.

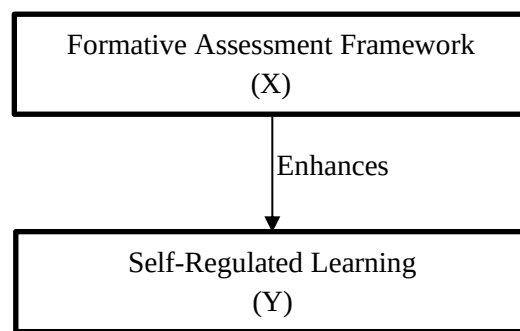


Figure 1. Conceptual Model of Research Hypothesis
Source: Developed by the author (2026)

This research offers both theoretical and practical contributions. Theoretically, it enriches the field of educational technology by integrating learning analytics, formative assessment, and self-regulated learning into a single framework oriented toward strengthening learning independence. Practically, the results can serve as a reference for lecturers and higher education institutions in designing data-based assessment strategies that not only measure learning outcomes but also support the student learning process sustainably. Thus, this research is expected to offer alternative solutions to digital learning challenges that require a more adaptive, personalized, and evidence-based evaluation approach.

METHODS OF RESEARCH

Types of Research

The research population comprised university students participating in digital-based learning using the LMS. The research sample consisted of 60 students selected using a non-probability, purposive sampling technique. Sample selection was based on the criterion that students actively use the LMS, so that data on digital learning activities such as access to materials, assignment completion, and learning interactions would be available. The use of a classroom-based sample is consistent with the characteristics of learning analytics research, which focuses on analyzing learning behavior in a digital learning environment (Matcha et al., 2020).

Population and Sample

The research population is university students who participate in digital-based learning using the Learning Management System (LMS). The research sample amounted to 60 students who were selected using a non-probability sampling technique with a purposive sampling method. The sample selection was based on the criteria of students who actively use the LMS so that data on digital learning activities is available, such as access to materials, assignment completion, and learning interactions. The use of classroom-based samples is in accordance with the characteristics of learning analytics research that focuses on analyzing learning behavior in a digital learning environment (Matcha et al., 2020).

Research Instruments

The research instruments consisted of a self-regulated learning questionnaire and student activity data from the LMS. The SRL questionnaire was developed based on the concept of Zheng et al. (2020), covering learning planning, learning strategies, monitoring of the learning process, and self-evaluation. The instrument used a five-point Likert scale. LMS data were used to obtain information on student learning

activities during implementation of the learning analytics-based formative assessment framework.

The instrument's validity was established through a content validity test conducted by experts in education and learning technology, while its reliability was tested using Cronbach's Alpha to determine internal consistency. Integrating questionnaire data with digital activity data is consistent with a learning analytics approach that combines data on student learning behavior with reflection (Blumenstein, 2020).

Data Collection Procedure

The research was carried out in three main stages. The first stage was preparation, comprising the development of SRL instruments and the setup of the learning analytics-based formative assessment framework on the LMS. The second stage was implementation, comprising collection of pretest data, application of the learning analytics-based formative assessment, and recording of student learning activity through the LMS. The third stage was posttest data collection after the treatment was completed, to determine the change in students' SRL ability.

Data Analysis Techniques

The data were analyzed using IBM SPSS Statistics. The analysis began with descriptive statistics to characterize students' SRL scores, followed by a Shapiro-Wilk normality test as a prerequisite for further analysis. Hypothesis testing was conducted using a paired-sample t-test to determine the difference in SRL scores before and after implementation of the learning analytics-based formative assessment framework. The test used a significance level of 5% ($\alpha = 0.05$), with the criterion that a p-value < 0.05 indicates a significant difference between the pretest and posttest scores.

RESULTS

Description of Student Self-Regulated Learning Data

Research data were obtained from 60 students through measurements of self-regulated learning before (pretest) and after (posttest) implementation of the learning analytics-based formative assessment framework. Measurement was based on four main indicators: learning planning, learning strategies, monitoring of the learning process, and self-evaluation.

Descriptive statistical analysis showed an increase in the average SRL score following implementation of the framework.

Table 1. Descriptive Statistics of Student Self-Regulated Learning Scores

Measurement	N	Mean	Standard Deviation	Minimum	Maximum
Pretest SRL	60	63,45	5,21	52	72
Posttest SRL	60	80,26	5,48	68	91

Source: Primary data, processed using IBM SPSS Statistics (2026)

Based on Table 1, students' average SRL score increased from 63.45 at the initial measurement to **80.26** after implementation of the learning analytics-based formative assessment framework. This increase of 16.81 points indicates a change in students' self-regulation ability following treatment.

Learning Management System Activity Analysis Results

In addition to SRL questionnaire data, this study also used student activity data from the LMS as part of the learning analytics application. Activity data were used to identify student engagement during the learning process based on the formative assessment.

Table 2. Student Learning Activities on the Learning Management System

Learning Activities	Average Activity
Access learning materials per week	7.8 times
Formative quiz completion	88,5%
Use of learning feedback	7.1 times
Learning discussion activities	5.2 activities

Source: LMS activity data, processed by the author (2026)

The data show that students actively used the digital learning features during implementation of the framework. The highest activity was observed in completing formative quizzes and accessing learning materials.

Instrument Validity and Reliability Test Results

The self-regulated learning instrument was first tested to establish measurement feasibility. The validity test was conducted through content validity assessment by experts in education and learning technology, while instrument reliability was analyzed using Cronbach's Alpha.

Table 3. SRL Instrument Reliability Test Results

Instruments	Cronbach's Alpha	Remarks
Self-Regulated Learning	0,87	Reliabel

Source: Primary data, processed using IBM SPSS Statistics (2026)

Cronbach's Alpha value of 0.87 indicates that the instrument has a good level of internal consistency to measure students' self-regulated learning abilities.

Data Normality Test Results

The normality test was carried out using the Shapiro-Wilk method as a prerequisite before hypothesis testing using a paired sample t-test. The analysis was carried out with the help of IBM SPSS Statistics software.

Table 4. Shapiro-Wilk Normality Test Results

Data	Sig.	Remarks
Pretest SRL	0,126	Normal
Posttest SRL	0,092	Normal

Source: Primary data, processed using IBM SPSS Statistics (2026)

The test results show that the significance values for both measurements were greater than 0.05, indicating that the data met the assumption of normal distribution.

Hypothesis Testing Results

Hypothesis testing was conducted using a paired-sample t-test to determine the difference in students' self-regulated learning scores before and after implementation of the learning analytics-based formative assessment framework.

Table 5. Paired Sample t-Test Results

Comparison	Mean Difference	t	Sig. (2-tailed)
Posttest – Pretest SRL	16,81	18,42	0,000

Source: Primary data, processed using IBM SPSS Statistics (2026)

The test results show a significance value of 0.000 ($p < 0.05$) with a t-value of 18.42. These results indicate a significant difference between students' self-regulated learning scores before and after implementation of the learning analytics-based formative assessment framework.

Score Change Based on Self-Regulated Learning Indicators

Analysis of score changes was performed to examine improvement in each measured aspect of SRL.

Table 6. Improvement of Self-Regulated Learning Indicators

Indicator SRL	Pretest	Posttest	Improvement
Learning planning	64,10	81,20	17,10
Learning strategies	63,20	79,80	16,60
Monitoring the learning process	62,90	80,40	17,50
Self-evaluation	63,60	79,70	16,10

Source: Primary data, processed by the author (2026)

The results show that all self-regulated learning indicators improved following implementation of the framework. The highest increase occurred in monitoring of the learning process, while the lowest increase occurred in self-evaluation.

Discussion

The results show that implementation of the learning analytics-based formative assessment framework had a positive influence on students' self-regulated learning (SRL). The increase in the average SRL score from 63.45 at pretest to 80.26 at posttest, a gain of 16.81 points, together with the results of the paired-sample t-test ($t = 18.42$; $p = 0.000$), indicates a significant change following implementation of the framework. These findings support the research hypothesis that learning analytics-based formative assessment can improve students' self-regulation skills through data-based learning information, formative feedback, and continuous monitoring of learning progress. These results are consistent with Zimmerman's SRL concept, which explains that self-regulation develops through the processes of planning, monitoring, and evaluating learning activities. This finding is also consistent with Granberg et al. (2021), who emphasized that formative assessment practices combined with self-regulation strategies can strengthen students' ability to plan, monitor, and evaluate their own learning processes.

The improvement across all SRL indicators shows that the framework not only affected learning outcomes but also supported students' metacognitive processes. The largest increase occurred in monitoring of the learning process, at 17.50 points, indicating that the use of LMS learning activity data helped students gain a clearer picture of their learning progress. These findings reinforce Winne (2022), who states that learning analytics support can increase students' metacognitive awareness by providing information about their learning patterns. In this study, LMS activity data served as a medium for reflection, enabling students to recognize their engagement and learning progress more systematically. Sedrakyan et al. (2020) similarly explained that learning analytics dashboards provide students with meaningful information about their learning behavior, which can facilitate reflective practice and improve learners' metacognitive regulation.

Student activity on the LMS also indicated good engagement during implementation of the framework, with an average of 7.8 material accesses per week, 88.5% completion of formative quizzes, 7.1 uses of feedback, and 5.2 discussion activities. These data show that the learning analytics-based formative assessment component encouraged students to interact more actively with the digital learning environment. These findings support Aslan and Imelda (2025), who found that digital learning data can improve the

quality of feedback and help learners understand their competency development. Thus, learning analytics in this study served not only as a data collection tool but also as a supporting mechanism for the student learning regulation process. According to Duan et al. (2022), the effectiveness of learning analytics depends on how learning data are translated into actionable feedback that encourages students to regulate their learning activities more effectively.

These results also reinforce the findings of Ifenthaler et al. (2021), who stated that the main challenge in implementing learning analytics lies not only in data collection but in translating that data into pedagogical strategies with a direct impact on learning. In contrast to previous studies that used learning analytics primarily to detect at-risk students or predict academic achievement, this study positions learning analytics as part of a formative assessment strategy that directly supports students' ability to manage their own learning process. This contributes to the development of educational technology research, particularly in integrating digital learning data, formative assessment, and the development of student learning independence. Similarly, Velmurugan et al. (2025) highlighted that the pedagogical value of learning analytics lies in its capacity to create personalized learning environments in which students receive timely information to improve their learning decisions and academic behaviors.

Although the results support the proposed hypothesis, several limitations should be considered. This study used a one-group pretest-posttest design without a control group, so the observed changes in SRL cannot be fully compared with a non-intervention group. In addition, the sample was limited to 60 students selected through purposive sampling, meaning that the generalizability of the findings should be interpreted with caution. Further research is recommended using an experimental design with a control group and a larger number of respondents, and combining LMS behavioral data with qualitative approaches, such as interviews or student reflections, to gain a deeper understanding of the mechanisms underlying SRL change.

Overall, this study shows that a learning analytics-based formative assessment framework can be a promising approach for supporting more adaptive, student-centered digital learning. The main contribution of this research lies in developing an assessment approach that functions not only as an evaluation tool but also as a supporting instrument for students in planning, monitoring, and evaluating their learning process independently. These findings offer practical implications for universities in designing data-driven learning strategies that can improve the quality of students' learning experience.

CONCLUSION

This study shows that implementation of a learning analytics-based formative assessment framework had a positive influence on improving students' self-regulated learning in a digital learning environment. Based on the analysis of 60 students, the average SRL score increased from 63.45 at pretest to 80.26 at posttest, with the paired-sample t-test showing a significant difference following implementation of the framework ($t = 18.42$; $p = 0.000$). Improvements occurred across all aspects of SRL, including learning planning, learning strategies, monitoring of the learning process, and self-evaluation. These findings show that using learning activity data from the LMS in combination with formative assessment can support students in understanding, monitoring, and managing their learning process more independently. This research contributes to the development of educational technology by strengthening the application of learning analytics not only as a learning-monitoring tool but also as a pedagogical strategy for improving students' self-regulation.

Despite these positive results, the study has limitations related to the use of a one-group pretest-posttest design without a control group and a limited sample of 60 students selected through purposive sampling. Further research is therefore recommended to employ experimental designs with control groups, involve a larger number of respondents, and expand the research context to other study programs or institutions. In addition, follow-up research could combine quantitative LMS activity data with qualitative approaches, such as student interviews or reflections, to gain a deeper understanding of how learning analytics-based formative assessment supports the development of self-regulated learning. With further development, this framework is expected to be applied more widely as an adaptive, student-centered, data-based assessment approach.

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