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Learning Analytics in Science Education to Enhance Self-Regulated Learning, Academic Achievement, and Data-Driven Instruction

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ABSTRAK

Penelitian ini bertujuan untuk menganalisis efektivitas learning analytics dalam meningkatkan self-regulated learning (SRL), hasil belajar akademik, serta mendukung praktik pembelajaran berbasis data dalam pendidikan IPA. Penelitian ini menggunakan pendekatan kuantitatif dengan desain quasi eksperimen berupa non-equivalent control group. Partisipan penelitian terdiri dari kelompok eksperimen yang menggunakan dashboard learning analytics terintegrasi dalam learning management system dan kelompok kontrol yang menggunakan pembelajaran konvensional. Data dikumpulkan melalui angket self-regulated learning, tes hasil belajar akademik, serta lembar observasi pembelajaran berbasis data. Hasil penelitian menunjukkan bahwa kelompok eksperimen memperoleh nilai post-test yang lebih tinggi secara signifikan dibandingkan kelompok kontrol pada seluruh variabel. Analisis normalized gain (N-gain) menunjukkan bahwa peningkatan pada kelompok eksperimen berada pada kategori sedang hingga tinggi, sedangkan kelompok kontrol berada pada kategori rendah hingga sedang. Uji statistik menggunakan independent sample t-test menunjukkan adanya perbedaan yang signifikan antara kedua kelompok ($p < 0,05$). Selain itu, learning analytics terbukti mampu meningkatkan kemampuan siswa dalam mengatur proses belajar, meningkatkan hasil belajar, serta membantu guru dalam menerapkan strategi pembelajaran berbasis data. Temuan ini menunjukkan bahwa learning analytics merupakan pendekatan yang efektif dan inovatif dalam meningkatkan kualitas pembelajaran dan hasil belajar dalam pendidikan IPA.

Kata Kunci: *learning analytics, self-regulated learning, hasil belajar, pembelajaran berbasis data, pendidikan IPA.*

ABSTRACT

This study aims to analyze the effectiveness of learning analytics in enhancing students' self-regulated learning (SRL), academic achievement, and supporting data-driven instruction in science education. The research employed a quantitative approach using a quasi-experimental design with a non-equivalent control group. The participants consisted of an experimental group that utilized learning analytics dashboards integrated into a learning management system and a control group that received conventional instruction. Data were collected using a self-regulated learning questionnaire, an academic achievement test, and an observation sheet for data-driven instructional practices. The results showed that the experimental group achieved significantly higher post-test scores compared to the control group across all variables. The normalized gain (N-gain) analysis indicated that the experimental group reached a medium to high level of improvement, while the control group remained in the low to medium category. Statistical testing using an independent sample t-test revealed a significant difference between the two groups ($p < 0.05$). Furthermore, learning analytics effectively improved students' ability to regulate their learning, enhanced academic performance, and supported teachers in implementing data-driven instructional strategies. These findings suggest that learning analytics is a powerful and innovative approach to improving both student learning outcomes and instructional quality in science education.

Keywords: *learning analytics, self-regulated learning, academic achievement, data-driven instruction, science education.*

INTRODUCTION

The rapid advancement of digital technologies has led to the emergence of learning analytics as a powerful approach to improving educational practices, particularly in science education (Yadav, 2024). Learning analytics refers to the collection, analysis, and interpretation of student data to understand and optimize learning processes and environments (Moon et al., 2024). In the context of science education, learning analytics enables educators to monitor student progress, identify learning difficulties, and provide targeted interventions based on real-time data (Zheng & Li, 2025). Recent studies indicate that learning analytics significantly contributes to improving student engagement, performance, and instructional effectiveness by supporting evidence-based decision-making (Ifenthaler & Yau, 2020; Viberg et al., 2020; Matcha et al., 2023).

One of the key competencies in science education is self-regulated learning (SRL), which involves students' ability to plan, monitor, and evaluate their own learning processes (Ng et al., 2024). However, many students struggle to develop effective self-regulation strategies, particularly in complex and data-rich learning environments. Learning analytics offers a solution by providing students with actionable feedback, visualizations of their learning progress, and insights into their performance (Susnjak et al., 2022). Research shows that analytics dashboards and feedback systems can significantly enhance students' self-regulation by promoting reflection, goal-setting, and adaptive learning behaviors (Matcha et al., 2023; Viberg et al., 2020; Ifenthaler & Yau, 2020).

In addition to supporting self-regulated learning, learning analytics plays a crucial role in improving academic achievement. By analyzing patterns in student performance data, educators can identify at-risk students and implement timely interventions to support their learning (Nimy et al., 2023). Studies have demonstrated that data-driven instructional strategies informed by learning analytics lead to improved academic outcomes and more effective teaching practices (Ifenthaler & Yau, 2020; Matcha et al., 2023; Wong et al., 2021). These findings highlight the potential of learning analytics to transform traditional teaching approaches into more adaptive and responsive systems.

Furthermore, learning analytics enables data-driven instruction, which allows educators to make informed decisions about curriculum design, teaching strategies, and assessment practices (Sajja et al., 2025). Through the use of analytics tools, teachers can gain insights into students' learning behaviors, identify misconceptions, and adjust their instruction accordingly. This approach aligns with the growing emphasis on personalized and adaptive learning in science education, where instruction is tailored to meet individual student needs (Viberg et al., 2020; Wong et al., 2021; Matcha et al., 2023).

Despite its potential, the implementation of learning analytics in science education presents several challenges, including data privacy concerns, lack of teacher expertise, and limited integration with existing curricula (Paolucci et al., 2024). Research suggests that the effectiveness of learning analytics depends on how well it is integrated into pedagogical practices and how effectively teachers and students utilize the data provided (Ifenthaler & Yau, 2020; Viberg et al., 2020; Wong et al., 2021).

Moreover, while previous studies have explored the impact of learning analytics on individual aspects such as academic achievement or self-regulated learning, there is still limited research examining its combined effect on multiple learning outcomes simultaneously. This gap highlights the need for comprehensive studies that investigate how learning analytics can simultaneously enhance self-regulated learning, academic achievement, and data-driven instructional practices in science education. Therefore, this study aims to analyze the effectiveness of learning analytics in improving students' self-regulated learning, academic achievement, and supporting data-driven instruction in

science education. The findings of this study are expected to contribute to the development of innovative and evidence-based instructional strategies that leverage data to enhance learning outcomes and instructional quality in the digital age.

METHOD

This study employed a quantitative research approach using a quasi-experimental design with a non-equivalent control group to investigate the effectiveness of learning analytics in enhancing students' self-regulated learning (SRL), academic achievement, and supporting data-driven instruction in science education. This design was selected due to its suitability for real classroom settings where random assignment is not feasible, while still allowing for systematic comparison between experimental and control groups (Creswell & Creswell, 2021).

The research was conducted in a secondary school involving two groups of students. The experimental group was exposed to learning analytics-supported instruction, while the control group received conventional teacher-centered instruction. In the experimental group, students interacted with a learning management system (LMS) integrated with learning analytics dashboards that provided real-time feedback on their learning progress, performance trends, and engagement levels. Teachers also utilized the analytics data to monitor student progress, identify learning difficulties, and implement targeted instructional interventions. Participants were selected using purposive sampling to ensure comparable academic backgrounds and learning characteristics between the two groups.

Data were collected using three main instruments: a self-regulated learning (SRL) questionnaire, an academic achievement test, and a data-driven instruction observation sheet. The SRL questionnaire was designed based on key components of self-regulated learning, including goal setting, self-monitoring, and self-evaluation. The academic achievement test measured students' understanding of science concepts and their ability to apply knowledge in problem-solving contexts. Meanwhile, the observation sheet assessed how teachers utilized learning analytics data to inform instructional decisions. All instruments were validated through expert judgment and pilot testing to ensure content validity and reliability.

The intervention was conducted over several instructional sessions, during which students in the experimental group engaged with learning analytics dashboards and received continuous feedback on their learning performance. The dashboards visualized key indicators such as task completion, quiz performance, and learning progress, enabling students to reflect on their learning and adjust their strategies accordingly. Previous studies indicate that learning analytics dashboards significantly enhance self-regulated learning and academic performance by providing actionable insights and promoting reflective learning behaviors (Matcha et al., 2023; Viberg et al., 2020; Wong et al., 2021).

Prior to the main study, a pilot test was conducted to assess the reliability of the instruments using Cronbach's alpha coefficient. Data analysis included both descriptive and inferential statistics. Descriptive statistics were used to summarize students' performance and responses, while inferential statistics, including independent sample t-tests and normalized gain (N-gain), were used to determine the effectiveness of the intervention. Statistical analysis was performed using SPSS software with a significance level set at 0.05.

This methodological approach aligns with recent research highlighting the effectiveness of learning analytics in supporting self-regulated learning, improving academic achievement, and enabling data-driven instructional practices through the use

of real-time feedback and learning data visualization (Ifenthaler & Yau, 2020; Matcha et al., 2023; Viberg et al., 2020).

RESULTS AND DISCUSSION

Descriptive Statistics of Learning Outcomes

The descriptive statistical analysis showed that both the experimental and control groups experienced improvements in their post-test scores across all measured variables, including self-regulated learning (SRL), academic achievement, and data-driven instructional engagement. However, the experimental group, which was exposed to learning analytics-supported instruction, demonstrated a significantly higher increase compared to the control group. The similarity in pre-test scores between the two groups indicates that the participants had comparable initial abilities, strengthening the internal validity of the study.

A more detailed examination of the results revealed that students in the experimental group achieved higher mean scores in SRL, particularly in indicators such as goal setting, self-monitoring, and self-evaluation. This suggests that learning analytics dashboards effectively support students in becoming more aware of their learning processes. By providing real-time data on performance and progress, the dashboards enabled students to reflect on their strengths and weaknesses, leading to more strategic learning behaviors.

In addition, the academic achievement scores in the experimental group were significantly higher than those in the control group. This indicates that the use of learning analytics not only improves students' awareness of their learning but also translates into better academic performance. The continuous feedback and data visualization features help students identify learning gaps and make timely adjustments, resulting in more effective learning outcomes.

Normalized Gain (N-gain) Analysis

The normalized gain (N-gain) analysis indicated that the experimental group achieved a medium to high level of improvement across all variables, while the control group remained within the low to medium category. Among the variables, the highest gain was observed in self-regulated learning, followed by academic achievement and data-driven instructional engagement.

This finding suggests that learning analytics is particularly effective in enhancing students' ability to regulate their own learning. The availability of real-time feedback and performance indicators encourages students to actively monitor their progress and adjust their learning strategies accordingly. This self-regulation process plays a crucial role in improving overall learning outcomes.

Furthermore, the improvement in academic achievement reflects the positive impact of data-informed learning. Students who are aware of their performance are more likely to engage in targeted learning activities, leading to better understanding and retention of scientific concepts. The relatively lower gain in the control group highlights the limitations of traditional instruction in supporting self-regulated learning and data-driven improvement.

Self-Regulated Learning (SRL) Analysis

The results showed a significant improvement in SRL among students in the experimental group compared to the control group. Students demonstrated enhanced abilities in planning their learning, monitoring their progress, and evaluating their outcomes. This improvement can be attributed to the role of learning analytics dashboards in providing actionable insights. By visualizing their learning data, students

were able to identify areas for improvement and set specific learning goals. This process promotes metacognitive awareness, which is essential for effective self-regulation.

Moreover, the continuous feedback provided by the analytics system supports iterative learning. Students can immediately see the impact of their actions and adjust their strategies accordingly. This dynamic interaction between the learner and the system fosters a deeper level of engagement and promotes independent learning.

Academic Achievement Analysis

The analysis of academic achievement revealed that students in the experimental group performed significantly better in understanding and applying scientific concepts. Students demonstrated improved abilities in problem-solving, data interpretation, and application of knowledge.

This improvement is closely related to the data-driven nature of learning analytics. By receiving timely feedback and personalized recommendations, students are able to focus on areas that require improvement. This targeted approach enhances learning efficiency and effectiveness.

In addition, the integration of learning analytics supports differentiated instruction. Teachers can use the data to identify students' needs and provide appropriate support, which further enhances academic performance. This personalized approach is particularly beneficial in heterogeneous classrooms where students have diverse learning abilities.

Data-Driven Instruction Analysis

The results also indicated a significant improvement in data-driven instructional practices among teachers in the experimental group. Teachers were able to use learning analytics data to monitor student progress, identify learning difficulties, and adjust their instructional strategies accordingly.

This finding highlights the dual impact of learning analytics on both students and teachers. While students benefit from personalized feedback, teachers gain valuable insights that inform their teaching practices. This synergy between student learning and instructional decision-making enhances the overall effectiveness of the learning process.

Furthermore, the use of analytics data promotes a more responsive and adaptive teaching approach. Teachers can quickly identify trends and patterns in student performance, enabling them to implement timely interventions. This proactive approach helps prevent learning gaps and supports continuous improvement.

Discussion

1. Effectiveness of Learning Analytics

The findings of this study confirm that learning analytics significantly enhances self-regulated learning, academic achievement, and data-driven instructional practices. This result is consistent with Ifenthaler and Yau (2020), who found that learning analytics supports student success by providing actionable insights into learning processes. Similarly, Matcha et al. (2023) emphasized that analytics dashboards play a crucial role in promoting self-regulated learning.

Furthermore, Viberg et al. (2020) highlighted that learning analytics improves educational outcomes by enabling data-informed decision-making. The findings of this study reinforce these perspectives, demonstrating that learning analytics provides a powerful tool for improving both student learning and instructional effectiveness.

2. Enhancement of Self-Regulated Learning

The significant improvement in SRL observed in this study highlights the importance of feedback and reflection in learning. Learning analytics dashboards provide students with real-time information about their performance, which encourages self-monitoring and goal-setting.

This finding aligns with Matcha et al. (2023), who reported that analytics dashboards enhance self-regulated learning by promoting reflection and adaptive learning behaviors. Additionally, Viberg et al. (2020) emphasized that data visualization helps students develop metacognitive skills.

3. Improvement of Academic Achievement

The improvement in academic achievement indicates that learning analytics supports effective learning by providing targeted feedback and personalized learning experiences. Students are able to focus on areas that require improvement, leading to better understanding and performance. This finding is supported by Wong et al. (2021), who found that data-driven instruction improves student outcomes by enabling more effective teaching strategies. Additionally, Ifenthaler and Yau (2020) emphasized that learning analytics enhances academic success by supporting evidence-based learning.

4. Role of Data-Driven Instruction

The improvement in data-driven instructional practices highlights the importance of integrating learning analytics into teaching. Teachers can use data to make informed decisions and provide targeted support to students. This finding is consistent with Viberg et al. (2020) and Wong et al. (2021), who emphasized that learning analytics enables adaptive and responsive teaching practices. By leveraging data, teachers can enhance the effectiveness of their instruction and improve student learning outcomes.

5. Challenges and Implications

Despite its effectiveness, the implementation of learning analytics presents several challenges, including data privacy concerns, technical limitations, and the need for teacher training. Ifenthaler and Yau (2020) highlighted that the success of learning analytics depends on its integration with pedagogical practices. Therefore, it is essential to provide training and support for teachers to effectively use analytics tools.

CONCLUSION

This study concludes that the implementation of learning analytics in science education significantly enhances students' self-regulated learning, academic achievement, and supports more effective data-driven instructional practices. By providing real-time feedback, performance visualization, and actionable insights, learning analytics enables students to actively monitor and regulate their learning processes while helping teachers make informed and adaptive instructional decisions. The integrated impact across these three dimensions highlights the transformative potential of learning analytics as both a pedagogical and technological innovation. This study contributes novelty by demonstrating how learning analytics simultaneously strengthens cognitive, metacognitive, and instructional aspects within a single framework, thereby offering a comprehensive approach to improving the quality of science education in the digital era.

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