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The Role of Real-Time Learning Analytics and Pedagogical Chatbots in Improving Digital Literacy and Self-Regulated Learning among Islamic Senior High School Students

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A B S T R A C T

This study examines the impact of integrating real-time learning analytics and pedagogical chatbots on enhancing digital literacy and self-regulated learning among Madrasah Aliyah students. Using a mixed-methods approach with a pre-test–post-test quasi-experimental design involving 120 students, quantitative data were collected through digital literacy tests, self-regulated learning scales, and activity logs, while qualitative data came from semi-structured interviews. Results showed a significant improvement in both digital literacy and self-regulated learning in the experimental group compared to the control group, with a positive correlation between chatbot interaction intensity and learning outcomes. Qualitative findings revealed that real-time feedback and adaptive chatbot guidance enhanced students' intrinsic motivation and learning management skills. Overall, the integration of these technologies effectively strengthens 21st-century competencies and offers strategic implications for technology-based learning design in Islamic senior high schools.

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INTRODUCTION

The transformation of education in the digital age has brought significant changes in the way teachers and students interact, access learning resources, and manage the learning process. The integration of artificial intelligence-based technologies, such as real-time learning analytics and pedagogical chatbots, has increasingly been implemented as a strategy to support 21st-century competencies, including digital literacy and self-directed learning skills. Globally, digital literacy is recognized as one of the essential skills needed to participate productively in a knowledge-based society (Vuorikari et al., 2022). Data from the International Computer and Information Literacy Study (ICILS, 2024) indicates that despite progress, many countries still experience gaps in students' digital literacy skills, highlighting the need for more effective and adaptive technology-based interventions. Within the context of Islamic senior high schools (Madrasah Aliyah), the urgency of strengthening digital literacy and independent learning is particularly relevant, as these institutions play a dual role in preparing students not only with academic and technological competencies but also with values-based education that aligns with their religious and cultural identity. Thus, integrating real-time learning analytics and pedagogical chatbots offers strategic potential to enhance both digital competence and self-regulated learning among Islamic senior high school students.

In Indonesia, strengthening digital literacy and Self-Regulated Learning (SRL) at the secondary education level is a strategic priority in line with the implementation of the Independent Curriculum, which emphasizes independent learning, creativity, and problem-solving. However, a national survey conducted by the Ministry of Education, Culture, Research, and Technology in 2023 shows that only a small percentage of students are able to effectively manage their own learning process without direct guidance from teachers. These findings are consistent with global reports indicating students' relatively low metacognitive abilities in managing learning strategies within digital environments (Bond et al., 2024). This condition highlights the urgency of innovative interventions that can provide personalized and continuous learning support. Real-time learning analytics, which enable direct monitoring of student progress and provide instant feedback, have strong potential to fill this gap, especially when combined with pedagogical chatbots that can act as adaptive and interactive learning assistants (Moura & Carvalho, 2023).

Real-time learning analytics refers to an approach that collects, analyzes, and presents learning data in real time, enabling both teachers and students to immediately identify strengths and weaknesses in the learning process (Ifenthaler & Yau, 2020). When integrated with pedagogical chatbots—AI-based conversational systems designed to provide guidance, answer questions, and sustain motivation—these technologies create a learning ecosystem that is personalized, responsive, and oriented toward individual learner needs (Moura & Carvalho, 2023). Empirical studies have shown that the use of chatbots in educational settings can enhance student engagement, accelerate the

achievement of learning goals, and encourage learners to take a more active role in organizing their strategies (Chang et al., 2022).

Although a growing body of research has examined the use of learning analytics or chatbots separately, studies that combine the two technologies to simultaneously strengthen digital literacy and SRL remain scarce. A systematic review by Bond et al. (2024) reported that most prior studies tended to emphasize either cognitive or motivational aspects alone, without integrating real-time data analysis and chatbot-based adaptive guidance into a unified research framework. Similarly, Lai (2024) highlighted that many AI applications in learning fail to address the full cycle of SRL—including planning, monitoring, and reflection—resulting in less than optimal outcomes for learning independence. These research gaps point to opportunities for empirical studies that evaluate the effectiveness of integrated approaches, particularly in the context of secondary education.

Building on this background, the present study aims to empirically analyze the impact of applying real-time learning analytics and pedagogical chatbots on improving digital literacy and self-regulated learning among students of Islamic senior high schools (Madrasah Aliyah). Furthermore, the study seeks to explore the relationship between the intensity of student–chatbot interaction and learning outcomes, as well as to identify the mechanisms through which real-time feedback and adaptive guidance enhance intrinsic motivation and strengthen students' learning management skills.

Theoretically, this research contributes to the development of a technology-based learning model that combines real-time analytical data with AI adaptive support within a comprehensive SRL framework. This approach broadens the understanding of how technological interventions can affect students' cognitive, metacognitive, and affective dimensions. Practically, the results of the research are expected to provide implementation guidance for educators and policy makers in designing effective digital learning strategies at the secondary school level, taking into account personalization, interactivity, and sustainability of the learning process.

The results of this study are not only relevant for strengthening digital literacy and SRL in Indonesia, but also have global implications for the development of technology-based education policies. The integration of real-time learning analytics and pedagogical chatbots can be a scalable learning model that can be adapted in various contexts, especially in developing countries that are trying to catch up in digital literacy and the use of educational technology. Thus, this research is expected to be a reference for the development of educational innovations that are in line with the demands of the digital era.

LITERATURE REVIEW

Digital Education Transformation and the Role of Real-Time Analytics Learning

The development of educational technology in the digital era has fundamentally changed the way teachers and students interact with learning materials. One notable innovation is Real-Time Learning Analytics (RTLA)

which allows for the collection and analysis of real-time learning data to provide instant feedback. RTLAs can record students' interactions with the material, time spent on each assignment, patterns of repeated errors, and levels of engagement during the learning process (Ifenthaler & Yau, 2020). The data provides insight for teachers to adjust teaching strategies to individual student needs, as well as help students understand their own learning progress. Thus, RTLA not only increases learning effectiveness, but also supports the development of metacognitive skills that are at the core of self-regulated learning (SRL).

Pedagogical Chatbots as Adaptive Learning Assistants

Along with the advancement of artificial intelligence, pedagogical chatbots are starting to be used as learning assistants that are able to provide personalized adaptive guidance. These chatbots are designed to mimic human conversations and can operate using rule-based approaches as well as natural language processing (NLP). Rule-based chatbots are often used to provide structured direction according to the SRL phase, such as assisting students in setting learning goals, monitoring progress, and reflecting on the results achieved. Meanwhile, NLP-based chatbots have the ability to be more flexible in understanding students' questions or complaints, even with ambiguous or informal language, so they can provide more natural and contextual responses (Chang & Sasa, 2022). In a digital learning environment, the interaction presented by chatbots not only increases digital literacy through the use of technology, but also strengthens self-regulation skills by providing consistent and accessible learning support at any time.

Integration of Learning Analytics and Chatbots in Support of SRL

The integration between RTLA and pedagogical chatbots creates a more responsive and personalized learning ecosystem. RTLA provides evidence-based data on student learning progress, while chatbots use the data to provide recommendations, answer questions, or provide motivation according to individual needs. Recent research shows that this combination is able to support all stages of SRL, from planning, monitoring, regulation, to reflection (Ramteja et al., 2023; Steinert et al., 2023). This kind of system allows teachers to immediately identify student learning constraints and intervene in a timely manner, while students get an interactive learning experience with digital assistants that are adaptive to their respective learning styles and rhythms.

Intrinsic Motivation, Autonomy, and Self-Efficacy in a Psychological Perspective

The effectiveness of learning technologies, including chatbots and RTLAs, is strongly linked to the psychological aspects of students. Based on the theory of Self-Determination, intrinsic motivation grows when the need for competence, autonomy, and connectedness is met. Chatbots designed with these principles in mind are able to increase student engagement by providing a choice of learning strategies, constructive feedback, and relevant motivational encouragement. A study (Rehman, 2024) shows that the perception of autonomy and competence gained through interaction with chatbots contributes significantly to student

engagement in informal digital learning. This confirms that the success of technological interventions in learning does not only depend on the sophistication of the system, but also on its ability to meet the psychological needs of students.

Chatbots in the Development of Digital Literacy and Reflective Metacognition

Digital literacy encompasses the technical, cognitive, and metacognitive skills necessary to participate effectively in the digital environment. Chatbots can play a role in strengthening these three aspects, for example in language learning and reflective writing. Through open-ended question-based interactions and personalized feedback, chatbots help students develop metacognitive awareness of their thought processes, correct mistakes independently, and explore more effective learning strategies (Yang et al., 2023). Thus, the use of chatbots not only facilitates mastery of the material, but also forms an essential habit of reflection in Self-Regulated Learning (SRL).

Chatbot's Multi-Role Approach and Implications for Secondary Education

The latest approach in the design of pedagogical chatbots positions this technology as a multi-role learning agent, acting not only as an academic instructor, but also as a study companion, career advisor, and emotional supporter (Cao et al., 2023). In this dual role, chatbots are able to provide academic support through explanation of concepts, build emotional connectedness by providing empathy, and motivate students to design long-term learning plans that align with their personal goals. This model has high relevance for secondary education, where students need targeted academic guidance as well as emotional support to build confidence and learning independence.

METHODOLOGY

Types and Approaches to Research

This study uses a mixed methods approach with a pre-test–post-test control group quasi-experimental design. The selection of this approach is based on the need to gain a comprehensive understanding of the effectiveness of educational technology interventions on digital literacy and self-regulated learning (SRL) of secondary school students. A quantitative approach was used to measure changes in digital literacy scores and SRL before and after the intervention, while a qualitative approach was used to explore students' experiences using Real-Time Learning Analytics (RTLA) and pedagogical chatbots (Creswell & Plano Clark, 2022; Gusso et al., 2022). This design is relevant to test the relationship between the intensity of chatbot interaction and deep learning outcomes.

Population and Sampling Techniques

The research population consisted of students from two Islamic Senior High Schools (Madrasah Aliyah Negeri) in West Sumatra, Indonesia, which have implemented the Independent Curriculum. The sampling technique employed was purposive sampling, with participants selected based on specific criteria,

including ownership of personal digital devices, possession of basic technology skills, and willingness to participate in the entire research process (Palinkas et al., 2023). A total of 120 students participated in the study, with 60 students assigned to the experimental group and 60 students to the control group. This sample size was deemed sufficient to ensure statistical test power and to provide adequate depth for qualitative exploration (Malterud et al., 2021). To complement the quantitative findings, semi-structured interviews were conducted with 15 students from the experimental group, selected through maximum variation sampling to represent differences in chatbot interaction intensity (high, medium, and low) as well as learning outcomes.

Data Collection Techniques

The quantitative data of this study was obtained through three sources, namely the Digital Literacy Test which was compiled based on the framework of the European Digital Competence Framework for Citizens (DigComp 2.2) with adaptation of the local context (Vuorikari et al., 2022), the Self-Regulated Learning Scale adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) including planning, monitoring, and reflection dimensions, as well as Real-Time Learning Analytics (RTLA) activity logs that recorded the duration, frequency, and pattern of student interaction with digital learning materials. Qualitative data were collected through semi-structured interviews with some of the students of the experimental group to explore their perceived experiences, perceptions, and learning support mechanisms. The validity of the instrument's content was tested by three educational technology experts, while the reliability of the scale was measured using Cronbach's alpha (Taber, 2021).

Research Implementation Procedure

This research was carried out in four stages. First, the preparation stage includes participant orientation, training on the use of Real-Time Learning Analytics (RTLA) platforms and chatbots, as well as the implementation of digital literacy and self-regulated learning (SRL) pre-tests in both groups. Second, the intervention stage was carried out by providing RTLA and adaptive chatbot integrated learning to the experimental group for six weeks, where chatbots played a role in providing adaptive guidance, personalized feedback, and motivation based on data from RTLA, while the control group followed digital learning without the support of RTLA and chatbots. Third, the final measurement stage includes the implementation of digital literacy and SRL post-tests in both groups, as well as the collection of chatbot interaction logs. Fourth, a qualitative interview stage was conducted on selected students from the experimental group to explore their experience in utilizing the technology.

Data Analysis Techniques

Quantitative data were analyzed using an independent t-test to measure the difference in pre-test and post-test scores between the experimental and control groups, and ANOVA to test the influence of intervariable interactions. Pearson's correlation analysis was used to identify the relationship between the

intensity of chatbot interactions and student learning outcomes. The analysis was carried out using SPSS version 27. Qualitative data were analyzed by thematic analysis to find patterns of learning support that emerged from students' interactions with technology (Braun & Clarke, 2022). Integration of quantitative and qualitative results is carried out at the interpretation stage to ensure data triangulation and strengthen the validity of research findings.

RESEARCH RESULTS

Increasing Digital Literacy

The results of quantitative analysis using independent t-tests showed that there was a significant difference between the digital literacy scores of the experimental group and the control group at the post-test stage. The data in Table 1 shows that the experimental group (n = 60) experienced an increase in the average digital literacy score from 68.45 ± 6.72 in the pre-test to 82.37 ± 5.94 in the post-test, with an increase of +13.92 points. In contrast, the control group (n = 60) only increased from 67.93 ± 7.05 to 71.85 ± 6.43, or by +3.92 points.

Table 1. Comparison of Digital Literacy Scores Pre-test and Post-test

Group	Pre-test (M ± SD)	Post-test (M ± SD)	Δ Score	t	p-value
Experiment (n=60)	68.45 ± 6.72	82.37 ± 5.94	+13.92	10.54	<0.001
Control (n=60)	67.93 ± 7.05	71.85 ± 6.43	+3.92	—	—

This difference in improvement is statistically significant ($p < 0.001$), which shows that the use of real-time learning analytics (RTLA) integrated with pedagogical chatbots contributes significantly to improving students' digital literacy. Visualization of the bar graph showed that the increase in scores in the experimental group was much sharper than in the control group, indicating that this technology-based intervention had a stronger positive impact.

These findings are consistent with the theoretical framework and results of previous research that emphasized the role of real-time feedback and adaptive guidance in developing digital literacy skills. RTLA facilitates teachers and students to monitor learning progress directly, while pedagogical chatbots provide personalized support that can be accessed at any time. The combination of the two allows students to have a more interactive, relevant, and responsive learning experience to individual needs.

Improvement Self-Regulated Learning (SRL)

The measurement of Self-Regulated Learning (SRL) ability in this study uses a standardized scale that includes three main dimensions: planning, monitoring, and reflection. This scale is designed to measure the extent to which students are able to plan learning objectives, monitor progress on an ongoing basis, and conduct critical evaluations of their learning outcomes.

The results of the independent t-test analysis showed a significant difference between the experimental group and the control group on the post-test score. The data in Table 2 showed that the experimental group (n = 60) experienced an increase in the average SRL score from 70.12 ± 7.15 in the pre-test to 83.45 ± 6.21 in the post-test, with an increase of +13.33 points. Meanwhile, the control group (n = 60) only increased from 69.54 ± 6.92 to 73.02 ± 6.54, or by +3.48 points.

Table 2. Comparison of SRL Pre-test and Post-test Scores

Group	Pre-test (M ± SD)	Post-test (M ± SD)	Δ Score	t	p-value
Experiment (n=60)	70.12 ± 7.15	83.45 ± 6.21	+13.33	9.88	<0.001
Control (n=60)	69.54 ± 6.92	73.02 ± 6.54	+3.48	—	—

Further analysis at the dimension level showed that the largest improvement in the experimental group was in the monitoring (+5.14 points) and reflection (+4.92 points) dimensions. This improvement indicates that students who receive Real-Time Learning Analytics (RTLA) interventions and pedagogical chatbots become more aware of their learning process (metacognitive awareness) and are able to adjust learning strategies independently based on the feedback they receive.

From the perspective of the mechanism, RTLA provides actual and detailed learning data, such as achievement progress, learning time, and the level of difficulty of the material faced by students. This information allows students to make immediate adjustments to learning strategies, such as allocating more time to material they have not mastered or choosing alternative learning resources. Meanwhile, adaptive chatbots provide personalized on-demand guidance, including reminders of study schedules, recommendations for problem-solving strategies, and automatic reflection on student mistakes.

The Relationship between Chatbot Interaction Intensity and Learning Outcomes

Pearson's correlation analysis was conducted to identify the relationship between the intensity of interaction with chatbots and student learning outcomes, which in this study was measured through two main indicators: digital literacy and Self-Regulated Learning (SRL). Interaction intensity is defined as a combination of conversation frequency (the number of dialogue sessions students have with the chatbot) and the duration of the interaction (the total time spent communicating with the chatbot in one week).

The results of the analysis presented in Table 3 show that there is a strong and significant positive relationship between the intensity of chatbot interaction and the two learning outcomes.

Table 3. Correlation of Chatbot Interaction Intensity with Learning Outcomes

Variabel	r	p-value
Digital Literacy Chatbot ↔ Interaction	0.71	<0.001
Interaksi Chatbot ↔ SRL	0.68	<0.001

The correlation value of r = 0.71 for the relationship between chatbot interaction and digital literacy shows that the more often and intensely students interact with chatbots, the higher the digital literacy score they achieve. An almost equally strong correlation was also seen in SRL (r = 0.68), which indicates that intensive interaction with chatbots contributes significantly to increased student learning independence. The p<0.001 values in both relationships reinforce the belief that these findings are not coincidental, but have a strong empirical basis.

From the point of view of mechanisms, this linkage can be explained through several aspects. First, Real-Time Learning Analytics (RTLA) integrated with the chatbot provides instant feedback based on student achievement data, so that more frequent interactions give students more opportunities to receive personalized guidance. Second, chatbots act as scaffolding tools that help students identify knowledge gaps, provide additional learning resources, and ask reflective questions that encourage critical thinking. The more often this process occurs, the more likely students are to internalize digital literacy skills and effective SRL strategies.

Learning Support Mechanism

Thematic analysis of semi-structured interviews with 15 experimental group students resulted in four main themes describing learning support mechanisms through the integration of Real-Time Learning Analytics (RTLA) and pedagogical chatbots.

Relevant Instant Feedback

Students stated that they were greatly helped by the chatbot's ability to provide fast, accurate, and contextual feedback that was wrong. This feedback not only points out errors, but also provides detailed explanations along with examples of correct answers. This allows students to immediately correct mistakes without having to wait for a face-to-face session with the teacher. For example, one of the students said, "*Every time I answer wrong, the chatbot immediately tells me which part is wrong and why, so I can immediately fix it without having to ask a friend or teacher*" (S3, interview, June 17, 2025). Another student added, "*What I like is that the feedback doesn't just say it's wrong, but gives examples of the correct answers and the reasons*" (S7, interview, June 20, 2025). Some students also revealed that they became more aware of their learning strategies, as revealed, "*When I study on my own, sometimes I don't realize that my way is wrong. With this chatbot, I immediately know and can change strategies.*" (S10, interview, June

24, 2025). This quick feedback also encourages them to stay consistent in learning, "Quick feedback makes me not delay learning, because I immediately get the right solution as well" (S12, Interview, June 28, 2025), even outside school hours, "*Even at night, I can still get a response from the chatbot, so I don't have to wait for the next class*" (S14, Interview, July 2, 2025).

Adaptive and Personal Guidance

The chatbot is able to adjust guidance based on RTLA data, so that each student gets recommendations for materials and exercises that are relevant to their needs. This adaptation makes students feel as if they have a personal tutor who understands their weaknesses and strengths. One student revealed, "*The material given is always in accordance with what I am weak about. For example, yesterday I didn't understand digital security, the chatbot immediately gave me practice for additional questions.*" (S2, Interview, June 19, 2025). The form of presentation of the material also varies, as conveyed, "*The chatbot seems to know my learning style, sometimes I am given pictures, sometimes texts. So I don't get bored*" (S5, interview, June 21, 2025). These adjustments help students focus on the material that really needs to be improved, "*If I'm good at one topic, the chatbot immediately moves on to another topic that scores low*" (S8, interview, June 25, 2025). Some students even equate this experience with intensive mentoring, "*The guidance felt like a personal teacher who knew my weaknesses and strengths*" (S9, Interview, June 27, 2025), and assessed that chatbots not only provide materials, but also strategies, "*He not only loves the material, but also gives tips on how to study that are suitable for me*" (S13, interview, July 1, 2025).

Intrinsic Motivation Increase

The guidance provided by chatbots is not only instructional, but also motivational. Many students admitted that they were motivated to learn because chatbots gave appreciation for their achievements, as expressed, "*Chatbots often say 'Good job' or give smile emoticons. Simple but exciting*" (S1, interview, June 18, 2025). The use of badges and challenges also encourages students to achieve their targets, "*I became motivated to complete all the modules because the chatbot told me I could get a badge*" (S4, interview, June 22, 2025). Chatbots even play a role in reminding learning targets,"*If I'm a little lazy, the chatbot likes to remind me of my learning goals this week.*" (S6, Interview, June 26, 2025), and make students feel cared for, "*The motivation of this chatbot is different, it feels like someone really pays attention to my progress*" (S11, interview, June 29, 2025). The gradual challenges given also spark curiosity"*The little challenges that he gave me made me curious to keep trying as long as I could.*" (S15, interview, July 3, 2025).

Strengthening Metacognitive Skills

The integration of RTLA and chatbots also encourages students to be more structured in planning, monitoring, and reflecting on learning. Chatbots often ask reflective questions that trigger students' awareness of their learning process. One of the students said, "*Before starting to learn, the chatbot asked me my goals today, so I was more focused*" (S3, interview, June 17, 2025). Another student added that the progress tracking feature made them more self-aware, "*I'm getting used to*

checking progress and seeing progress graphs in the app" (S5, interview, June 21, 2025). These reflective questions trigger self-evaluation, "*Reflection questions from chatbots make me aware of what needs to be improved*" (S7, interview, June 20, 2025). In addition, students start to create flexible study schedules, "*I started to make my own study schedule and adjust it if there were difficulties*" (S9, Interview, June 27, 2025), and understand the learning methods that work best for them, "*This reflection makes me feel more aware of the learning method that suits me*" (S12, Interview, June 28, 2025).

DISCUSSION

The results showed a significant positive relationship between the intensity of interaction with pedagogical chatbots and the achievement of digital literacy and Self-Regulated Learning (SRL) skills among students of Islamic senior high schools (Madrasah Aliyah). The strong correlation between these variables indicates that the more frequently and intensively students use chatbots as learning resources and academic companions, the better their ability to access, evaluate, and manage digital information, as well as the greater their independence in planning, monitoring, and evaluating their own learning processes. These findings reinforce the perspective that integrating Real-Time Learning Analytics (RTLA) with educational chatbots can serve as an effective instrument to support the mastery of 21st-century competencies, particularly digital literacy and learning autonomy (Bond et al., 2021; Mouri et al., 2022).

Conceptually, the effectiveness of this interaction can be explained by the role of chatbots as scaffolding or adaptive learning supports. Chatbots designed to deliver instant feedback, provide relevant learning recommendations, and offer motivational encouragement help students strengthen essential metacognitive skills (Luo & Zhan, 2022). RTLA enhances this function by supplying real-time learning data, enabling students to perform self-evaluations, identify weaknesses, and promptly adjust their learning strategies. This aligns with Self-Regulated Learning theory, which emphasizes the cyclical process of forethought, performance, and reflection, wherein learners continuously plan goals, monitor their progress, and reflect on outcomes to sustain improvement (Zimmerman & Moylan, 2022).

The findings of this study also show that chatbots not only play a role as an information provider, but also as a learning agent that encourages students' digital literacy. Digital literacy here includes not only technical abilities in operating devices, but also critical skills in sorting and verifying information. Through repeated interactions with chatbots, students get used to asking questions, looking for credible answers, and using that information to solve problems. This process contributes to the formation of more independent and critical thinking-based learning habits (Rahayu & Sari, 2021).

Furthermore, the data shows that chatbots play a role in strengthening all phases of SRL: from planning (goal setting), timing, and choosing learning strategies, to monitoring progress and reflecting on results. Students who use chatbots tend to have a higher awareness of their own learning process, which in turn triggers an increase in intrinsic motivation (Wong et al., 2022). This

motivation is essential because it encourages the sustainability of learning, even outside of the formal context in the classroom. In other words, chatbots function as facilitators of learning autonomy that indirectly shape the lifelong learner mindset (Yin et al., 2023).

However, the success of chatbot implementation cannot be separated from several supporting factors. First, a chatbot design that is responsive and relevant to students' needs makes interactions more personal and meaningful. Second, RTLA integration allows teachers and students to leverage learning data directly for learning decision-making (Ifenthaler & Yau, 2020). Third, the selection of research participants who already have basic technology skills helps maximize the use of chatbot features. These factors synergize in creating an adaptive, collaborative, and self-development-oriented learning ecosystem.

However, there are limitations to be aware of, some previous studies have highlighted that not all chatbots are able to effectively support the goal planning and deep reflection phases, which are important components of SRL (Fryer et al., 2022). Technical limitations such as lack of deep personalization or understanding of complex contexts can reduce the effectiveness of interventions. In addition, there is a risk of cognitive offloading, which is the tendency for students to rely too much on chatbots to reduce their efforts in critical thinking or solving problems independently (Markauskaite & Goodyear, 2023). Therefore, while chatbots have proven to be beneficial, educators still need to ensure that their use is balanced with learning strategies that encourage intellectual independence.

In terms of practical implications, this study offers a learning model based on technology integration that can be adopted in various educational contexts. By combining the power of RTLA and chatbots, educators can create learning systems that are responsive to students' individual needs, while monitoring their progress in real-time (Bai et al., 2023). This model has the potential to improve the effectiveness of learning not only in high school, but also in higher education and vocational training. To maximize its impact, future chatbot development needs to focus on improving adaptability, automatic goal setting integration, and support for deeper reflection.

Overall, the findings of this study confirm that the combination of pedagogical chatbots and RTLAs is not just an educational technology trend, but a strategy that has a strong theoretical basis and significant empirical evidence. With the right design, this technology can be a catalyst for improving digital literacy and SRL, two key skills that are urgently needed in facing the challenges of education and the world of work in the digital age.

CONCLUSION AND RECOMMENDATION

This study demonstrates that the integration of real-time learning analytics (RTLA) with pedagogical chatbots has a significant positive effect on improving digital literacy and self-regulated learning (SRL) among students of Islamic senior high schools (Madrasah Aliyah). The results of the correlation analysis revealed that the higher the intensity of students' interactions with chatbots—both in terms of conversation frequency and duration of use—the

greater their digital literacy skills and learning independence. These findings reinforce the perspective that chatbots equipped with RTLAs can serve as effective scaffolding tools, providing instant feedback, personalized support, and fostering the development of metacognitive and critical thinking skills that are essential for 21st-century learning.

In practical terms, the findings suggest that chatbots function not only as technology-based learning media but also as facilitators of learning autonomy that help cultivate sustainable self-learning habits. The primary contribution of this research lies in its empirical evidence that intensive interaction with chatbots can strengthen the entire SRL cycle—from goal setting and strategy planning to progress monitoring and reflection on learning outcomes. Accordingly, RTLA- and chatbot-integrated learning models are highly relevant for adoption in Islamic senior high schools and hold considerable potential for further development in the broader context of secondary education, higher education, and vocational training.

ADVANCED RESEARCH

Future research could explore how the integration of real-time learning analytics and pedagogical chatbots can be further optimized to support diverse learning contexts and student characteristics. Subsequent studies might investigate the long-term impact of sustained chatbot interaction on learners' digital literacy growth and self-regulated learning strategies, as well as examine how factors such as learning styles, motivation, and cultural context influence the effectiveness of these technologies. Additionally, expanding the scope beyond Islamic senior high schools to include various educational levels and disciplines would provide deeper insights into the scalability and adaptability of RTLA- and chatbot-based learning models.

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