Development of an Artificial Intelligence-Based SMART Strategy to Facilitate Self-Regulated Learning Among Senior High School Students: A Systematic Literature Review

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ABSTRACT

Data indicate that, among 640 senior high school students, 82% demonstrated a moderate level of self-regulated learning (SRL), while 15.3% were categorized as having a low level of SRL. These findings suggest that students' self-regulated learning skills remain suboptimal, highlighting the need for a learning strategy that systematically leverages artificial intelligence (AI) to foster SRL. This study aims to synthesize empirical evidence on the integration of AI in promoting SRL and to propose the SMART Strategy (Set Learning Goals, AI-Guided Scaffolding, Monitor Learning Progress, Reflect on Learning, and Transform Learning Strategies) as an AI-assisted conceptual framework for learning. The study employs a Systematic Literature Review (SLR) using the SPIDER protocol (Sample, Phenomenon of Interest, Design, Evaluation, and Research Type) to identify, screen, evaluate, and synthesize relevant articles from reputable databases. The synthesis is expected to produce a strategic framework that systematically integrates AI into the stages of self-regulated learning. The SMART Strategy has the potential to serve as a reference for designing AI-based learning by integrating technological support with pedagogical strategies to strengthen students' self-regulated learning while encouraging the use of AI as a facilitator of the learning process rather than merely a tool for generating answers. The findings are expected to provide a conceptual contribution to the development of AI-based learning strategies and support the achievement of Sustainable Development Goal (SDG) 4 through improving the quality of education in Indonesia.

ABSTRAK

Data menunjukkan bahwa 640 siswa SMA dengan persentase sebesar 82% berada pada kategori *self-regulated learning* (SRL) sedang, dan 15,3% pada kategori rendah. Persentase tersebut menunjukkan bahwa kemampuan regulasi belajar siswa masih belum optimal sehingga diperlukan strategi pembelajaran yang mampu mengoptimalkan pemanfaatan *artificial intelligence* (AI) untuk mendukung pengembangan SRL secara sistematis. Penelitian ini bertujuan mensintesiskan bukti empiris mengenai integrasi AI dalam pengembangan SRL serta merumuskan strategi SMART (*Set Learning Goals, Monitor Learning Progress, AI-Guided Scaffolding, Reflect on Learning, and Transform Learning Strategies*) berbantuan AI sebagai kerangka konseptual pembelajaran. Penelitian menggunakan metode Systematic Literature Review (SLR) dengan protokol SPIDER (*Sample, Phenomenon of Interest, Design, Evaluation*, dan *Research Type*) untuk mengidentifikasi, menyeleksi, mengevaluasi, dan mensintesis artikel dari basis data bereputasi. Hasil sintesis diharapkan menghasilkan kerangka strategi yang mengintegrasikan pemanfaatan AI dengan tahapan SRL secara sistematis. Strategi SMART berpotensi menjadi acuan dalam mengembangkan pembelajaran berbasis AI yang mengintegrasikan dukungan teknologi dan strategi pedagogis untuk memperkuat kemampuan SRL siswa secara sistematis, sekaligus mengarahkan pemanfaatan AI agar lebih berorientasi pada proses belajar daripada sekadar menghasilkan jawaban. Hasil penelitian ini diharapkan memberikan kontribusi konseptual bagi pengembangan inovasi strategi pembelajaran berbasis AI sekaligus mendukung pencapaian SDGs Nomor 4 melalui peningkatan kualitas pembelajaran di Indonesia.

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KEYWORDS

SMART Strategy, Self-Regulated Learning, Artificial Intelligence, Senior High School Students.

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INTRODUCTION

Higher education requires students to demonstrate a greater degree of autonomy by actively constructing their own knowledge rather than passively receiving information (Bollas & Bennett, 2026). In this context, self-regulated learning (SRL) has become a critical competency, particularly in the digital era and within student-centered learning environments (Azhary et al., 2021; Lammi & Mulyani, 2026). Previous studies have consistently demonstrated that self-regulated learning is positively associated with academic achievement because it enables students to effectively plan, monitor, and regulate their learning processes, apply appropriate learning strategies, and manage their time efficiently (Sari & Handayani, 2021). Moreover, students with higher levels of self-regulation are more likely to employ effective learning strategies, demonstrate greater persistence in the face of academic challenges, and engage in continuous self-reflection than those who adopt a more passive approach to learning (Firmansyah et al., 2025; Pratama, 2024). This conceptualization is consistent with that proposed by Nilson and Zimmerman (2023), who define self-regulated learning as an active, goal-directed process in which learners establish learning goals, monitor their progress, and consciously regulate their cognitive and behavioral processes to optimize learning outcomes. Therefore, fostering self-regulated learning is essential for preparing students to become independent, lifelong learners who are capable of continuously acquiring new knowledge and adapting to evolving educational and professional demands, both within and beyond formal educational settings.

However, descriptive analysis of 640 senior high school students (Figure 1) showed that most students demonstrated a moderate level of self-regulated learning (82%), while 15.3% were classified as having a low level of self-regulated learning. These findings indicate that senior high school students' self-regulation skills are not yet optimal, particularly in terms of learning planning, progress monitoring, self-reflection, motivation management, learning focus, and independent learning strategies (Andrianie et al., 2025). One possible reason is that teachers continue to serve as the primary source of information, while students have limited opportunities to independently access, manage, and evaluate learning resources (Tambunan et al., 2024). As a result, students may become more dependent on external guidance, which can lead to learned helplessness and reduce their ability to evaluate their own learning process (Wati & Nurhasannah, 2024). Similarly, (Aksela et al. 2024) found that secondary school students tend to spend more time on orientation activities and rereading learning materials than on self-monitoring and self-evaluation, despite these being essential components of self-regulated learning. Therefore, additional instructional support and the effective use of educational technology are needed to help students develop stronger self-regulation skills throughout the learning process.

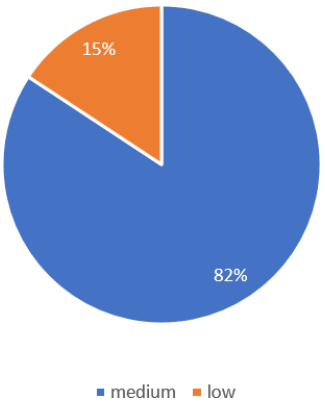


Figure 1. Self-regulated learning categories of senior high school students

In parallel with these developments, advances in computer technology have enabled the development of systems capable of replicating human intelligence and cognitive processes through artificial intelligence (AI). Artificial intelligence is widely recognized as playing a pivotal role in teaching and learning processes (Chiu, 2024). With the rapid advancement of AI, numerous applications based on Generative Artificial Intelligence (GenAI) have emerged. GenAI has been increasingly recognized for it is substantial impact on education by providing a wide range of learning resources, including recommendations for books and scholarly articles, delivering personalized learning support, and enhancing learning outcomes, motivation, self-efficacy, and other factors that contribute to students' academic success (Ansari et al., 2024; Labadze et al., 2023; Wu & Yu, 2024).

Several studies have explored the application of artificial intelligence in education from diverse perspectives. (Xia et al. 2024) investigated the implementation of GenAI in higher education assessment by considering the perspectives of educators and institutions. Xu and Ouyang (2022) reviewed the application of AI in STEM

education through the lens of general systems theory, while Chang and Sun (2024) explored the integration of AI into self-regulated language learning as a means of supporting classroom learning. Collectively, these studies indicate that AI is playing an increasingly significant role in education, not only in supporting teaching and learning across formal educational settings but also in addressing more contextualized learning needs. Therefore, integrating AI into self-regulated learning has the potential to optimize each component of the self-regulated learning process, thereby maximizing the learning outcomes achieved through self-regulated learning strategies.

Previous studies have examined the use of AI to support teaching and learning processes. (Xia et al. 2023) also demonstrated that the use of AI, particularly chatbots in learning, can support self-regulated learning by fulfilling students' psychological needs, such as autonomy and competence, thereby providing important implications for the development of intelligent learning environments that can strengthen students' self-regulation. In addition, (Mirriahi et al. 2025) found that self-regulated learning skills, particularly self-efficacy, intrinsic motivation, effort regulation, and social support, are associated with the acceptance and use of Generative Artificial Intelligence (GenAI) to support student learning. This is further supported by the findings of (Fütterer et al. 2026) and Nguyen and Nguyen (2025), who showed that AI support can help maintain the motivational, planning, and reflective aspects of self-regulated learning, although strengthening cognitive strategies and improving learning outcomes still require further development. Although previous studies have shown that AI has the potential to support motivation, planning, reflection, and technology acceptance in self-regulated learning, most studies have facilitated only individual components of self-regulated learning and have not systematically integrated AI support across the entire self-regulated learning process, from goal setting and learning progress monitoring to reflection and the continuous adaptation of learning strategies.

Based on the challenges and potential described above, the authors initiated the development of the SMART strategy (Set Learning Goals, Monitor Learning Progress, AI-Guided Scaffolding, Reflect on Learning, and Transform Learning Strategies), an artificial intelligence-based strategy designed to facilitate self-regulated learning among senior high school students. This study aims to identify the use of AI in supporting self-regulated learning, analyze the components of self-regulated learning that have been facilitated by AI, and formulate a conceptual foundation for developing a strategy that supports goal setting, adaptive scaffolding, learning progress monitoring, reflection, and the adaptation of learning strategies. The findings of this study are expected to provide a foundation for the development of AI-based learning that promotes students' learning autonomy, while also supporting the achievement of Sustainable Development Goal 4 (Quality Education) through improving the quality of learning and expanding students' access to learning experiences.

METHODS

This study employed a systematic literature review to synthesize empirical evidence on the integration of artificial intelligence (AI) in the development of self-regulated learning (SRL) and to formulate an AI-assisted SMART strategy as a conceptual framework for learning. The literature search was conducted systematically using the SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, and Research Type) protocol through the stages of identification, selection, eligibility assessment, and article synthesis across three reputable databases: Scopus, ERIC, and Google Scholar. The inclusion and exclusion criteria applied in this study are presented in Table 1.

Table 1. Inclusion and Exclusion Criteria.

Inclusion	Exclusion
Articles written in English.	Articles with inaccessible full-text versions.
Publications within the period of 2021–2026.	Publications before 2021 (< 2021).
Studies discussing the integration of artificial intelligence in supporting or developing self-regulated learning.	Studies that do not discuss the relationship between AI and SRL or only discuss AI in general without its connection to SRL.
Articles available in open access and accessible in full text.	Articles that are not available in open access or only provide abstracts.
Original research articles	Review article, systematic review, meta-analysis, book chapter, conference abstract, editorial, opinion paper, atau thesis/dissertation.

Keywords

The keywords used in the literature search were selected in accordance with the objective of this systematic literature review, which was to identify and synthesize studies on the integration of AI in the development of

SRL. The search keywords were developed in English by incorporating synonyms and variations of technical terms to broaden the search scope and improve the relevance of the retrieved literature. The search terms were then combined using the Boolean operators "AND" and "OR" across the scientific databases to facilitate both broadening and narrowing the search results Table 2. In addition, the use of various terms related to AI and the components of self-regulated learning enabled the researchers to obtain a wider range of literature that was consistent with recent developments in educational technology. Thus, this structured keyword search strategy helped ensure that the retrieved literature was relevant to the research objectives and supported a comprehensive process of analysis and synthesis in this systematic literature review.

Table 2. Keyword based article search.

Component	Keyword
Artificial Intelligence	"AI" OR "Artificial Intelligence"
Self-Regulated Learning	"Self-Regulated Learning"
Jenjang Pendidikan	"Senior High School"
String pencarian akhir	("AI" OR "Artificial Intelligence") AND "Self-Regulated Learning" AND "Senior High School"

Study Selection and Quality Assessment

Following the literature search using the predefined combination of keywords across the Scopus, ERIC, and Google Scholar databases, 358 records were identified from Scopus, 604 from ERIC, and 158 from Google Scholar. In total, 1,120 records were retrieved. Title and abstract screening resulted in 22 articles being retained for further review, while 1,098 records were excluded due to their lack of relevance to the research topic. The remaining articles then underwent a final selection process through full-text assessment to evaluate their eligibility and methodological quality. Based on the predefined inclusion and exclusion criteria, 22 full-text articles were assessed for eligibility, of which 11 were excluded because they involved an inappropriate population (n = 5), did not align with the intended intervention or research focus (n = 4), or had unsuitable outcomes or study designs (n = 2). Ultimately, 11 articles met all eligibility criteria and were included in the final synthesis of this systematic literature review. The flow of the identification, screening, eligibility assessment, and study selection process is presented in Figure 2.

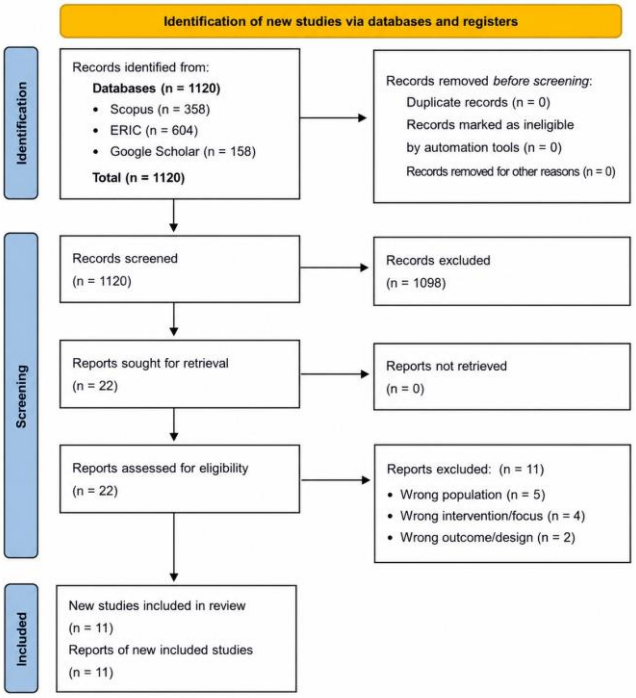


Figure 1. PRISMA flow diagram of article selection

RESULTS AND DISCUSSIONS

The findings of this systematic literature review were synthesized from studies that met the predefined inclusion and exclusion criteria. The literature selection process was conducted systematically to identify relevant empirical evidence on the use of artificial intelligence (AI) to support self-regulated learning (SRL) among senior high school students. The selected studies were then analyzed thematically to identify recurring findings, the ways in which AI supports different phases of SRL, implementation challenges, and the implications for developing AI-based learning strategies.

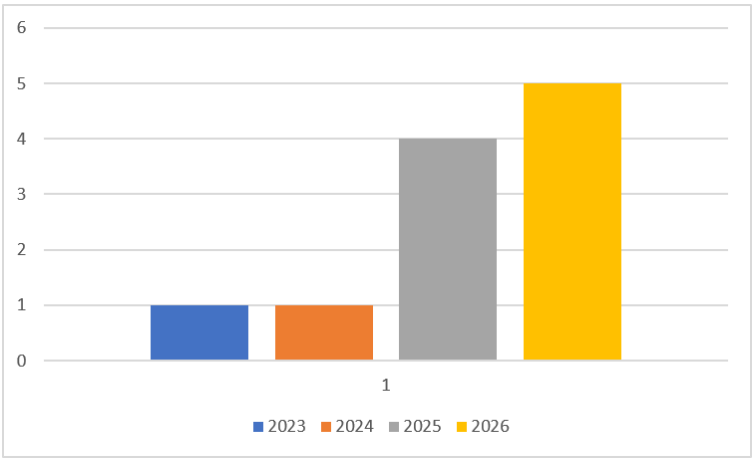


Figure 3. Distribution of included articles by year of publication.

According to Figure 3, the included studies showed an increasing publication trend over the 2023–2026 period. One study was published in 2023, followed by one in 2024. This increased to four studies in 2025 and five studies in 2026.One article was published in 2023, followed by one article in 2024. The number then increased to four articles in 2025 and reached five articles in 2026. This trend indicates that research on the integration of AI to support SRL among senior high school students has expanded more rapidly over the past two years. The growing number of publications suggests that AI and SRL have attracted increasing attention in educational research, particularly with the widespread adoption of generative AI and adaptive learning technologies in school settings.

The observed trend is consistent with the findings of Xia et al. (2023),who reported that AI-based chatbots can support self-regulated learning by enhancing students' autonomy and perceived competence. Similarly, the empirical study by Rakhmetov et al. (2025) demonstrated that adaptive AI-based feedback systems were associated with greater engagement with feedback, improved learning planning behaviors, and better academic performance in digital learning environments. These findings suggest that advances in AI technology have not only contributed to the increasing volume of research but have also expanded its application in supporting more personalized and sustainable self-regulated learning. Overall, the distribution of articles in this review indicates that the integration of AI to foster SRL has become an increasingly relevant area of research with considerable potential for further development in senior high school education.

To provide a more comprehensive overview of AI integration in supporting SRL among senior high school students, the 11 included studies were further analyzed and synthesized. The findings are summarized in Table 3, which presents the research characteristics, learning contexts, the focus of AI applications across different phases of SRL, and the key findings related to the development of students' self-regulated learning. The synthesis presented in Table 3 also serves as the foundation for formulating the AI-Based SMART Strategy (Set Learning Goals, AI-Guided Scaffolding, Monitor Learning Progress, Reflect on Learning, and Transform Learning Strategies) as a conceptual learning framework for fostering self-regulated learning in a more integrated manner.

Table 3. Selected articles on AI and SRL in education

Author	AI Focus on SRL	Research Findings
Lim et al. (2025)	GenAI support for SRL	GenAI can support self-regulated learning by assisting students with learning goal setting, learning progress monitoring, feedback provision, and learning reflection.

Ratnawati et al. (2026)	AI and learning autonomy	Students reported positive perceptions of AI use in self-regulated learning because AI enhances learning autonomy, supports goal setting and time management, and facilitates more effective decision-making during writing activities.
Yan et al. (2024)	AI for learning autonomy	STEM.AI-based adaptive practice systems improve knowledge tracing, self-confidence, and learning autonomy while supporting self-regulated learning in STEM education.
Abdallah (2025)	AI chatbots for self-regulated learning	AI chatbots equipped with personalized feedback and support facilitate self-regulated learning through goal setting, learning monitoring, learning reflection, and enhanced students' motivation and language learning skills.
Hero & Gloria (2025)	SRL in flexible learning	Most students demonstrated good self-regulated learning; however, they continued to experience challenges related to academic planning, goal setting, and learning support.
Mehmood et al. (2025)	AI for real-time feedback, personalized support, and metacognition in SRL	AI enhances students' motivation, engagement, metacognitive awareness, and self-regulated learning among secondary school students.
Xia et al. (2024)	AI chatbots for motivation and feedback in SRL	AI supports self-regulated learning, while learners' prior English knowledge and their needs for autonomy and competence play important roles in the effectiveness of AI chatbots for independent learning.
Wang et al. (2026)	AI for literacy, feedback, and learning autonomy in SRL	AI enhances the cognitive and metacognitive aspects of self-regulated learning, whereas balanced AI literacy and AI use are essential for maintaining students' learning autonomy and learning effectiveness.
Baker (2023)	AI for theory development and SRL analysis	AI contributes to the development of self-regulated learning theory by analyzing empirical findings, identifying previously unaddressed constructs, and generating testable predictions.
Zhao & Jin (2026)	AI for strategic learning and self-regulated learning in language education	The strategic use of AI enhances self-regulated learning, critical monitoring, and students' autonomy and competence in language learning environments.
Ayaz et al. (2026)	AI for cognitive regulation, metacognitive regulation, and learning awareness in SRL	AI improves cognitive regulation, metacognitive regulation, and learning awareness in self-regulated learning, although motivational support remains more effective when complemented by human support.

The synthesis of the studies that met the selection criteria indicates that the use of artificial intelligence (AI) to support SRL has been examined across a variety of educational contexts, including language learning, STEM education, flexible learning, and technology-enhanced learning. These studies demonstrate that AI has been utilized to support goal setting, learning progress monitoring, feedback provision, reflection, the promotion of learner autonomy, as well as students' cognitive and metacognitive regulation. Based on these findings, the following discussion first focuses on how SRL is conceptualized and developed in school learning as a foundation for understanding the role of AI in supporting students' SRL processes.

SRL in School Education

The synthesis of the literature indicates that self-regulated learning (SRL) is an essential competency that supports students' academic success. SRL encompasses the ability to plan learning activities, set learning goals, monitor progress, evaluate learning outcomes, and adjust learning strategies according to individual needs. In educational contexts that increasingly require learner autonomy, students are expected not only to understand the subject matter but also to actively and continuously manage their own learning processes. Several studies included in this review indicate that students' SRL abilities vary considerably. Hero and Gloria (2025) found that most students demonstrated relatively good SRL skills in flexible learning environments; however, they continued to face challenges related to academic planning, goal setting, and learning support. These findings suggest that planning and learning management remain areas that require further strengthening to enable students to learn more independently and purposefully.

In addition, the literature shows that SRL is closely associated with learning awareness, learning strategies, engagement, and reflective ability. Ayaz et al. (2026) identified cognitive and metacognitive regulation as key components of SRL, whereas Zhao and Jin (2026) emphasized the importance of strategic learning, critical monitoring, and the development of students' autonomy and competence throughout the learning process. These findings indicate that students with stronger SRL are generally better able to regulate their thinking, evaluate their own understanding, and make more effective learning decisions. Overall, the literature suggests that SRL is not merely an additional competency but rather a fundamental foundation for students' learning. The abilities to set goals, monitor learning progress, reflect on learning outcomes, and adapt learning strategies contribute to long-term academic success. Therefore, strengthening SRL should be considered a key priority in school learning through approaches that promote active engagement, reflection, and learner autonomy.

Findings from several studies also indicate that successful self-regulated learning depends on students' ability to manage their learning processes continuously through repeated cycles of regulation. Students who consistently engage in planning, monitoring, and reflection are generally better prepared to cope with increasingly complex and independent learning demands. In this review, Zhao and Jin (2026) showed that strategic learning and critical monitoring contribute to strengthening students' autonomy and competence, whereas Hero and Gloria (2025) highlighted that insufficient support for planning and learning management remains a major challenge in the development of SRL. These findings suggest that SRL is not a one-time process but an ongoing cycle that requires continuous practice, feedback, and support to help students refine their learning strategies in response to their evolving learning needs and goals.

Overall, the findings of this literature review indicate that self-regulated learning is not merely an additional competency but a fundamental foundation for students' learning. The abilities to set goals, monitor progress, reflect on learning outcomes, and adapt learning strategies are essential factors that support long-term academic success. Nevertheless, challenges related to planning, monitoring, reflection, and the management of learning strategies remain evident among some students, highlighting the need for support that can facilitate these self-regulatory processes. Within the context of the rapid development of educational technology, one form of support that has received increasing attention in the literature is the use of AI to facilitate various phases of self-regulated learning. This topic is discussed in the following section.

The Role of Artificial Intelligence in Supporting SRL

The synthesis of the literature indicates that artificial intelligence (AI) is increasingly being utilized to support various stages of self-regulated learning (SRL) among school students. One of the most prominent forms of support is AI's ability to assist students in setting learning goals and monitoring their learning progress in a more structured manner. Lim et al. (2025) demonstrated that GenAI can facilitate goal setting, progress monitoring, feedback provision, and learning reflection. These findings suggest that AI has the potential to help students engage in the self-regulation cycle more systematically, particularly when they are required to manage their learning independently. Such support is important because goal setting and monitoring serve as fundamental components of SRL that determine the direction and continuity of students' learning processes.

Beyond supporting planning and monitoring, AI also plays a role in strengthening students' learning autonomy. Ratnawati et al. (2026) found that students had positive perceptions of AI use because it assisted them in time management, goal setting, and decision-making during writing activities. These findings indicate that AI is not merely used to complete assignments but also helps students manage their learning processes more independently. When students receive support that aligns with their needs, they tend to become more confident in determining their next learning steps and more responsible for their own learning processes. Thus, AI can function as a tool that strengthens independence and autonomy in learning.

In addition, supporting adaptive learning is also demonstrated in the study by Yan et al. (2024). The study showed that AI-based adaptive practice systems improved students' knowledge tracking, self-confidence, and learning autonomy in STEM learning. The ability of AI to adjust difficulty levels and provide information regarding learning progress helps students identify the concepts they have mastered and the areas that still require improvement. This adaptive support enables learning processes to become more personalized and aligned with students' developing abilities. Within the context of SRL, knowledge tracking and self-confidence are important aspects because they influence how students evaluate their abilities and determine the learning strategies they will apply.

Similar findings were reported by Abdallah (2025), who examined the use of AI chatbots in language learning. The results showed that AI chatbots with personalized support could assist students in goal setting, monitoring, reflection, and improving language learning motivation. Unlike adaptive practice systems, chatbots provide support through conversational interactions that allow students to receive explanations, guidance, and immediate feedback. This interactive form of support can help students remain engaged in the learning process and encourage them to reflect on their understanding. Therefore, AI does not only serve as an information provider but also as a facilitator that helps students engage in self-regulated learning processes more actively and reflectively.

The study by Mehmood et al. (2025) demonstrated that AI utilization can improve students' motivation, engagement, metacognitive awareness, and SRL abilities in secondary education. Meanwhile, Xia et al. (2024) emphasized that the effectiveness of AI chatbots in supporting SRL is influenced by students' prior knowledge as well as their needs for autonomy and competence in independent learning. These findings indicate that the success of AI in supporting SRL is not solely determined by technological sophistication but also by students' readiness and involvement in utilizing the technology. Students with stronger prior knowledge and the ability to actively use AI tend to gain greater benefits compared with those who remain fully dependent on AI assistance. Therefore, the findings of this review suggest that AI has considerable potential to support goal setting, monitoring, reflection, autonomy, and metacognition within SRL. However, its implementation should be accompanied by the development of AI literacy and active student engagement to ensure that the provided support becomes meaningful for the learning process.

Considering the findings across the reviewed studies, artificial intelligence (AI) has significant potential in supporting various aspects of self-regulated learning (SRL), including goal setting, progress monitoring, feedback provision, reflection, and the enhancement of students' autonomy and metacognitive awareness.Nevertheless, these findings also reveal that most existing studies have primarily facilitated individual components of SRL separately and have not yet integrated AI support into a complete, adaptive, and sustainable self-regulation cycle. Therefore, a learning framework that systematically connects planning, monitoring, adaptive support, reflection, and learning strategy adjustment is needed. Based on this need, the findings of this review provide a foundation for developing an Artificial Intelligence-Based SMART Strategy to Facilitate Self-Regulated Learning, which aims to integrate AI support across all stages of SRL. This approach emphasizes strengthening students' independence and their ability to manage learning processes sustainably by optimizing the use of technology.

Development of an AI- Based SMART Strategy to Facilitate SRL

The synthesis of various studies indicates that the use of artificial intelligence (AI) has the potential to support several important aspects of self-regulated learning (SRL), including learning goal setting, adaptive scaffolding provision, learning progress monitoring, self-reflection, and learning strategy adjustment. However, most existing studies have still addressed these components separately and have not yet integrated AI support across the entire self-regulated learning cycle in a systematic manner. Therefore, this study initiates the development of the Artificial Intelligence-Based SMART Strategy as a set of learning steps designed to facilitate SRL among senior high school students. The SMART Strategy is an acronym for Set learning goals, Monitor learning progress, AI-guided scaffolding, Reflect on learning, and Transform learning strategies, as illustrated in Figure 4. Through the integration of these five components, the strategy is designed to connect AI-based technological support with the stages of self-regulated learning in a more structured, adaptive, and sustainable manner. Accordingly, AI does not merely function as a tool for providing answers but also serves as a facilitator that helps students independently manage their learning processes.

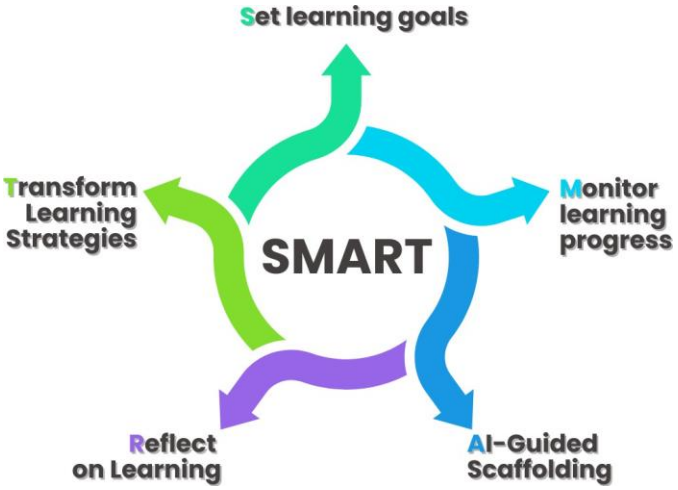


Figure 4. SMART Strategy

The first stage of the SMART strategy is set learning goals. Set learning goals represents the initial stage of the AI-Based SMART Strategy, which focuses on students' ability to establish clear, specific, and targeted learning objectives before beginning the learning process. At this stage, AI functions as a supporting tool that assists students in identifying their learning needs, determining the targets they aim to achieve, and prioritizing learning activities based on their previous abilities and progress. Structured goal setting is important because it can improve students' motivation, focus, and awareness of the learning process they are undertaking. Therefore, students do not only learn to complete tasks but also understand the direction and purpose of their learning. Within the context of self-regulated learning, the ability to set goals serves as the foundation for subsequent regulatory processes, such as monitoring, reflection, and learning strategy adjustment. This finding is supported by Yan et al. (2024), who demonstrated that technology-assisted adaptive practice designs can help learners establish learning targets that are more aligned with their abilities and development while supporting independent learning planning and regulation.

The second stage of the SMART strategy is monitor learning progress. Monitor learning progress focuses on continuously tracking students' learning development to ensure that the learning process remains aligned with the previously established goals. At this stage, AI assists students in collecting and presenting information regarding their learning progress, including task completion, level of understanding, frequently occurring errors, learning time, and achievement of predetermined targets. Through AI support, students can receive faster and more personalized feedback, enabling them to identify concepts they have mastered and areas that still require improvement. This monitoring process is not only performed automatically by the system but also involves students' awareness of comparing their current learning condition with the goals they intend to achieve. Within the context of self-regulated learning, monitoring is an essential stage because it helps students make more informed learning decisions, such as continuing effective strategies, increasing practice, or seeking additional support when needed. This finding is supported by Achuthan et al. (2025), who showed that artificial intelligence-based interventions significantly improved self-regulated learning and self-directed learning, particularly through personalized feedback, learning progress monitoring, and support for students' learning strategy regulation.

The next stage is AI-guided scaffolding. AI-guided scaffolding refers to a stage in the AI-Based SMART Strategy that focuses on providing adaptive and gradual learning support according to students' needs, abilities, and development. At this stage, AI does not directly provide final answers but functions as a facilitator that helps students understand concepts, guides their thinking processes, and provides prompts, guiding questions, examples, or recommendations for relevant learning resources. The implementation of this stage involves adjusting the form of support based on the difficulties experienced by students. When students encounter challenges, AI can provide additional explanations or step-by-step guidance, whereas when students' abilities improve, the level of support can gradually be reduced to encourage the development of independent learning. Thus, AI-assisted scaffolding helps students build understanding progressively without eliminating opportunities to think and solve problems independently. Within the context of self-regulated learning, this stage is important because it can enhance students' sense of competence, maintain learning motivation, and support the development of more effective learning strategies. This is supported by Tai and Chen (2023), who demonstrated

that the use of AI conversational agents in learning provides scaffolding through gradual guidance, feedback, and interactive support that helps students regulate their learning processes and develop self-regulated learning skills.

The fourth stage of the SMART strategy is reflect on learning. Reflect on learning emphasizes the importance of students reviewing their learning experiences after completing a learning activity. At this stage, artificial intelligence is utilized to assist students in identifying what they have understood well, which areas remain challenging, which strategies have been most helpful, and what changes need to be made in future learning processes. Reflection does not only focus on final outcomes but also on thinking processes, time management, concentration levels, and the effectiveness of strategies used during learning. AI can facilitate this process through reflective questions, summaries of learning progress, or feedback that encourages students to conduct deeper self-evaluation. Through regular reflection, students can develop metacognitive awareness and understand the relationship between their learning actions and the outcomes they achieve. Within the context of self-regulated learning, reflection serves as an important mechanism for improving learning processes and enhancing decision-making abilities in subsequent learning activities. This finding is supported by Ratnawati, Mukminatien, Basthomi, and Laksmi (2026), who showed that the use of AI in online writing activities based on self-regulated learning helped students conduct self-evaluation, reflect on their learning processes, and enhance learning autonomy in a more meaningful way.

The final stage of the SMART strategy is transforming learning strategies. This stage focuses on students' efforts to modify, improve, or adjust their learning strategies based on learning progress monitoring results and reflections on previous learning experiences. When monitoring results indicate that learning goals have not been achieved optimally, and reflection reveals difficulties or ineffective strategies, artificial intelligence assists students in identifying factors that influence the failure to achieve targets, such as insufficient conceptual understanding, inappropriate learning methods, ineffective time management, or practice activities that do not meet learning needs. Based on this information, AI can provide recommendations for improvement, such as applying different learning approaches, increasing practice on specific materials, selecting more relevant learning resources, or reorganizing learning plans to make them more structured. Therefore, this stage demonstrates that self-regulated learning is a dynamic and cyclical process in which monitoring and reflection outcomes become the basis for students to transform their learning strategies before continuing to the next learning cycle. Consequently, failure to achieve learning targets is not viewed as an unsuccessful outcome but rather as an opportunity to adapt and improve learning strategies continuously. This finding is supported by Hero and Gloria (2025), who showed that students with stronger self-regulated learning abilities tend to be more capable of evaluating their learning processes and independently adjusting their learning strategies in flexible learning environments.

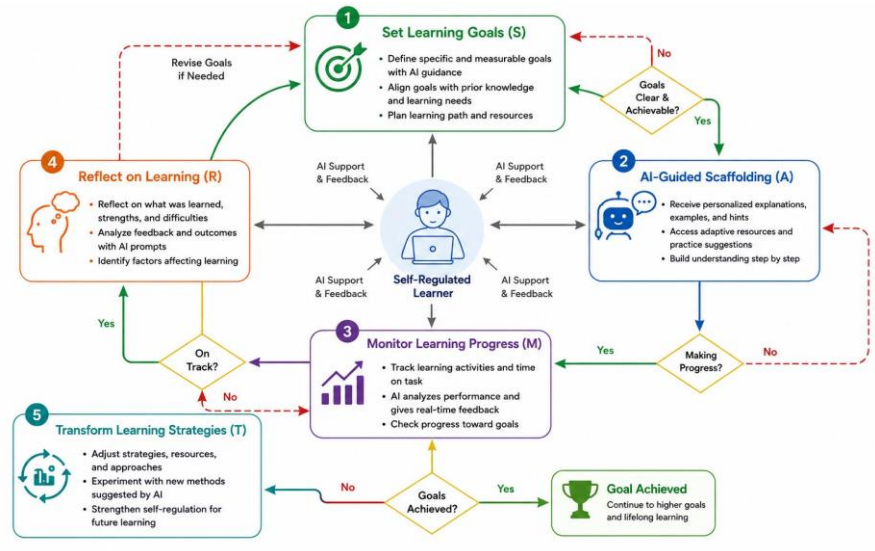


Figure 5. The Implementation Flow of the SMART Strategy

The implementation of the AI-Based SMART Strategy follows a cyclical and adaptive process, enabling students to engage in self-regulated learning continuously. The process begins with set learning goals, during which students establish clear, specific, and targeted learning goals based on their needs and abilities. Students then proceed to monitor learning progress, where they monitor their learning development, compare their achievements with the previously established goals, and obtain information about the concepts they have

mastered as well as those that still require improvement. The results of this monitoring process then provide the basis for the AI-guided scaffolding stage. At this stage, artificial intelligence provides adaptive learning support through guidance, explanations, examples, guiding questions, or recommendations for relevant learning resources based on the difficulties experienced by students. After receiving this support, students continue to reflect on learning by evaluating their understanding, learning strategies, and learning processes while identifying the factors that have influenced their learning outcomes. If the reflection indicates that the learning goals have not yet been achieved optimally, students proceed to transform learning strategies by modifying or improving their learning strategies before continuing to the next learning cycle. Accordingly, the implementation of the SMART Strategy does not follow a linear sequence but instead forms a continuous cycle of self-regulated learning until the intended learning goals are achieved. The implementation process of the AI-Based SMART Strategy is presented in greater detail in Figure 5.

The sustainability of the AI-Based SMART Strategy is designed as a gradual development process that involves strengthening the underlying concept, implementing the strategy in learning activities, conducting evaluations, refining the strategy, and integrating it into broader educational practice. For this reason, the SMART Strategy is intended not only to promote the use of AI in the short term but also to support the development of a self-regulated learning culture that can evolve adaptively and sustainably in response to students' needs and advances in educational technology. The stages of the development and implementation of the AI-Based SMART Strategy are presented more systematically in Table 4.

Table 4. The Sustainability of the AI-Based SMART strategy.

Year	Stage	Main Target
2026	Development	Development of the AI-Based SMART Strategy Conceptual Framework through Literature Synthesis
2027	Validation	Expert Validation and Refinement of SMART Components Based on SRL and AI Pedagogy Principles
2028	Pilot Implementation	Limited Trial Implementation with Senior High School Students to Evaluate Feasibility and User Responses
2029	Evaluation & Refinement	Evaluation of Effectiveness on Motivation, Monitoring, Reflection, and Learning Strategies, as well as Model Revision
2030	Sustainability & Scaling-Up	Integration of the SMART Strategy into Regular Learning and Expansion of Implementation to More Schools

Based on the synthesis of the reviewed studies, the AI-Based SMART Strategy demonstrates potential as a learning framework that integrates goal setting, learning progress monitoring, AI-based adaptive scaffolding, reflection, and learning strategy transformation into a comprehensive self-regulated learning cycle. This integration enables students to receive more personalized learning support, make independent learning decisions, and adjust their learning strategies based on evidence from their own learning progress. Consequently, by promoting inclusive, adaptive, and learner-centered learning that strengthens students' capacity for independent learning, the development of the AI-Based SMART Strategy contributes to the achievement of Sustainable Development Goal (SDG) 4, particularly by supporting efforts to improve the quality of education and expand access to effective and sustainable learning opportunities for all learners.

CONCLUSIONS

This study examines the use of AI to support SRL among senior high school students through the synthesis of empirical studies. Using a systematic literature review approach, this study identifies the forms of AI support for SRL, analyzes the SRL components that have been facilitated by AI, and establishes the conceptual foundation for developing the AI-Based SMART Strategy. The findings indicate that AI has been used to support learning goal setting, learning progress monitoring, adaptive scaffolding, self-reflection, and learning strategy adjustment, although most existing studies have addressed these components separately. Based on these findings, this study proposes the SMART Strategy, which consists of Set Learning Goals, Monitor Learning Progress, AI-Guided Scaffolding, Reflect on Learning, and Transform Learning Strategies, as a conceptual learning framework that follows a cyclical and adaptive process. Theoretically, this study contributes by integrating AI support across all stages of SRL, positioning AI not only as a source of information but also as a

facilitator that helps students independently plan, monitor, reflect on, and adjust their learning processes. The findings further suggest that meaningful AI-supported learning depends not only on the availability of technology but also on students' active engagement, appropriate instructional support, and the continuity of self-regulated learning throughout the learning process.

Despite these contributions, this study has several limitations. First, this study is based on a literature review and therefore does not provide direct empirical evidence regarding the effectiveness of the AI-Based SMART Strategy in authentic learning contexts. Second, the number of studies that met the selection criteria was relatively limited; therefore, the findings should be generalized with caution. Third, variations in learning contexts, educational levels, and the types of AI technologies used across the reviewed studies may have influenced the consistency of the synthesized findings. Accordingly, future research is recommended to conduct expert validation of the SMART Strategy components and examine the implementation of the strategy through longitudinal studies, experimental research, or design-based research across diverse school settings and student populations. Such efforts would provide a deeper understanding of how self-regulated learning can be developed within AI-supported learning environments.

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