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The Impact of AI-Driven Real-Time Feedback Systems on Students' Self-Regulated Learning and Academic Persistence in Secondary Schools, Nigeria

NUHU, Kehinde Muritala[1,*], MAKPA, Danjuma Anji-Hassan[2], OGUNLADE Janet Bamidele[3], ADEIYZA Anayimi Justina[4], DAUDA Usman[5], IBRAHEEM Sarafadeen Arisekola[6]

Abstract

Self-regulated learning (SRL) is essential for secondary school students to achieve academic success and lifelong learning competencies, particularly in contexts requiring greater learner autonomy. This expository article examines the potential of Artificial Intelligence (AI)-driven real-time feedback systems to support SRL processes—planning (forethought), monitoring (performance/control), and reflection—within Nigerian secondary education. Grounded in Zimmerman's cyclical SRL model and Bandura's Social Cognitive Theory, the paper conceptualises AI tools (e.g., intelligent tutoring systems, learning analytics dashboards, chatbots, and adaptive feedback platforms) as environmental scaffolds that enhance metacognition, motivation, self-efficacy, and behavioural regulation. Drawing on global and emerging empirical evidence, AI facilitates personalised, timely feedback that targets process- and self-regulation levels, promoting deeper engagement, strategy adaptation, and persistence. However, implementation in Nigeria faces significant challenges, including infrastructural deficits (e.g., unreliable internet and power), limited digital literacy, teacher readiness, unequal access, and ethical concerns such as data privacy, bias, and over-reliance, leading to diminished learner agency. The conceptual framework positions AI as a mediator of SRL dimensions while moderated by contextual and ethical factors. Empirical reviews indicate positive associations between AI-supported feedback and improved SRL behaviours, though longitudinal studies in developing contexts remain scarce. The article underscores the need for balanced, human-centred integration to foster genuine autonomy rather than dependency. It concludes with practical recommendations for policymakers, educators, and developers to advance equitable AI adoption in resource-constrained secondary settings.

Keywords: AI-driven feedback, self-regulated learning, academic persistence, generative AI, secondary education, Nigeria

***Author for Correspondence**
NUHU, Kehinde Muritala
E-mail: nuhu.km@unilorin.edu.ng

Lecturer, Department of Educational Technology, Faculty of Education, University of Ilorin, Nigeria
Student, Department of Social Studies, Faculty of Education, University of Ilorin, Nigeria

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INTRODUCTION

The transition into secondary education represents a critical phase in students' academic development, during which the ability to take responsibility for one's thoughts and actions becomes essential for realising individual potential and achieving academic success (Latipah et al., 2021) [1]. At this stage, competencies such as planning learning activities, collaborating with peers, and communicating ideas through both physical and digital media significantly enhance academic achievement (Tadesse et al., 2022) [2]. These competencies are foundational to self-regulated learning (SRL), a process through which learners set goals, monitor their progress, and evaluate their outcomes.

The development of SRL skills particularly planning, monitoring, and reflection is increasingly recognised as essential in secondary education contexts, where students are expected to engage in more independent learning with limited direct guidance (Zimmerman, 2000) [3]. Empirical evidence consistently shows that SRL enhances problem-solving abilities, academic achievement, intrinsic motivation, and task interest (Cleary & Zimmerman, 2004; Perry & Vandekamp, 2000; Pintrich, 2000; Zimmerman, 2002) [4, 5, 6, 7]. Beyond academic outcomes, SRL contributes to broader developmental benefits, including positive future orientation, effective social behaviour management, and the cultivation of lifelong learning competencies (Bandura, 2006) [8]. These skills are also critical for navigating future challenges such as increasing labour market competitiveness (Latipah et al., 2021; Muwonge et al., 2020; Nguyen & Zarra-Nezhad, 2023) [1, 9, 10]. Despite its importance, many learners struggle to effectively regulate their learning, often underutilizing SRL strategies (Greene & Azevedo, 2010; Jansen et al., 2020; Winne & Baker, 2013) [11, 12, 13]. This highlights the need for structured and scalable support systems to enhance SRL in secondary education. One promising approach is the integration of artificial intelligence (AI) into learning environments.

AI offers significant potential to address these challenges by providing timely, task-specific, and individualised feedback that supports self-directed learning. By analysing learners' engagement and performance data, AI-driven systems can generate real-time prompts that scaffold key SRL processes, including planning, monitoring, and reflection (Cavalcanti et al., 2021; Lim et al., 2023) [14, 15]. Unlike traditional feedback, which often focuses on correctness, AI-enabled feedback can target deeper cognitive and metacognitive processes. Furthermore, such systems provide consistent, scalable, and adaptive support without requiring continuous human intervention (Mejeh, Sarbach, & Hascher, 2024) [16].

The application of AI in supporting SRL is typically guided by two core functions: (1) assessing and interpreting learners' SRL behaviours in digital environments, and (2) providing scaffolded support to enhance these processes (Roll & Winne, 2015) [17]. Various AI-powered tools—such as planning assistants, intelligent tutoring systems and pedagogical agents (Goel & Polepeddi, 2016) [18]—have been developed to facilitate SRL. Evidence suggests that these technologies can improve student performance, engagement, and interest, particularly in STEAM disciplines (Salas-Pilco et al., 2022) [19]. For instance, adaptive learning systems and learning analytics platforms could provide real-time feedback and personalised learning pathways that promote deeper understanding and knowledge retention.

Feedback, more broadly, remains a critical determinant of knowledge acquisition and skill development. When delivered at the point of need, it enhances both the effectiveness and efficiency of learning. High-quality feedback supports self-regulation, improves learning outcomes, and fosters academic persistence (Hattie & Timperley, 2007) [20]. However, delivering timely and individualized feedback particularly for open-ended or constructed-response tasks—continues to pose a challenge in traditional classroom settings.

Recent advancements in automated scoring technologies, including natural language processing and machine learning, are helping to address this limitation by enabling immediate feedback on students' written work (Dzikovska et al., 2013) [21]. In digital learning environments, feedback serves cognitive, metacognitive, and motivational functions (Panadero & Lipnevich, 2022) [22]. AI-driven systems can now generate continuous, real-time feedback that helps learners identify misconceptions, regulate their learning, and sustain motivation (Cavalcanti et al., 2021; Wisniewski et al., 2020) [15, 23]. The effectiveness of such feedback, however, depends on its design, timing, and alignment with learner needs (Shute, 2008) [24]. These benefits are further amplified in computer-based environments, where feedback can be personalised and delivered at scale (Azevedo & Bernard, 1995) [25].

Among AI innovations, conversational agents such as chatbots offer particularly promising opportunities for supporting SRL. Chatbots function as virtual learning companions capable of

providing on-demand, personalised academic support. By interacting with learners in real time, they can facilitate key SRL processes, including goal setting, self-monitoring, and reflection. SRL strategies—defined as deliberate actions used to plan, regulate, and evaluate learning are grounded in cognitive and metacognitive processes. While traditional strategies such as note-taking, rehearsal, and mnemonic techniques remain valuable, they often lack the adaptability and personalisation enabled by digital technologies.

The integration of AI into SRL practices, therefore, represents a significant shift from traditional approaches. It enables personalised learning experiences, enhances conceptual understanding, strengthens problem-solving skills, and increases learner engagement. By embedding intelligent feedback mechanisms into learning environments, AI systems can help address persistent educational challenges such as underachievement, low engagement, and high attrition rates. In contemporary education systems where knowledge is abundant and instructors increasingly act as facilitators—learners must develop the capacity to manage their own learning. Accordingly, self-regulation is critical for academic success and persistence, particularly in online and hybrid learning contexts.

However, fostering SRL remains challenging, particularly in contexts characterised by rote learning, teacher dependency, and limited emphasis on metacognitive instruction. This is especially evident in secondary education in Nigeria, where traditional lecture-based approaches often restrict learner autonomy and strategic thinking. In such contexts, AI has the potential to enhance SRL by providing timely feedback, supporting reflective thinking, scaffolding goal setting, and simulating tutor–learner interactions. AI tools can analyse students' learning behaviours and recommend personalised strategies, thereby supporting more effective academic self-management. Furthermore, emerging technologies such as AI and 5G have the potential to democratise access to quality education by enabling personalised learning regardless of geographical or socioeconomic constraints.

Despite growing research on SRL and formative feedback, several important gaps remain. Many studies examine these constructs in isolation, with limited attention to how AI-driven real-time feedback simultaneously influences SRL processes within integrated learning environments. There is also insufficient longitudinal evidence on how such feedback supports the sustained development of planning, monitoring, and reflection. Moreover, although AI applications in education are expanding globally, their implementation in secondary education contexts within developing countries, including Nigeria, remains underexplored. This gap is particularly significant given challenges related to limited access to personalised feedback, variability in instructional quality, and infrastructural constraints.

Against this backdrop, there is a need for a comprehensive and context-sensitive examination of how AI-driven real-time feedback systems can support self-regulated learning and enhance academic persistence. Accordingly, this paper adopts an expository approach to examine how such systems influence students' ability to plan, monitor, and reflect on their learning within Nigerian secondary schools. It further explores underlying mechanisms, reviews relevant empirical evidence, highlights context-specific applications and challenges, and offers practical recommendations for effective implementation.

OBJECTIVES OF THE STUDY

This expository article aims to examine the potential of Artificial Intelligence (AI)-driven real-time feedback systems in supporting students' self-regulated learning (SRL) and academic persistence within Nigerian secondary school contexts. Specifically, the study pursues the following objectives:

1. To examine how AI-driven real-time feedback systems can scaffold the core phases of self-regulated learning—planning (forethought), monitoring (performance/control), and reflection—among secondary school students in Nigeria.
2. To explore the mechanisms through which AI-powered tools, such as intelligent tutoring systems, learning analytics dashboards, adaptive learning platforms, and conversational agents (chatbots), enhance students' metacognition, motivation, self-efficacy, and behavioural regulation.

3. To analyse the influence of AI-supported real-time feedback on students' academic persistence, engagement, strategy adaptation, and overall learning outcomes in Nigerian secondary education.
4. To identify the major contextual challenges and opportunities for implementing AI-driven feedback systems in Nigerian secondary schools, including infrastructural limitations, digital literacy gaps, teacher readiness, equitable access, and ethical concerns such as data privacy and algorithmic bias.
5. To develop a conceptual framework that positions AI tools as mediators of SRL processes while accounting for key moderating factors specific to the Nigerian secondary education environment.
6. To offer practical, context-sensitive recommendations for policymakers, school administrators, teachers, and technology developers on the effective, equitable, and human-centred integration of AI-driven real-time feedback systems that promote genuine learner autonomy rather than over-dependence.

By achieving these objectives, the paper seeks to bridge the gap between global advancements in AI-enhanced learning and the unique realities of secondary education in Nigeria, contributing to more autonomous, motivated, and persistent learners in resource-constrained settings.

Conceptual Framework

The conceptual framework for this study illustrates the dynamic relationship between Artificial Intelligence (AI) tools and the core dimensions of Self-Regulated Learning (SRL)—planning, monitoring, and reflection—within the context of Nigerian higher education. Grounded in Barry J. Zimmerman's Self-Regulated Learning theory and Albert Bandura's Social Cognitive Theory, the framework conceptualises learning as both a self-driven and socially influenced process, shaped by the interaction of cognitive, behavioural, and environmental factors.

As depicted in Figure 1, AI tools function as critical environmental supports that enhance the three cyclical phases of SRL. Specifically, intelligent tutoring systems facilitate the planning phase by guiding goal setting and strategy selection; learning analytics dashboards and chatbots support the monitoring phase by enabling learners to track their progress and adjust their strategies in real time; while feedback systems and analytics tools strengthen the reflection phase by providing actionable insights that help learners evaluate their performance and refine future learning approaches. Through these mechanisms, AI tools operationalize key principles of SRL by scaffolding learners' metacognitive processes and promoting active engagement in learning.

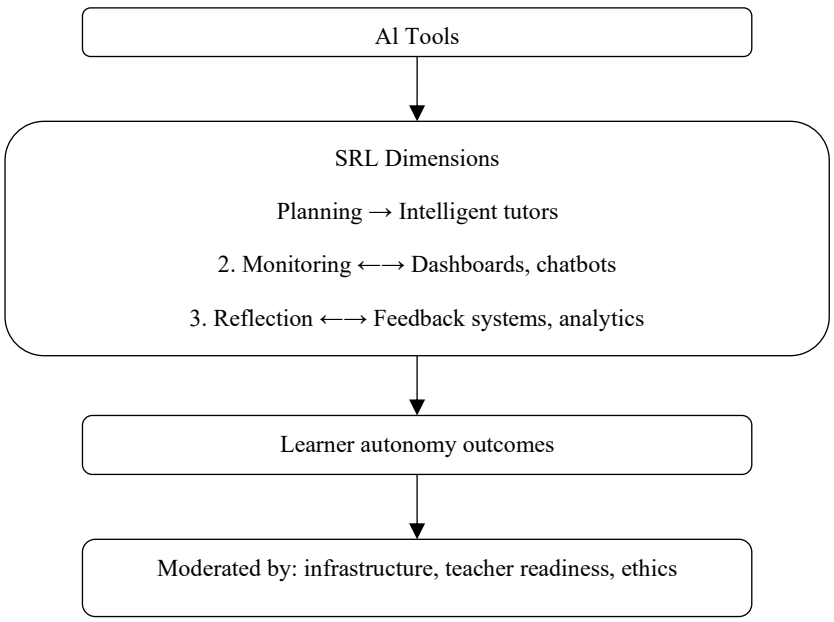

Figure 1. AI-SRL-LR model
Source: Omoyajowo, Bambi, Femi, & Ayeni (2025)

Consistent with Bandura's Social Cognitive Theory, these AI-driven interventions also influence learners' motivation and self-efficacy by providing continuous feedback, modelling effective learning strategies, and reducing uncertainty during task engagement. This reciprocal interaction between the learner and the AI-supported environment fosters persistence, strategic behaviour, and increased confidence in learning tasks. Consequently, the integration of AI within SRL processes leads to enhanced learner autonomy outcomes, characterized by improved self-direction, independent problem-solving, and sustained academic engagement.

However, the effectiveness of this relationship is moderated by contextual factors, including infrastructural capacity, teacher readiness, and ethical considerations. In the Nigerian higher education context, persistent challenges such as limited teacher-student interaction, inadequate digital infrastructure, and unequal access to technological resources may constrain the optimal use of AI tools (Petrie C et al, 2020) [26]. Furthermore, the deployment of AI in education must be guided by ethical standards and pedagogical alignment to ensure responsible use, data privacy, and meaningful learning experiences (Nguyen et al.,2022; Jin et al, 2023; Hooda et al, 2022) [27,28, 29].

Accordingly, this framework positions AI tools as both enablers and mediators of self-regulated learning, highlighting their role in strengthening learners' planning, monitoring, and reflection processes while emphasizing the importance of contextual and ethical factors in shaping educational outcomes. The framework presented in Figure 1, therefore, provides a structured lens for examining how AI-driven interventions can enhance learner autonomy and academic success in Nigerian higher education.

Theoretical Framework

This study is grounded in Barry J. Zimmerman's Self-Regulated Learning (SRL) model and Albert Bandura's Social Cognitive Theory (SCT), which together provide a comprehensive explanation of how learners regulate their cognition, motivation, and behavior within technology-enhanced learning environments.

Zimmerman's SRL model posits that effective learning occurs through a cyclical process of forethought, performance, and self-reflection, wherein learners actively set goals, monitor their progress, and evaluate learning outcomes (Zimmerman, 2000; Zimmerman, 2002) [3,7]. Building on earlier conceptualizations, self-regulated learners are characterized by their proactive engagement in selecting strategies, tracking their performance, and reflecting on outcomes to improve future learning. Within secondary and higher education, the increasing expectation for independent learning introduces substantial cognitive and metacognitive demands. When learners lack essential regulatory skills such as planning, monitoring, and reflective evaluation this imbalance often results in disengagement, reduced academic persistence, and suboptimal learning outcomes. Furthermore, self-regulated learning is not an innate ability but a developmental process that can be cultivated through structured support and targeted interventions, particularly in contexts where learner autonomy is critical.

Thus, self-regulated learning extends beyond a mere study skill; it represents a complex and active process requiring sustained cognitive effort, strategic action, and motivational control. These processes are further illuminated by Bandura's Social Cognitive Theory, which emphasizes the reciprocal interaction among personal factors (e.g., self-efficacy and beliefs), behavioral patterns (e.g., strategy use and persistence), and environmental influences (e.g., feedback and instructional support). Central to SCT is the concept of reciprocal determinism, as well as observational learning, where individuals acquire knowledge and skills through modelling others' behaviors. A key tenet of the theory is that learners' beliefs about their capabilities significantly shape their level of engagement, effort, and resilience when confronted with academic challenges.

In technology-mediated learning environments, AI-driven real-time feedback systems emerge as a critical environmental resource capable of addressing the demands of self-regulated learning. By

delivering immediate, personalized, and adaptive feedback, these systems support learners in goal setting, progress monitoring, and performance reflection. Additionally, AI tools—such as intelligent tutoring systems, adaptive feedback platforms, and virtual tutors—can model effective problem-solving strategies, simulate aspects of social interaction, and provide motivational scaffolding, thereby aligning Bandura's emphasis on observational learning and environmental support. Such feedback mechanisms not only scaffold SRL processes but also enhance self-efficacy by providing timely evidence of progress and reducing uncertainty during task engagement, particularly in resource-constrained educational contexts.

Accordingly, this study adopts an integrated SRL–SCT perspective to examine how AI-driven real-time feedback functions as an external regulatory support that strengthens learners' capacity to plan, monitor, and reflect, while simultaneously shaping their motivation, self-efficacy, and persistence. From this perspective, AI-enabled feedback is conceptualized as both a cognitive scaffold and an environmental resource that promotes effective self-regulation, learner autonomy, and sustained academic engagement in secondary education contexts.

Empirical Review

Self-regulated learning (SRL) refers to the extent to which learners actively manage their own learning processes through goal setting, strategy selection, self-monitoring, and reflection. It is widely conceptualised as a cyclical process involving cognitive, metacognitive, motivational, and behavioural components. Within contemporary educational contexts, particularly technology-enhanced environments, SRL has gained increasing attention as a critical determinant of student success.

Recent empirical studies highlight the role of Artificial Intelligence (AI) in supporting SRL processes. For instance, Chardonnens (2025) [30] emphasises the integration of metacognitive strategies into technology-enhanced learning environments, arguing that AI-powered tools can facilitate SRL by providing real-time feedback, recommending learning strategies, and enabling learners to visualise their progress. This perspective is supported by Khan et al, (2026) [31], whose quantitative study examined the impact of AI-based personalised learning on students' motivation and SRL in higher education. Their findings revealed a significant positive relationship between AI-driven personalised learning, student motivation, and SRL, suggesting that adaptive AI systems enhance learner engagement, autonomy, and strategic learning behaviours. However, the study also identified challenges such as digital literacy gaps, ethical concerns, and issues of equitable access, indicating that the benefits of AI are contingent on thoughtful and inclusive implementation.

Similarly, Faraz, Bushra, Zarina, and Asia (2025) [32] investigated the relationship between AI educational technologies, SRL, and academic performance using a quantitative approach. Their correlation analysis showed a strong positive association between AI use and SRL, while regression results indicated that SRL significantly predicts academic achievement. The study further demonstrated that increased engagement with AI tools improves learners' abilities in planning, monitoring, and reflective practices. Nonetheless, concerns were raised about over-reliance on AI systems, emphasising the need for learners to develop autonomy and self-pacing skills to avoid dependency. These findings reinforce the complementary relationship between AI and SRL in fostering continuous learning and improved academic outcomes.

At a broader level, Lan and Zhou (2025) [33], through a systematic review guided by PRISMA protocols, synthesised empirical studies on AI-enabled SRL in higher education. Their findings reveal that AI can effectively support the forethought, performance, and reflection phases of SRL. However, they also highlight a critical tension between human-centred and AI-centred regulation, which may influence the nature and effectiveness of SRL processes. The review underscores the importance of balancing technological support with the preservation of learner agency and self-efficacy, and calls for further research to optimise this integration. Empirical evidence also points to the importance of AI-

driven feedback systems in enhancing SRL. Rakhmetov et al. (2025) [34] evaluated an AI-based feedback system and found that students who received adaptive feedback demonstrated significantly stronger SRL behaviours, including earlier task initiation, greater use of supplementary learning resources, and more consistent study routines. Their findings suggest that even lightweight AI-driven feedback mechanisms can be effectively integrated into digital learning environments to support SRL at scale and improve academic engagement.

In the context of online learning, Jin et al. (2023) [28] examined students' perceptions of AI applications for supporting SRL. The results indicated that learners perceived AI tools as effective in supporting cognitive, metacognitive, and behavioural regulation, although they were less effective in addressing motivational aspects of SRL. The study further highlighted the need to consider key pedagogical and psychological factors—such as learner identity, activeness, and positionality—in the design of AI-supported learning systems. Complementing these findings, Huang, Stephens and Brown (2025) [35] conducted a systematic review of technology-enhanced feedback systems and concluded that feedback remains a central component of SRL and learning. Their review shows that AI and other technologies enhance feedback processes by enabling real-time, multimodal, and multi-source feedback. Additionally, such systems support self-assessment and help learners interpret and utilise feedback more effectively. However, the authors emphasize the need for greater attention to how students engage with and apply feedback in practice.

Importantly, Nigeria-specific evidence on the integration of AI and SRL is still emerging but highly promising. Preliminary studies within the Nigerian higher education context suggest growing adoption of technology-enhanced learning tools, particularly in response to large class sizes, limited instructional resources, and increasing demand for personalised learning. While direct large-scale empirical studies remain limited, existing evidence indicates that AI-supported feedback and learning systems have the potential to improve students' self-regulatory skills, engagement, and academic outcomes. However, contextual challenges such as infrastructural deficits, digital literacy gaps, and unequal access to technology remain critical factors that may influence the effectiveness and scalability of these innovations.

Overall, the empirical literature demonstrates a consistent positive relationship between AI applications, feedback mechanisms, and the development of SRL. AI technologies, particularly those offering personalised learning and adaptive feedback, have significant potential to enhance learners' autonomy, engagement, and academic performance. Nevertheless, recurring concerns regarding equity, ethical use, digital literacy, and learner dependency highlight the importance of careful and context-sensitive implementation. These insights suggest that while AI can serve as a powerful enabler of SRL, its effectiveness ultimately depends on maintaining a balance between technological support and the development of independent learning competencies.

Artificial Intelligence and Self-Regulated Learning

Self-regulated learning is particularly valuable for students as it allows them to organize their study activities, self-monitor their progress, and adapt their learning for better outcomes. Most scholars agree that self-regulated students are high achievers whose effectiveness arises from self-imposed goals, controlled study schedules, and continuous self-evaluation. While self-regulation strategies are highly effective, not all learners develop them spontaneously, which has fostered interest in exploring the support that Artificial Intelligence can provide. Adaptive learning tools, educational chatbots, and intelligent tutoring systems are AI applications designed to help students through various SRL phases. As students learn, these systems evaluate performance, identify gaps, and suggest ways to bridge them. For instance, when students work on a challenging topic, AI can offer hints and scaffolding that sustain motivation and engagement. Evidence also shows that AI is particularly effective in assisting with the planning and monitoring phases but rarely supports goal-setting and reflection, essential components of autonomous learning (Laak & Aru, 2025) [36].

The ability of Artificial Intelligence to provide personalized support is one of its greatest contributions to self-regulated learning. Personalization—and the learning paths that come with it helps students remain motivated because the material is relevant to their needs. For instance, adaptive learning systems that prompt students to reflect and revise after making mistakes encourage deeper engagement. These systems help students become active participants in their learning and strengthen their self-management and monitoring skills (Holmes & Littlejohn, 2024) [37]. Similarly, AI-driven chatbots and intelligent tutoring systems can send plan reminders, encourage active self-monitoring, and promote the practice of self-regulation. Yet, the literature clearly warns of potential risks. Excessive dependence on AI for prompts that support self-monitoring and regulation may lead to learned passivity. Over-reliance on AI can diminish genuine self-regulation, limiting learners' ability to direct their own study (Lee, Hwang,& Chen, 2025) [38]. Technology-based interactive guidance to promote learning performance and self-regulation: a chatbot-assisted self-regulated learning approach. This shows that Artificial Intelligence is most effective when it acts as a facilitator, while the student remains responsible for regulating learning.

Artificial Intelligence has the capability to enhance self-regulated learning; however, several risks and challenges remain. One risk is that students might lose the ability to work independently. With increasing automation, students may skip critical steps of goal-setting, planning, and reflection as they accept automated recommendations that dictate their learning process. There is also the issue of inequity and access. In contexts where schools and students are poorly resourced, advanced technologies remain limited, creating disproportionate barriers to using AI-based SRL tools (Billman, 2024) [39]. Ethical risks surrounding AI use—such as fairness, privacy, and data security—are equally concerning because AI relies on sensitive learner data. Researchers further highlight the lack of long-term studies on AI's impact on SRL to determine whether benefits are sustained and whether students can transfer these skills to new contexts (Wu et al., 2023) [40]. Concerns like these must be dealt with in design and implementation that deliberately and equitably integrate and transparently use AI.

Self-Regulated Learning and Ai Tools

Self-regulated learning (SRL) reflects a learner's capacity to plan, monitor, and evaluate their learning strategies, encompassing both cognitive and metacognitive skills. SRL can be actively supported through AI-based personalised learning environments, which provide scaffolds such as goal-setting tools, progress dashboards, and timely prompts. These features facilitate reflection, strategy adjustment, and more effective learning management. For example, learning analytics can notify students when they are falling behind or suggest alternative approaches for mastering material, thereby increasing awareness of individual learning patterns. Research indicates that students using AI-based systems demonstrate improvements in goal-setting, time management, and strategic thinking compared with peers in traditional classroom settings (Achuthan, 2025) [41].

Several AI applications have been developed to enhance SRL across different domains. Somasundaram et al. (2020) [42] created an AI-based plan organiser that helps students set learning goals, propose action plans, and provide study tips based on historical institutional data and current student performance. Craig and Schroeder (2017) [43] introduced a virtual human with multiple voice options, demonstrating positive effects on learning outcomes and cognitive load. Luckin (2017) [44] proposed an intelligent assessment system capable of recommending study materials and strategies based on each student's online interactions. Further examples include Seo et al. (2021) [45], who developed an AI analytics tool providing instructors with analyses of students' behavioural data (e.g., clickstream, quiz attempts, login/logout patterns, and eye-tracking) within specific learning contexts (e.g., course week, exams, or video rewatch). Woolf et al. (2010) [46] designed an AI companion that boosts motivation by offering emotional support to students progressing more slowly than planned and recommending achievable goals aligned with their career aspirations. Goel and Polepeddi (2018) [18] created an AI agent capable of answering student questions before, during, or after online courses, drawing on previous course data. Srinivasa et al. (2021) [47] developed Notelink, an application

allowing students to photograph notes and retrieve relevant instructional videos on their devices. Taylor et al. (2025) [48] implemented an adaptive quiz system where AI generates personalised exercises tailored to individual knowledge levels. Conati et al. (2021) [49] emphasised the importance of interpretable machine learning to enable AI to support students' self-reflection over extended periods.

Despite the proliferation of AI tools for SRL, their effects in online learning environments remain unclear. Seo et al. (2021) [45] found that while students generally perceive AI applications as useful, they may also feel dissatisfied due to concerns that reliance on AI could reduce creativity. Students have expressed apprehensions regarding responsibility, agency, and surveillance issues associated with AI in online learning. Understanding learners' perceptions of AI-supported SRL is therefore critical. Such insights can guide the design of AI applications that effectively support SRL while respecting social and ethical boundaries within online learning contexts (Luria et al., 2020) [50].

CONCLUSION

This expository exploration highlights the transformative potential of AI-driven real-time feedback systems in cultivating self-regulated learning (SRL) among secondary school students, particularly in Nigeria, where traditional pedagogical approaches often limit learner autonomy and metacognitive development. Anchored in Zimmerman's cyclical model and Bandura's Social Cognitive Theory, the discussion demonstrates how AI tools—ranging from intelligent tutors and analytics dashboards to conversational agents—can scaffold the core SRL phases of planning, monitoring, and reflection. These technologies provide personalized, adaptive support that addresses gaps in timely feedback, fosters self-efficacy through mastery experiences, and promotes motivational regulation in increasingly independent learning environments.

Empirical evidence from global and emerging studies consistently shows positive links between AI interventions and enhanced SRL outcomes, including improved goal setting, progress tracking, strategic adjustment, reflective evaluation, engagement, and academic persistence. In Nigerian secondary education, where challenges such as large class sizes, limited teacher-student interaction, rote learning dominance, and infrastructural constraints prevail, AI offers a scalable means to democratize access to individualised guidance and bridge resource disparities.

Nevertheless, the integration is not without risks. Over-reliance on AI may erode independent self-regulation, while inequities in access, ethical issues (e.g., privacy and bias), and insufficient teacher preparation could exacerbate divides rather than mitigate them. The conceptual framework emphasises that AI's effectiveness as an environmental mediator depends on contextual moderators and ethical safeguards, ensuring it complements rather than supplants human agency.

Ultimately, AI-driven feedback represents a promising pathway toward more autonomous, motivated, and effective learners in Nigerian secondary schools. By thoughtfully addressing barriers and prioritizing learner-centered design, AI can contribute to broader educational equity, resilience, and preparation for future challenges in a knowledge-driven world.

Recommendations

To maximize the benefits of AI-driven real-time feedback for SRL in Nigerian secondary education while mitigating risks, the following context-sensitive recommendations are proposed:

1. Government and educational authorities should prioritize investments in reliable digital infrastructure (e.g., affordable internet, power backups, and device access) in secondary schools, particularly in underserved rural and peri-urban areas. Policies mandating ethical AI guidelines—aligned with frameworks like those from Nguyen et al. (2022)—should address data privacy, bias mitigation, and equitable deployment to prevent widening the digital divide.
2. Integrate mandatory training programs on AI literacy, SRL scaffolding, and hybrid human-AI pedagogy into teacher professional development. This should equip educators to interpret AI-

generated insights, facilitate reflective discussions, and guide students in using tools without over-dependence, fostering complementary roles where teachers focus on motivation and socio-emotional support.

3. Developers and educators should prioritize open-source or low-cost, mobile-compatible AI tools (e.g., chatbots via SMS/WhatsApp integration) that emphasize process-oriented feedback over mere correctness. Designs must incorporate features promoting learner agency, such as optional prompts, explainable outputs, and gradual fading of scaffolds to encourage independent regulation.
4. Initiate localized pilot interventions in diverse Nigerian secondary contexts (urban/rural, public/private) to generate longitudinal evidence on AI's sustained impact on SRL and academic outcomes. Collaborate with researchers to evaluate not only performance gains but also risks like reduced creativity or dependency, informing iterative improvements.
5. Embed student and parental consent mechanisms, transparent AI usage policies, and monitoring for equity in all implementations. Promote hybrid models where AI supports SRL in resource-limited settings while preserving human interaction to build trust, self-efficacy, and transferable skills.

These steps, if pursued collaboratively, can position AI as a powerful enabler of SRL, ultimately advancing academic equity and preparing Nigerian secondary students for lifelong, self-directed learning.

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