HNUE JOURNAL OF SCIENCE
Educational Sciences 2025, Volume 70, Issue 7, pp. 155-168
This paper is available online at http://hnuejs.edu.vn/es
DOI: 10.18173/2354-1075.2025-0139

DESIGN AND IMPLEMENTATION OF AN AI TEACHING ASSISTANT FOR ENHANCING STUDENTS' SELF-STUDY IN 1OTH GRADE BIOLOGY

Truong Thuy Phuong[1], Phan Thi Thanh Hoi[2,*] and Le Minh Thu[1]
[1]*Student of the Faculty of Biology, Hanoi National University of Education, Hanoi city, Vietnam*
[2]*Faculty of Biology, Hanoi National University of Education, Hanoi, Vietnam*
*Corresponding author: Phan Thi Thanh Hoi, e-mail: hoiptt@hnue.edu.vn

Received: December 12, 2025; Revised: December 24, 2025; Accepted: December 31, 2025.

Abstract. While AI applications in education are expanding, a baseline survey revealed that 60% of students (N = 184) expressed concerns that AI might impair their critical thinking. To address this, a six-component self-directed learning (SDL) competency model was employed to evaluate students' SDL competence before and after learning with the AI teaching assistant (N = 223), with the most notable gains observed in "Inquiry and Questioning skills" ($\Delta M = 0.57$) and "Strategic Study Plan" ($\Delta M = 0.38$). Additionally, a customized AI teaching assistant for Grade 10 Biology was developed through a systematic five-step process to ensure strict alignment with the curriculum and academic accuracy. The tool was implemented in a high school setting utilizing the Human-AI-Human model combined with the Gradual Release of Responsibility (GRR) framework, transitioning students from teacher-led instruction to independent mastery. The pedagogical experiment results indicated significant improvements across all six SDL components, with the experimental class achieving a substantially higher midterm mean score (7.84) compared to the control class (6.97) with a large effect size ($d = 0.86$). These results reveal that a customized AI teaching assistant, especially when integrated within a structured pedagogical framework, acts as an effective learning scaffold that supports both SDL competence and academic performance.

Keywords: self-directed learning (SDL), Artificial intelligence in education (AIEd), AI teaching assistant**,** Biology education, secondary education.

1. Introduction

The rapid advancement of artificial intelligence (AI) is reshaping educational systems worldwide. As outlined in Decision No. 131/QĐ-TTG, the Vietnamese government's scheme for "Strengthening the application of information technology and digital transformation in education and training for the period of 2022-2025, with a vision towards 2030," establishes that "learners and teachers are the epicenter of the digital transformation process" [1]. In this context, the core value of education lies in the balance between equipping learners with essential knowledge and fostering cognitive capacities, particularly self-directed learning (SDL) competence, to facilitate lifelong learning and adaptation to an ever-changing world [2].

A growing body of international research has highlighted the potential of AI chatbots to enhance learning motivation, offer personalized feedback, and support academic tasks across various disciplines. Studies utilizing general generative AI systems such as ChatGPT or Gemini have demonstrated their value in improving learning efficiency and supporting problem-solving [3], [4]. Parallel to this trend, research on custom-built educational chatbots has emerged to support subject-specific learning, affirming the role of teachers in mastering technology and executing targeted pedagogical functions [5]-[7].

Nevertheless, alongside these benefits, AI tools pose significant risks and challenges, including the potential attrition of higher-order thinking skills and cognitive over-reliance, which may hinder students' competence in critical thinking development [3], [4]. These concerns underscore the urgency of integrating AI strategically to avoid diminishing intellectual autonomy and emphasize the need for pedagogically oriented models that mitigate such drawbacks.

While a subset of studies investigates the role of AI chatbots in fostering SDL, notably theoretical frameworks presented by Chang & et al. and Giam & et al. (2023), empirical classroom-based evidence remains limited [8], [9]. Addressing these gaps, the present study designs and applies a custom-built AI teaching assistant for Grade 10 Biology, aiming to support students' self-study activities and improve learning outcomes through structured, teacher-mediated AI integration.

Unlike previous works, this research introduces a tailored SDL competency framework specifically optimized for an AI-supported Biology learning environment and demonstrates teacher-mediated synergies where AI guidance is complemented by teacher supervision. Additionally, the study deploys a chatbot trained exclusively on the official Grade 10 Biology textbook, directly responding to concerns about misinformation and academic integrity. By applying AI in a pedagogically appropriate manner, this approach not only minimizes risks but also enhances SDL capabilities, contributing to sustainable educational innovation and empowering students for lifelong learning [6]-[8].

2. Content

2.1. Research methodology

Theoretical research method: A systematic literature review was conducted to synthesize existing research and theoretical frameworks regarding: (i) AI-powered chatbot applications in educational settings, (ii) students' self-directed learning (SDL) competence, and (iii) the structural components of SDL competence when interacting with AI-driven pedagogical tools.

Practical research method: A quantitative approach was employed, utilizing structured questionnaires to evaluate students' perspectives on AI-powered chatbot applications in Biology education. The survey specifically investigated how customized AI teaching assistants support SDL competence among Grade 10 students. Sample duration: The study surveyed 223 Grade 10 students across various high schools in Hanoi and Dong Gia High School (Hai Phong city) between June 2025 and November 2025; *Instrument:* Data were collected via an online questionnaire (*Google Forms*) featuring five-point Likert-scale items. The survey was distributed through professional teacher networks on *Zalo* and *Facebook*. Content and metric*:* This instrument comprised two primary sections: (1) Perceived effectiveness and associated risks, along with students' needs and expectations; and (2) an assessment of AI support across six core-sub skills of SDL competence.

Pedagogical experiment method: A quasi-experimental study was conducted to evaluate the impact of a customized AI teaching on the SDL competence and Biology learning outcomes of Grade 10 students. Two intact classes (n=84), instructed by the same teacher to minimize pedagogical variance, were selected for the study. One class was designated as the experimental group, utilizing the AI assistant, while the other served as the control group, following conventional institutional methods. A pre-test confirmed that the initial academic levels and SDL profiles of both groups were comparable.

Experimental instruments: SDL assessment*:* A 13-item, using a 5-point Likert-scale questionnaire was administered before and after the intervention to measure changes in students' self-directed learning competence; Learning outcomes: Student achievement was evaluated through the school's standardized midterm examination. To ensure objectivity and eliminate bias, the tests were graded anonymously by an exam committee.

Experimental duration and scope: The pedagogical experiment was conducted during the first term of the 2025 - 2026 academic year (from September to November 2025) at Dong Gia High School, Hai Phong City. The intervention focused on four core Grade 10 Biology topics: Levels of Organization of Living Systems, The Cells and Chemical Components of the Cells.

Experimental procedure: (1) Pre-intervention Phase*:* Baseline SDL competence for both the experimental and control groups was established using a validated 13-item, 5-point Likert scale questionnaire; (2) Intervention Phase*:* The experimental group integrated the custom-built AI teaching assistant into their learning workflow to complete SDL-specific tasks, under teacher supervision. Conversely, the control class adhered to traditional institutional methodologies without an AI assistant; (3) Post-intervention Phase: Students' SDL competence was reassessed using a 13-item post-experiment questionnaire to quantify development. To evaluate academic achievement, standardized midterm examination scores were collected. The examinations were uniform across all Grade 10 students and were graded anonymously by the school's independent examination committee to ensure impartial results.

Statistical analysis method: Quantitative and Qualitative data were processed using Microsoft Excel and SPSS (Version 22.0), employing descriptive statistics and T-tests (Independent and Paired Samples) to demonstrate the feasibility and effectiveness of the AI-powered teaching assistant in enhancing SDL competence and learning outcomes.

2.2. Research result

2.2.1. Theoretical basis

2.2.1.1. AI teaching assistant

**** Concept of AI teaching: Teaching assistant***

A chatbot is commonly defined as a computer program designed to simulate human conversation, often conducted via the Internet [10], [11]. The term "AI-powered chatbot" highlights the integration of advanced technologies, such as natural language processing, machine learning, and deep learning, which have evolved chatbots into increasingly sophisticated and intelligent entities [11], [12]. While traditional teaching assistants (TAs) are paraprofessional school staff and supporting classroom activities, AI teaching assistants (AI TAs) refer to an artificial intelligence system engineered to perform complex pedagogical tasks. [13]. These educational chatbots offer significant potential for delivering personalized, interactive learning experiences by analyzing user inputs and providing multi-format (text or voice-based) responses [8]. In the context of digital transformation, AI teaching assistants are expected to complement rather than replace traditional human TAs by automating routine analytical tasks, allowing human educators to focus on emotional engagement and complex academic interactions [14].

**** Potentials of an AI teaching assistant in cultivating self-directed learning competence***

Beyond classroom assistance, AI teaching assistants play an increasingly vital role in fostering students' self-directed learning (SDL) competence. By providing instant feedback, adaptive content recommendations, and data-driven insights. AI TAs support students' self-regulated learning (SRL) processes, specifically in goal setting, progress monitoring, and selfreflection [15]. These AI systems guide students through the interactive cycle of defining objectives and evaluating performance-key pillars of SDL [16].

Recent research indicates that generative AI and AI literacy empower students to take agency over their learning by supporting goal setting, resource selection, and continuous practice [3], [17]. Furthermore, the 24/7 accessibility of AI systems facilitates asynchronous learning, which strengthens students' academic self-efficacy and autonomy. In blended and online learning environments, this capability makes AI TAs transformative tools for sustaining learner motivation and engagement outside traditional classroom boundaries. The integration of AI TAs thus represents a significant step toward personalized learning ecosystems, where technology acts as both a learning companion and a cognitive scaffold that nurtures independent, lifelong learners.

2.2.1.2. The human-AI-human model

To ensure Artificial Intelligence (AI) fosters comprehensive human development, instructional guidelines for self-study are framed within the "Human - AI - Human" (H-AI-H) model. This principle dictates that technology use must be rooted in human needs and culminate in human growth. According to the *Guidelines for using artificial intelligence in teaching and learning,* the model delineates the learning process into three interconnected phases: *Human inquiry*, *AI assistance*, and *human empowerment* [18].

Scholars emphasize that without the initial *Human inquiry* phase - characterized by critical inquiry, independent thinking, and autonomous goal setting - students risk becoming passive recipients of algorithm outputs. Furthermore, the final phase, *Human empowerment*, is critical for "pedagogical transposition", where raw AI-generated data is synthesized and transformed into internalized knowledge through critical evaluation and meta-reflection [18].

2.2.1.3. Self-directed learning in an AI-supported learning environment

**** Concept of self-directed learning***

Self-directed learning (SDL) is recognized as a fundamental general competency that must be integrated across subjects and grade levels [19]. Scholars commonly define SDL as the learner's autonomous ability to manage the entire learning process - ranging from identifying objectives to planning, implementing, evaluating, and recalibrating learning activities - to optimize knowledge and skill development [20].

In alignment with the Vietnamese General Education Curriculum 2018, SDL is a personal attribute that enables students to proactively mobilize their existing resources to successfully plan, implement, evaluate, and adjust their learning activities to achieve predefined goals [21]. Drawing from these perspectives, this study defines SDL as a learner's capacity to independently organize, execute, and monitor activities systematically and effectively to attain specific learning outcomes.

**** Structure of self-learning competence in an AI-supported learning environment***

The structure of SDL varies across theoretical approaches. Knowles (1975) conceptualized SDL as a linear seven-step process, including identifying needs, setting goals, selecting resources, planning, implementing, committing to a learning contract, and evaluating outcomes [22]. In the Vietnamese General Education Curriculum 2018, SDL is represented through four groups of behaviors: identifying tasks and goals; planning and adjusting learning plans; implementing plans through resource searching, academic interaction, note-taking, and presentation; and self-evaluating learning processes [21].

Furthermore, in technology-mediated environments, particularly those supported by AI tools, the SDL competence framework, therefore, extends beyond traditional components to include digital influence. This includes the critical evaluation and management of digital data, content, and information [9], [23]. As AI tools increasingly mediate how students access and engage with learning materials, assessing SDL requires an integrated approach that merges fundamental SDL skills with digital information literacy.

Consequently, this study proposes a specialized SDL structure tailored for AI-supported environments comprising five key components: (1) Defining self-learning purposes; (2) Establishing self-learning goals; (3) Formulating a strategic self-learning plan; (4) Executing self-learning activities (including three sub-skills: inquiry-based questioning, evaluating digital content, and managing digital information); (5) Critically evaluating and adjusting the learning process.

Collectively, six specific skills provide a comprehensive framework for evaluating SDL competence in the age of Artificial Intelligence.

Table 1. Specification of self-directed learning competence in an AI-supported learning environment

Basic SDL components	Traditional SDL competence	SDL in an AI-supported learning environment
1. Defining learning purposes.	While students' recognition of their learning purpose is a fundamental driver of SDL, this study observes that this intrinsic motivation remains consistent across both the experimental and control groups. Furthermore, learning purposes often involve deep-seated psychological constructs that are challenging to measure reliably with the constraints of a short-term classroom intervention. Consequently, while this component serves as a critical conceptual anchor, it was excluded from the empirical assessment to ensure the internal validity and focus of the measurement instrument.	
2. Establishing learning goals.	Students identify the specific tasks and requirements needed to meet their objectives.	(1) AI TAs assist in deconstructing broad objectives into concrete, actionable tasks, ensuring that learning targets remain manageable and clearly defined.
3. Formulating a strategic self-study plan.	Students create study schedules, organize steps, and prepare backup plans independently.	(2) AI provides scaffolded, step-by-step guidance, including automated reminders, real-time progress feedback, and adaptive adjustment suggestions tailored to the student's individual learning pace.
4. Executing self-learning activities.	Students execute their plans by searching for physical resources, taking notes, and interacting with peers/teachers in a general manner.	(3) Inquiry-based questioning (Digital interaction): Students engage with AI TAs by formulating logical and concise inquiries, through "reverse prompting", the AI poses guiding questions rather than merely providing direct answers, thereby stimulating critical thinking and deep pedagogical regulation. As a dynamic instructional partner, the AI enquires students to master multi-level questioning to drive meaningful inquiry. (4) Critically evaluating digital content: To mitigate risks of hallucinations, students are encouraged to maintain rigorous critical judgment. This skill ensures they remain active evaluators of AI-generated output, rather than becoming passive recipients of algorithmic data.

		(5) Managing digital information: AI facilitates the creation of systematic knowledge structures (e.g, mind maps, flashcards) and helps bridge new concepts with prior knowledge. Given the high volume of AI- generated data, students must master the systematic recording, categorization, and retrieval of materials to ensure effective long-term retention.
5. Critically Evaluating and adjusting the learning process.	Students reflect on their performance and adjust strategies after the learning process ends.	(6) Monitoring and Adjusting Learning: AI provides instantaneous, objective feedback based on predefined assessment criteria. This allows students to autonomously evaluate their learning trajectory and recalibrate their strategies in real-time.

2.2.2. Practical basis

* ***Current status of students learning with AI teaching assistant (AI TA) support***

The results obtained are shown in Table 2.

Table 2. Students' perception and expectation regarding AI teaching assistant (N = 184)

Survey Item	**Mean**	**SD**	**%agree + strongly agree**	**Factor 1 loading: effective -ness and desires**	**Factor 2 loading: risks and replacement**	**Commun -ality**
Students' Perception of AI effectiveness and potential risks (Cronbach's α = 0.85)						
AI Chatbot as an effective tool for personalized learning support.	4.20	1.09	87.0%	0.868	0.294	0.841
AI Chatbot enhances learning effectiveness.	4.08	1.06	81.5%	0.826	0.276	0.75758
AI Chatbot provides information that aligns with individual learning needs.	3.61	1.14	56.5%	0.502	0.691	0.729
AI Chatbot has the potential to replace teachers in the future.	2.82	1.49	35.9%	0.206	0.874	0.806
Reliance on an AI Chatbot reduces critical thinking and independent learning.	3.53	1.27	59.9%	0.198	0.799	0.678
Needs and Expectations (Cronbach's α = 0.93)						
The need for specific regulations regarding AI Chatbot usage in learning.	4.12	1.02	85.3%	0.828	0.268	0.758

Desires to acquire skills for effective AI Chatbot utilization.	4.13	1.06	88.0%	0.898	0.171	0.835
Expansion of AI Chatbot applications across diverse lessons and subjects.	3.93	1.08	74.5%	0.809	0.317	0.755
Expectations for specialized AI Chatbots capable of providing accurate and reliable information.	4.18	1.04	87.5%	0.859	0.272	0.811

High mean scores and agreement rates (>80%) confirm that students perceive AI Chatbots as effective tools for personalized learning support and express a strong demand for guidance on effective utilization and regulated implementation. However, moderate ratings regarding information adequacy (M = 3.61) and significant concerns about potential reductions in critical thinking (59.9%) reveal underlying skepticism. Notably, the low endorsement of teacher replacement (M = 2.82) underscores the preference for AI as a supportive, rather than substitutive, teaching assistant. Although applications of AI chatbots in education are becoming increasingly prevalent, there is an urgent need to develop specialized, reliable, and accurate AI systems tailored for pedagogical support, accompanied by clear instructions for both teachers and students on how to use them responsibly and effectively.

**** Self-Directed Learning (SDL) competence in an AI-supported learning environment (without instructional intervention)***

The results regarding the development of students' self-directed learning (SDL) competence through interactions with an AI assistant, as captured via the survey, are presented in Tables 3 and 4.

Table 3. Student's SDL competence before (n = 191) and after (n = 223) using an AI teaching assistant

Skills	**Main variables**	**Before (Mean ± SD)**	**After (Mean ± SD)**	**ΔMean**	**ΔAlpha**
1. Defining self-learning purposes	Identifying assignment objectives	3.78 ± 0.97	3.80 ± 1.04	+0.02	-0.099
2. Establishing self-learning goals	Formulating clear plans and monitoring progress	3.38 ± 0.94	3.76 ± 1.02	+0.38	-0.031
3. Executing self-learning activities (including three sub-skills: inquiry-based questioning, verifying and selecting digital information, and organizing systematic notes)	Formulating multi-level questions and logical answers	3.35 ± 0.93	3.92 ± 0.95	+0.57	-0.012

4. Evaluating digital content	Verifying and selecting digital information	3.62 ± 0.99	3.91 ± 0.95	+0.35	
5. Managing digital information	organizing systematic notes connecting knowledge	3.56 ± 0.95	3.91 ± 0.95	+0.35	
6. Evaluating and adjusting the learning process	Self-assessing and adjusting learning strategy	3.45 ± 0.96	3.81 ± 1.00	+0.36	+0.011

As shown in Table 3, mean scores increased across all six SDL skills, with the largest gains observed in *asking and answering questions* (ΔMean = +0.57). In contrast, *identifying learning goals* showed almost no change (+0.02), suggesting this skill is less sensitive to AI support. The small ΔAlpha values show that the internal consistency of the scales remained stable over time.

Table 4. Development of each skill component in the student's self-directed learning competence

Group of skills	**Main variables (Before → After)**	**Mean Before**	**Mean After**	**t-value**	**df**	**p-value**
1. Defining self-learning purposes	Identifying assignment objectives	3.79	3.79	0.05	190	0.959
	Identifying required tasks to achieve objectives	3.76	3.87	-1.10	190	0.274
2. Establishing self-learning goals	Planning clearly & developing backup strategies	3.42	3.85	-4.22	190	<0.001***
	Executing and completing plans on schedule	3.33	3.70	-3.55	190	<0.001***
3. *Executing self-learning activities* (including three sub-skills: inquiry-based questioning, verifying and selecting digital information, and organizing systematic notes)	Formulating multi-level questions	3.26	3.93	-6.64	190	<0.001***
	Constructing and expressing answers logically	3.44	3.86	-4.30	190	<0.001***
4. Evaluating digital content	Verifying information reliability	3.62	3.93	-3.18	190	0.002**

	Selecting & critically evaluating digital information	3.62	4.05	-4.44	190	<0.001***
5. Managing digital information	Practising flexible note-taking	3.66	3.88	-2.18	190	0.031*
	Organizing systematic notes and storage	3.71	3.92	-2.03	190	0.044*
6. Evaluating and adjusting the learning process	Connecting prior knowledge with new information	3.30	3.92	-5.98	190	<0.001***
	Engaging in self- and peer-assessment	3.24	3.77	-4.88	190	<0.001***

*Note: *ΔMean = Mean After – Mean Before (all >0, indicating improvement). ***$p < 0.001$, **$p < 0.01$, $p < 0.05$. Means are rounded to two decimal places for brevity.*

Table 4 provides inferential evidence regarding this trend. Paired-sample t-tests reveal statistically significant improvements ($p < 0.05$ to $p < 0.001$) across most variables, particularly in strategic planning, inquiry-based questioning, information evaluation, and reflective adjustment. Conversely, no significant change was observed in the ability to identify learning objectives ($p = 0.959$), which reinforces the aforementioned descriptive results. Overall, the findings suggest that AI Chatbots possess the potential to enhance SDL competence, providing a robust foundation for further research on their integration into teacher-scaffolded contexts.

2.2.3. Designing and applying a custom-built AI teaching assistant for self-learning Grade 10 Biology

2.2.3.1. Designing a custom-built AI teaching assistant

By synthesizing the findings from the "Expectations and needs" survey with the design framework for AI teaching assistant (AI TAs) in Biology education proposed by LM Thu et al. (2025), a specialized AI teaching assistant is developed. This assistant was designed to support Grade 10 students in self-studying using the NotebookLM platform, following a structured five-step process:

(1) Authentication: Users sign in NotebookLM using their Google account.

(2) Workspace initialization: A dedicated notebook environment is created for the subject.

(3) Knowledge base curation: The teacher deliberately curated a curriculum-aligned knowledge base. This ensures that all generated content remains rigorous and appropriate for the students' cognitive levels.

(4) System configuration and Prompt Engineering: The teacher configured the assistant's conversational guidelines, defining the response style, scaffolding level, questioning strategies, and preferred explanation formats. This configuration ensures the AI models' cognitive processes rather than merely providing direct answers. Furthermore, the assistant was instructed to restrict responses to the approved sources and decline out-of-scope inquiries, thereby upholding academic integrity and safety.

(5) Pedagogical tool integration: Utilizing the "Studio" features, the teachers generated customized learning materials (e.g, mind maps, flashcards, video reviews, and infographics) with specified objectives and difficulty levels. As these learning materials are generated based on the teacher-led prompt within a verified knowledge base, they are strictly aligned with the national curriculum, providing a reliable package for self-directed activities.

Following this methodology, a specialized AI TA for Grade 10 Biology was fully customized and named "Hạt Đậu Nành," serving as an optimized support system for student self-learning (Figure 1).

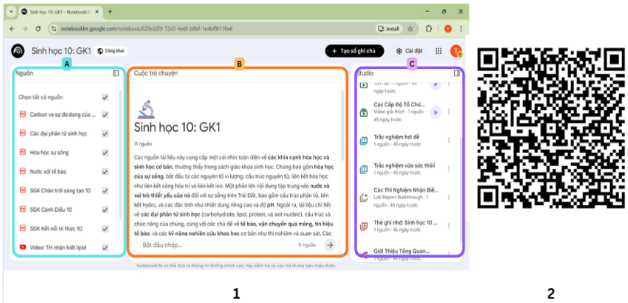

Figure 1. (1) The customized AI teaching assistant for Grade 10 Biology interface: (A) Sources display usable sources for AI answers, (B) Conversation where students ask questions, (C) Studios: additional self-study tools generated based on sources; (2) QR to access the AI teaching assistant

2.2.3.2. Applying a customized AI teaching assistant for self-learning Grade 10 Biology

Transitioning students from novice AI users to autonomous learners requires a systematic and structured pedagogical approach. To achieve this, the implementation of the H-AI-H model is operationalized by synergizing AI capabilities with the Gradual Release of Responsibility (GRR) framework [24]. This framework facilitates a progressive transfer of cognitive load from the instructor to the student across four distinct stages: Focused instruction ("I Do"), Guided instruction ("We do"), Collaborative learning ("You do together"), and Independent learning ("You do alone").

To ensure the effective development of SDL competence, the instructional process was meticulously designed to transition responsibility from the teacher to the students, as detailed in Table 5.

Table 5. Pedagogical framework for integrating an AI teaching assistant in Biology based on the GRR model

Step	Details of the step	Example of "Water properties" lesson
Step 1. Focused Instruction "I do"	The teacher explicitly models the cognitive process through a "think-aloud" strategy) while interacting with the AI chatbot. The primary objective is to demystify the technology and demonstrate rigorous skepticism. Specifically, the teacher illustrates how to formulate effective prompts and perform rigorous fact-checking of the AI-generated outputs. By purposefully highlighting potential errors or algorithmic hallucinations, the teacher establishes a high standard of caution and academic integrity for students to follow.	The teacher presents the lesson objective and demonstrates the interactive process of AI interaction by writing an initial sample prompt: "Which property of water explains why ice floats on liquid water?" Upon receiving the response, the teacher performs an immediate fact-check and defines the inquiry to achieve greater depth: "Explain the buoyancy of ice by comparing the crystal structures of ice and liquid water." Through this process, students actively observe how the teacher identifies information gaps, detects potential inaccuracies, and calibrates the AI output to meet rigorous scientific standards.

Step 2. Guided Instruction "We do"	The teacher and students collaboratively co-construct prompts and critically analyze the generated outputs. This approach establishes a scaffolded environment for productive trial and error, enabling the teacher to identify and address misconceptions regarding AI capabilities and limitations in real-time. By engaging in this shared inquiry, students begin to internalize the evaluative criteria necessary for effective AI-human collaboration.	Students collaborate with the AI by posing targeted inquiries, such as "How does this property of water benefit organisms living in cold environments?" Under the teacher's guidance, students refine the output by applying specific constraints (e.g., limiting the response to 50 words) and cross-referencing the information with their textbooks. This process reinforces a critical pedagogical lesson: while AI chatbots are powerful auxiliary tools, their outputs must be rigorously verified against authoritative sources to ensure scientific accuracy.
Step 3. Collaborative Learning "You do together"	In this stage, students work in small groups to solve complex biological problems by leveraging AI chatbots. This pedagogical phase utilizes "collective intelligence" to critically monitor and evaluate "artificial intelligence." Group members are required to deliberate and debate the accuracy and relevance of the AI's suggestions, fostering a peer-review environment where no AI-generated output is accepted without consensual verification.	Student groups utilize the AI teaching assistant to investigate experimental principles of surface tension and solubility. During this process, they critically debate the validity of the AI's suggestions, subsequently synthesizing their findings to identify the three fundamental roles of water within cellular environments. To conclude this session, groups present their results extemporaneously, demonstrating a deep conceptual understanding rather than a mere reliance on prepared notes.
Step 4. Independent learning "You do it alone"	In the final stage, students interact with AI chatbots autonomously to facilitate personalized learning and self-regulation. At this level of proficiency, students independently apply the EDIT strategy (Evaluate, Detect, Improve, and Transcribe / Transform) to finalize their academic products. This systematic approach ensures that students leverage AI as a sophisticated cognitive partner while maintaining absolute academic integrity and ensuring the final output reflects their own intellectual growth.	Students engage with a real-world scenario: "A patient has a high fever. Using your knowledge of water's thermal properties, explain how water helps regulate body temperature. While students may consult the AI teaching assistant for conceptual clarification, they are required to construct their own original explanations. Subsequently, they apply the EDIT strategy to define their work and critically reflect on how the AI facilitated their thinking process. This stage ensures that the AI serves as a scaffold for metacognition rather than a substitute for individual effort.

Evaluation of effectiveness and pedagogical safeguards: To validate the efficiency of the H-AI-H model, assessment strategies must shift from evaluating only the final product to a process-oriented evaluation. Assessments should prioritize the student's ability to identify algorithmic bias (cognitive risk management) and their proficiency in interactive prompt refinement. If students show signs of "cognitive offloading" - the tendency to let AI bypass their own critical thinking) - the teacher must strategically reintroduce "metacognitive friction" [18]. This is achieved by assigning tasks that require critiquing the AI's logic and verifying its evidentiary bias, rather than simply using it for content generation.

2.2.4. Pedagogical experiment

The impact of the H-AI-H model on student outcomes was evaluated by comparing midterm exam scores between the experimental and control groups. The statistical results regarding performance improvements are presented in Tables 6 and 7.

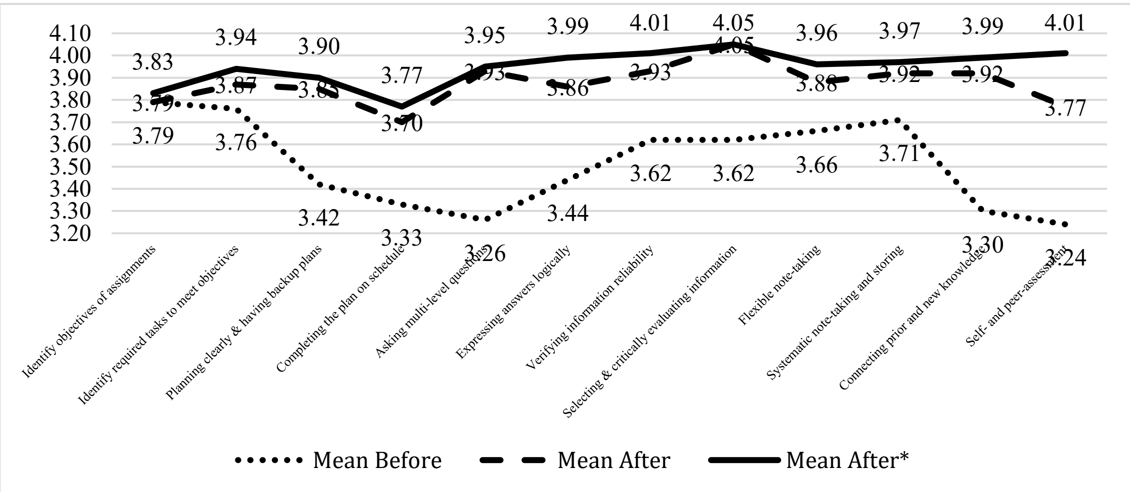

Figure 2. Comparison of Skills in SDL when learning with the AI TA under teacher supervision

The results illustrated in Figure 2 indicate that integrating the AI Teaching Assistant (AI TA) under teacher guidance significantly enhances SDL competence. The adjusted means show consistent improvements over raw post-intervention scores (Mean After), with the most notable gains in multi-level questioning, logical expression, information verification, knowledge synthesis, and collaborative assessment. These elevated values suggest that structured teacher mediation prevented passive reliance, instead empowering students to leverage AI effectively. Overall, the findings confirm that AI TA, when embedded in scaffolded pedagogical practices, serves as a robust catalyst for developing self-directed learners.

Table 6. Descriptive statistics of midterm exam scores for the control and experimental groups

Group	Mean	Standard deviation (SD)
Control (C)	6.97	0.84
Experimental (E)	7.84	1.14

Table 7. Independent Sample t-tests of the midterm scores between the control and experimental groups

Comparison	t	df	p	Mean difference	Cohen's d	95% CI
C vs E	-4.00	77.29	<.001	-0.86	0.86	[-1.29, -0.49]

The midterm examination results demonstrate significant academic benefits for students utilizing the customized AI TA in self-directed study. As detailed in Table 6 and Table 7, the experimental group achieved a notably higher mean score ($M = 7.84, SD = 1.14$) compared to the control group ($M = 6.97, SD = 0.84$). An independent samples t-test confirmed a statistically significant difference between the two groups ($t = -4.00, p < .001$). Furthermore, the large effect size (*Cohen's d = 0.86*) and a 95% confidence interval that excludes zero verify that the teacher-mediated AI TA integration has a substantial and meaningful impact on student learning outcomes.

3. Conclusions

This study provides empirical evidence that the integration of a custom AI teaching assistant significantly enhances both self-directed learning (SDL) competence and academic performance among high school students. Theoretically, it explores the SDL competence framework within an AI-supported learning environment that incorporates both digital and traditional self-study skills, and introduces the Human-AI-Human (H-AI-H) model as a robust pedagogical approach to mediate student-AI interactions and sustain high-level cognitive engagement. Practically, the study details the technical design of an AI teaching assistant and provides a structured implementation guide based on the gradual release of responsibility (GRR) framework for classroom settings.

While acknowledging the need for further validation across diverse contexts, these findings offer a scalable and responsible model for integrating artificial intelligence into secondary education, ensuring that technology serves as a catalyst for, rather than a substitute for, human intellect.

REFERENCES

[1] Prime Minister of Vietnam, (2022). Decision No. 131/QD-TTG on approving the scheme *"Strengthening application of information technology and digital transformation in education and training for the period of 2022-2025 with a vision towards 2030"*. Government of Vietnam.

[2] Nguyen CT, (2002). *Learning and Teaching How to Learn.* Hanoi National University of Education Publishing House (in Vietnamese).

[3] Curaming RN, (2025). Extent of Use and Perceptions of the Pros and Cons of AI-Powered Chatbots in Education: Teachers' and Students' Insights. *Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields,* 1(5). https://doi.org/10.5281/zenodo.15508389.

[4] Bravo FA, Cruz-Bohorquez JM, (2024). Engineering Education in the Age of AI: Analysis of the Impact of Chatbots on Learning in Engineering. *Education Sciences,* 14, 484. https://doi.org/10.3390/educsci14050484.

[5] Mageira K, Pittou D, Papasalouros A, Kotis K, Zangogianni P, Daradoumis A, (2022). Educational AI Chatbots for Content and Language Integrated Learning. *Applied Sciences*, 12(7):3239. https://doi.org/10.3390/app12073239.

[6] Le MT, Truong TP, Phan TTH, (2025). A Process for Developing an AI Teaching Assistant to Support Teachers in Teaching Biology at General Education Schools. *VJE Vietnam Journal of Education,* 25(7), 314-319 (in Vietnamese).

[7] Truong TD, Kieu PT, (2025). Research on building ai chatbot: TinBot 10 and suggestions for pedagogical methods using TinBot 10 to support teaching Python programming. *HNUE Journal of Science: Educational Sciences*, 70(6), 164-75. https://doi.org/10.18173/2354-1075.2025-0119.

[8] Chang DH, Lin MPC, Hajian S, Wang QQ, (2023). Educational design principles of using ai chatbot that supports self-regulated learning in education: Goal setting. *Feedback, and Personalization. Sustainability,* 15, 12921. https://doi.org/10.3390/su151712921.

[9] Nguyen MG, Nguyen VD, Nguyen THN, Nguyen THG, Ngo TT, (2023). Measures to develop chemistry self-learning capacity for secondary school students with the support of an AI Chatbot. *Journal of Education for Sustainable Innovation*, 1(1), 49-60. https://doi.org/10.56916/jesi.v1i1.519.

[10] Cambridge University Press, (2025, September). *Chatbot in the Cambridge dictionary.* https://dictionary.cambridge.org/vi/dictionary/english/chatbot.

[11] Aslam F, (2023). The Impact of Artificial Intelligence on Chatbot Technology: A Study on the Current Advancements and Leading Innovations. *European Journal of Technology*, 7(3), 62-72. https://doi.org/10.47672/ejt.1561.

[12] Adamopoulou E & Moussiades L, (2020). Chatbots: History, technology, and applications. *Machine Learning with Applications, 2*, Article 100006. https://doi.org/10.1016/j.mlwa.2020.100006.

[13] Alsafari B, Atwell E, Walker A & Callaghan M, (2024). Towards effective teaching assistants: From intent-based chatbots to LLM-powered teaching assistants. *Natural Language Processing Journal*, 8, 100101. https://doi.org/10.1016/j.nlp.2024.100101.

[14] Córdova-Esparza DM, (2025). AI-Powered Educational Agents: Opportunities, Innovations, and Ethical Challenges. *Information,*16*,* 469. https://doi.org/10.3390/info16060469.

[15] Lan M, Zhou X, (2025). A qualitative systematic review on AI empowered self-regulated learning in higher education. *Npj Science of Learning.* 10, 21. https://doi.org/10.1038/s41539-025-00319-0.

[16] Zimmerman BJ, (2002). *Becoming a self-regulated learner: An overview.* Theory into Practice, 41(2), 64-70. *https://doi.org/10.1207/s15430421tip4102_2.*

[17] Sengul T, Sarikose S, Uncu B & Kaya N, (2025). The effect of artificial intelligence literacy on self-directed learning skills: The mediating role of attitude towards artificial intelligence: A study on nursing and midwifery students. *Nurse education in practice*, 88, 104516. https://doi.org/10.1016/j.nepr.2025.104516.

[18] Vietnam National Institute of Educational Sciences, (2025). *Guidelines for using Artificial Intelligence in teaching and learning*. Hanoi: Vietnam National Institute of Educational Sciences.

[19] Nguyen HT & Bui TT, (2023). Applying the flipped classroom with information technology to foster high school students' self-directed learning competence in chemistry. *Vietnam Journal of Education,* 7(2), 15-25. https://doi.org/10.52296/vje.2023.214.

[20] Phan TTH, Kieu TG, (2016). Developing self-study capacity for students in teaching the chapter "Induction" (Biology 11). *Vietnam Journal of Education,* 7(1), 184-189 (in Vietnamese).

[21] Ministry of Education and Training, Vietnam, (2018). *General Education Program - Overall Program* (Issued attached to Circular No. 32/2018/TT-BGDĐT). Ministry of Education and Training, Vietnam. p. 43-45 (in Vietnamese).

[22] Knowles MS, (1975). *Self-directed learning: A guide for learners and teachers.* Chicago, Association Press.

[23] Ministry of Education and Training, Vietnam, (2025). Circular No.2/TT-BGDDT *Stipulating the Digital Competency Framework for Learners*. Ministry of Education and Training, Vietnam (in Vietnamese).

[24] Fisher D & Frey N, (2013). *Better learning through structured teaching: A framework for the gradual release of responsibility* (2nd ed.). ASCD.