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Building and using chatbots in the process of self-studying physics to improve the quality of learners' knowledge

Hai Tuong Duy[1]
Chat Tran Ngoc[2+]
Nam Tran Hai[3]

[1,2]*Hanoi National University of Education, Vietnam.*
[1]*Email: haitd@hnue.edu.vn*
[2]*Email: chattn@hnue.edu.vn*
[3]*High School for Gifted Students of VNU University of Sciences, Vietnam.*
[3]*Email: namtranhaikh@gmail.com*


(+ Corresponding author)

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ABSTRACT

The adoption of chatbots in education is steadily increasing, offering a myriad of benefits to learners engaging in self-directed study. However, the reliability of information provided by chatbots poses certain obstacles, particularly in subjects with high academic content such as physics. This study proposes a five-step process for constructing chatbots, enabling educators to independently develop chatbots to support self-learning among students. This process focuses on enabling chatbots to autonomously respond to physics-related inquiries, a capability often lacking in pre-built chatbots. A new chatbot for physics lessons on the conservation of energy law was developed by applying this methodology. To assess the feasibility and effectiveness of the developed chatbot, we conducted a pedagogical experimental study involving 100 tenth grade students divided into control and experimental groups. To ensure comparability between the groups, students were selected based on their physics grades and teacher feedback. Experimental data was collected through online feedback forms and a 45-minute physics test, processed using statistical techniques. The results indicate a high level of readiness among participants to utilize chatbots for self-learning and acknowledge their beneficial impact. Furthermore, students' knowledge quality improved with chatbot usage, affirming the feasibility and effectiveness of incorporating chatbots into physics education. These findings also validate the proposed five-step chatbot development process as rational and applicable.

Contribution/Originality: The study proposes a systematic five-step process for constructing physics-focused chatbots, empowering educators to tailor digital assistants for student self-learning. This unique approach addresses the limitations of generic chatbots in academic contexts, facilitating enhanced knowledge acquisition and engagement in physics education.

1. INTRODUCTION

The traditional way of teaching is gradually being replaced as society develops in the field of technology. However, traditional teaching cannot be completely abolished. By combining the two, the blended learning method was developed to help students learn better (Sharma, 2010). For this method to be effective, it is necessary to create an environment based on social networks, build learning websites, etc. Currently, artificial intelligence technology has been a topic of interest and researched globally. It has been studied for a long time and has developed very strongly, being selected for use in the teaching process (Shabbir, 2022). One of the applications of AI is a chatbot – a communication system that interacts with humans utilizing machine learning, conducting conversations through

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the interface in the form of messages or sounds (Nguyen, 2021). Initially, chatbots were mainly used to consult with users online through pre-written commands. In recent years, chatbots have become increasingly popular, and a system of many types of bots has been created that are especially effective in areas such as customer consultation, healthcare, online sales, public service, and education.

Currently, in the field of education and training, chatbots are strongly researched and deployed, especially in supporting teachers and learners in online teaching. Teaching can be referred to as a "chatbot for the education system". Hiremath, Hajare, Bhosale, Nanaware and Wagh (2018) developed a system that automatically answers user questions on behalf of teachers in teaching or research on building software to support students in solving exercises of kinematics - Physics 10. Da (2020) showed that chatbots are feasible when applied in education. The topic on building a chatbot to support training in universities on the MS power platform (Giang & Pham, 2023) also confirms that development. The development of chatbots has been pushed to a new level and is applied in many fields, especially in education and training (Sonderegger & Seufert, 2022). However, research on chatbots in education is still mainly theoretical and has not yet gone into practical application, and there are no clear or specific instructions for their use in general education. Therefore, we conducted research to provide a chatbot design process from creating a chatbot for use on Messenger, explaining the steps to build a database, and giving lectures using chatbots to support learning self-study students.

In the era of Industry 4.0, individuals frequently need to engage in self-learning and stay updated with various knowledge domains (Valliant & Betz, 2020). For students in this era, developing the ability to self-study is essential. The use of chatbots is considered an effective tool to support learners. Physics knowledge encompasses many academically oriented topics, and utilizing pre-existing chatbots often encounters challenges regarding the accuracy of information. Therefore, researching a simple method for teachers to construct chatbots for use in physics education holds significant importance. However, whether chatbots built by teachers are well-received by students during usage and whether such usage is effective remain subjects for investigation. Hence, this research address two key questions:

Research Question 1: What is the level of preference for using chatbots in the self-learning process of physics?

Research Question 2: How effective is the use of chatbots in the self-learning process of physics?

2. REVIEW OF LITERATURE

2.1. Theoretical Foundation of Self-Study Competence

Psychologist Rubakin (1973) posits self-discovery as synonymous with self-study, emphasizing the acquisition of knowledge and experiences through personal practice. The Dictionary of Education (Bui, 2001) defines self-study as autonomous learning, independent of direct teacher guidance or institutional management. Do, Nguyen, Tuong, Pham, and Duong (2019) expanded on this, highlighting the complexity of self-study in developing skills and motivations to meet job requirements driven by learners' internal forces (Dam, 2018). Thus, self-study entails self-discovery, research, and knowledge acquisition to develop individual skills, facilitated through various resources, such as documents, textbooks, and online materials, as well as teacher instructions.

For students, self-study encompasses a variety of activities beyond traditional classroom learning. These activities include engaging in professional exercises independently, participating in clubs, experimental groups, and various extracurricular pursuits. According to Nguyen (2021) self-study can be approached in several ways. Firstly, self-study without instructions involves learners independently seeking out and comprehending documents and applying the knowledge contained within them to their studies. This method allows students to take control of their learning process, relying on their own initiative and resources. Secondly, self-study with direct guidance entails teachers providing hands-on guidance within a classroom setting. In this approach, instructors offer direct assistance to students, helping them navigate through the subject matter in line with the learning objectives. Lastly,

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self-guided self-study involves remote instructors leveraging information technology to guide learners independently.

Through online platforms and virtual tools, teachers can offer guidance and support to students, even when not physically present in the classroom. These different approaches to self-study cater to the diverse learning styles and preferences of students, allowing them to take ownership of their education and deepen their understanding of the subject matter (Kurilovas, 2019). To enhance students' self-study ability, educators must consider the factors that influence the self-directed learning process. External factors, such as teaching methodologies employed by instructors, play a significant role, while internal factors stem from students' attitudes, determination, confidence, and enthusiasm (Canh, 2001). Thus, the instructional approach should consistently inspire and motivate students, fostering confidence, drive, and clear objectives to encourage active self-study.

In the 2018 Vietnamese General Education Program for high school students, specific guidelines for self-study and self-improvement are outlined by the Vietnam Ministry of Education and Training (2018). These guidelines encompass various facets of self-directed learning. Students are encouraged to identify learning tasks based on their achieved results, set detailed and specific learning goals, and address any limitations they encounter. Additionally, they are expected to evaluate and adjust their study plans, develop individualized learning styles, and carefully select materials suitable for different learning objectives. Documenting information in formats conducive to retention, application, and supplementation when necessary is also emphasized. Furthermore, students are urged to recognize and rectify mistakes and limitations independently during the learning process. They should reflect on their learning methodologies to draw insights applicable in diverse contexts and master self-regulation techniques to enhance their learning efficiency. Moreover, the program emphasizes the importance of regularly nurturing personal development aligned with individual goals and societal values. These components collectively underscore the significance of cultivating students' autonomy and self-awareness, empowering them to take ownership of their learning journey and continuously strive for growth.

In order to meet the requirements of developing self-directed learning for students, many models have been applied by teachers, including blended learning, which is an integrated learning method between face-to-face and online learning (Nguyen, 2021). This is a form of online training using familiar traditional learning combined with technology platforms. Blended learning focuses mainly on the role of the learner. When training using this method, students can freely access the online learning platform, autonomously acquire knowledge, enter a virtual classroom, watch slideshows, etc. at their own pace (Bosch & Spinath, 2023). Blended learning has many different models, but the most common one is the online driver model in which students can learn remotely and receive learning instructions through online platforms. In this study, we use chatbots as a tool for teachers and students to interact and exchange information.

2.2. Introduction to the Chatbot Program

2.2.1. Development of chatbots

A chatbot, as defined by Brush (2023) is a program intended to simulate internet-based conversations with users. By leveraging artificial intelligence (AI) and natural language processing, chatbots interpret user inquiries and provide automated responses. Typically, chatbots engage users through text or audio formats.

The first chatbot was created in 1966 by computer scientist Joseph Weizenbaum and named it ELIZA. The name was inspired by the fictional character Eliza Doolittle from a well-known play of that time. ELIZA is essentially a software program running on a computer, designed to simulate conversations using basic pattern matching and replacement techniques (Weizenbaum, 1966). Another chatbot, developed by Stanford psychiatrists Colby, Hilf, Weber, and Kraemer (1972) and named PARRY, an abbreviation for "Parallel Randomly," was designed to emulate the interaction method employed when the chatbot converses with individuals afflicted with paranoid schizophrenia. "Parallel" signifies the chatbot's simultaneous reception and response to information from

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the user, akin to a conversation. "Randomly" denotes the chatbot's responses being unpredictable, mimicking the unpredictable nature observed in patients.

With the rapid advancement of AI technology, the market has witnessed an influx of chatbots deployed across various sectors, ranging from technology firms, banks, and clinics to e-commerce enterprises, such as fashion, accessories, and food services, serving diverse purposes tailored to their specific domains (Minh, 2023a). Depending on their functionality, chatbots can be categorized into several popular types: Scripted chatbots, which operate based on pre-programmed data, making them widely utilized and easily adaptable to specialized fields; Keyword-based chatbots, which analyze user queries for relevant keywords and provide corresponding responses; Contextual chatbots, distinguished by their advanced capabilities in leveraging AI and machine learning algorithms to recall past interactions and engage users in sophisticated conversations, facilitating cognitive development and continual improvement; and Hybrid chatbots, which combine the functionalities of keyword-based chatbots with scripted conversations accessed via a menu interface, offering users a versatile and interactive experience.

Each category of chatbot serves a distinct purpose, with varying levels of complexity and adaptability, contributing to the ever-evolving landscape of AI-driven interactions in both commercial and specialized settings (Merlo, 2024).

2.2.2. Operational Principles and Chatbot Building Tools

Chatbots combine pre-programmed scripts with the ability to learn during interactions. They utilize natural language processing systems to analyze text inputs, selecting appropriate machine learning algorithms to generate responses accurately. This process involves scanning keywords in the input data and matching them with the database (Cahn, Computer, & Science, 2017). As the benefits of chatbots continue to grow, they are becoming increasingly popular, attracting attention and research from numerous developers. In Vietnam, several free and widely used chatbot creation tools include Chatfuel, Messnow, ManyChat, ChattyPeople, and Harafunnel (Minh, 2023b).

2.2.3. Chatbots that Support Students with Guided Self-Study

In the realm of education, the utilization of chatbots presents a promising avenue for enhancing the learning experience. Teachers, by capitalizing on the advantages offered by chatbots, can establish personalized data systems tailored to meet the unique needs of students. This approach proves to be more effective than traditional methods such as internet searches or solitary book-based self-study (Tuan & Truong, 2021). Chatbots are adept at assuming various roles typically performed by teachers. They interact with students, addressing inquiries and challenges within the subject matter (Han, Liu, Pan, Cai, & Shao, 2023). Moreover, chatbots assign learning tasks suited to each student's level and pace, offering a plethora of learning resources to enrich the educational experience (Galitsky & Galitsky, 2019). Additionally, they compile and organize student queries and apprehensions for further analysis. Furthermore, chatbots provide guidance and recommendations on optimal study programs aligned with students' learning objectives. They also disseminate important notices and updates to students promptly and efficiently (Roberts, 2023). By integrating chatbots into the educational landscape, educators can foster a dynamic and engaging learning environment that maximizes student potential and facilitates continuous academic growth (Kettler & Taliaferro, 2022). The Meaning of Experience chatbot creates an interactive learning experience for students, just like interacting with a teacher face-to-face (Stakland, 2023). From checking student behavior and tracking their progress, bots play an essential role in enhancing each student's abilities. Furthermore, they can also play an important role in motivating students to work by sending regular reminders and notifications. Chatbots can assist users in their daily tasks, answer students' questions, or even check their homework (Colace et al., 2018).

Utilizing chatbots can significantly enhance the learning outcomes, with a stronger impact observed at higher education levels. Research conducted on the use of chatbots in online physics education for Maritime University

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students in Ukraine demonstrated notable improvements in learners' knowledge quality (Bohomolova, Kushnir, & Moshkovska, 2021). The frequency of chatbot usage also yields varied effects, with shorter-term utilization showing more pronounced effectiveness compared to prolonged usage (Wu & Yu, 2024).

Dempere, Modugu, Hesham, and Ramasamy (2023) conducted a study on university students utilizing chatbots and revealed not only the benefits and appeal of chatbots in education but also highlighted the importance of ensuring the accuracy of information provided by chatbots. Additionally, concerns regarding the potential misuse of chatbots and the reduction of human-to-human interaction should be noted. Therefore, integrating aspects of emotion and human-like avatars into chatbots may prove more effective.

Contemporary chatbots can be easily constructed not only for automated messaging within commercial settings but also for integration into education. Research by Haristiani and Rifa'i (2020) has shown that in language teaching, educators can autonomously develop chatbots to enhance learners' language proficiency. At the university level, learners can engage in a pedagogical approach known as "learning by building chatbots," wherein they construct their own chatbots. Through database building and training chatbot response mechanisms, learners gain a deeper understanding of the subject matter (Nikou & Chang, 2023).

In addition to academic support, chatbots demonstrate robust capabilities in information management tasks. They facilitate and monitor the learning process, assess students' activity effectiveness, and provide automated, concise reports to educators for timely decision making (Chen, Jensen, Albert, Gupta, & Lee, 2023). Chatbot usage also fosters the development of critical thinking skills and cognitive processes, particularly evident among university students (Liu, Subbareddy, & Raghavendra, 2022). Throughout chatbot training, developers can incorporate problem-solving skills into chatbot response procedures, enabling learners to enhance their problem-solving abilities (Riabko & Vakaliuk, 2024).

2.3. Research Gap

The theoretical basis section on self-study introduces a number of key theories and terms. The relationship of self-discovery with self-study emphasizes the acquisition of knowledge through personal practice and comparison with real life situations. Self-study is also understood as independent learning without direct guidance from a teacher. Self-study is a multifaceted activity and is necessary to meet job requirements and for personal development. There are different self-study methods, catering to diverse learning styles, and students' attitudes affect their ability to self-study.

Chatbots offer a promising route to enhance the learning experience, taking on roles typically performed by teachers and providing interactive support. Although concerns still exist regarding the accuracy of information provided by chatbots and reduced human interaction, modern chatbots are easily integrated into education, facilitating support learning and developing critical thinking skills.

The use of chatbots in teaching has attracted considerable attention from researchers, who have thoroughly examined their effectiveness and their limitations. Existing studies mainly scrutinize pre-built chatbots developed by professional organizations or meticulously programmed organizations. However, educators face obstacles in directly building chatbots in both cases. Challenges can arise from the technical complexity involved in programming chatbots or the costs involved in obtaining pre-built solutions. Additionally, while research on chatbot implementation abounds in higher education contexts, there is little research exploring their applicability at lower levels of education. This gap highlights the need for further investigation into the use of chatbots in primary and secondary education settings. Understanding how to effectively integrate chatbots into K–12 education can yield valuable insights in optimizing the learning experience for young students, potentially increasing engagement, knowledge retention and overall learning outcomes. Furthermore, exploring the potential benefits and challenges specific to lower levels of education can help develop tailored chatbot solutions that address the unique needs and learning styles of younger students. Therefore, addressing these research gaps is important to advance

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our understanding of chatbot-supported learning at all educational levels. Based on a review of published studies, there is an urgent need for further research into the development of user-friendly chatbot solutions specifically designed for educators in the field of physics education. These chatbots require easy access and easy content creation, allowing educators to easily integrate them into the learning process to improve the quality of learners' knowledge during the learning process. By focusing on the ease of creating simple yet effective chatbots, researchers can address challenges raised in previous studies, such as technical complexity and cost barriers associated with existing solutions. Additionally, considering the current research landscape that mainly focuses on higher education, there is a critical need to extend this research to lower levels of education where the potential impact of chatbot-assisted learning remains largely unexplored. This requires a comprehensive investigation into the design, implementation and evaluation of chatbots in primary and secondary education settings, taking into account unique pedagogical requirements and learning dynamics in light of psychological factors of age. Therefore, by shedding light on methods for developing accessible chatbot tools and evaluating their effectiveness in improving the quality of learners' knowledge during self-study, researchers can contribute valuable insights to the advancement of physics education and the broader field of educational technology.

3. METHODOLOGY

The research process is divided into two stages. The first stage involves constructing the intervention tool, which entails developing a process for creating a chatbot for physics lessons. The second stage involves implementing and evaluating the effectiveness of the intervention. Pedagogical experiments were conducted in two classroom settings—a control group and an experimental group—to address the two research questions.

In the first research stage, the process of building the chatbot is outlined, which consists of five stages, with the most labor-intensive and time-consuming aspect being the creation of the database and training the chatbot.

Figure 1 illustrates the tasks required in both stages of the research.

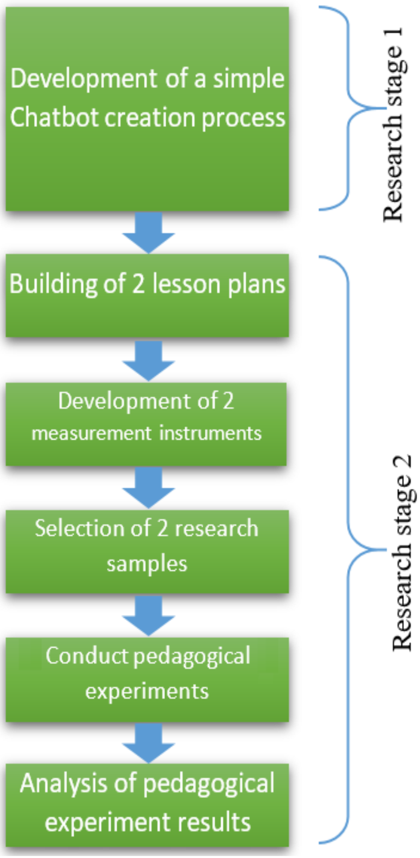

Figure 1. Research stages.

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The second research stage consists of five steps:

Step 1: Building lesson plans: Two lesson plans with self-study tasks are prepared for each of the two classes. For the control group, self-study tasks were devised conventionally without employing chatbots. For the experimental group, self-study tasks were formulated to include the requirement for students to use chatbots to complete the tasks.

Step 2: Development of measurement instruments: To collect data for the first question, we constructed an online feedback form. To collect data for the second question, we created a physics test with content related to the lesson that had been taught.

Step 3: Selection of the research sample: Two classes with similar academic levels were chosen from a secondary school. The selection criterion for similarity is based on the physics grades of the two classes and interviews with the physics teachers.

Step 4: Conducting pedagogical experiments: Both groups of students were assigned self-study tasks. After completing the tasks, the control group took a physics test, while the experimental group took the test and completed an online feedback form.

Step 5: Analysis of pedagogical experiment results: Drawing conclusions regarding the impact of the research process.

3.1. Instrument Development

The data collection instrument for the first research question was an online questionnaire consisting of six items, each rated on a four-point Likert scale. For the second research question, data was collected using a physics test comprising 30 objective multiple-choice questions.

3.2. Construction Process of the Online Questionnaire and Physics Test

Initially, the research team and three pre-service student teachers from Hanoi National University of Education developed an online questionnaire consisting of 15 questions and a physics test with 50 objective multiple-choice questions. Subsequently, both tools underwent content revision by consulting opinions from experts, including five physics didactic lecturers from Hanoi National University of Education, two of which are the authors of this paper and three are from the High School for Gifted Students, one of these three teachers is also the third author of the paper. Based on expert feedback, the final set of tools comprised an online questionnaire with 10 questions and a physics test with 40 questions.

3.3. Testing Process

Finally, the tools were piloted with a sample of eight tenth grade students from the High School for Gifted Students. These students were independent from the sample used during the pedagogical experiment. Through data analysis, items with corrected item-total correlation values less than 0.3 were eliminated, aiming for a Cronbach's alpha coefficient higher than 0.6. After removing four questions with low reliability, the revised online questionnaire achieved a Cronbach's alpha coefficient of 0.795. Similarly, after eliminating 10 questions, the revised physics test attained a Cronbach's alpha coefficient of 0.754.

3.4. Analysis of the Pedagogical Experiment Data

Upon collecting data from the online questionnaire, percentages were calculated, and the ratios were compared to draw conclusions corresponding to the first research question.

Data from the physics test was converted to a 10-point scale, and comparative graphs were generated between the control group and the experimental group. The analysis of these graphs will yield conclusions relevant to the second research question.

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4. RESEARCH PROCESS OVERVIEW

4.1. First Research Stage: Designing a Chatbot for Teaching

4.1.1. Step 1: Selecting a Physics Lesson

The physics lesson chosen for chatbot development is "The Laws of Conservation" (Physics 10). This lesson is part of the 2018 general education curriculum in Vietnam and was selected in September 2022, when the chatbot development commenced. According to the research timeline, students will study this lesson after five months. It is a lesson aimed at helping students form new physics knowledge; it is not a practical exercise or test lesson. This lesson contains a plethora of content knowledge components, providing favorable conditions for assessing the capabilities of the chatbot.

4.1.2. Step 2: Creating a Page on Facebook

In the above tools, to apply it in the teaching process, Messnow was chosen because it has advantages compared to other applications. These are as follows:

- The interface is entirely in Vietnamese.
- There is a menu with step-by-step instructions on how to install and deploy the chatbot.
- Integration with Zalo and Messenger messaging applications.
- Multilingual capabilities with more than 50 languages worldwide.
- Diverse application store, which helps you integrate more functions.
- Creates and deploys Facebook chatbot quickly and easily.
- Has the ability to process natural language accurately.
- Has a professional template store with hundreds of different preset templates.

4.1.3. Step 3: Link on Messnow Platform

Go to the website https://platform.messnow.com/admins/login?lang=en to link your Facebook account and the account on the Messnow platform. Chatbots can also be created on the Zalo application, a very popular chat and social networking application in Vietnam.

4.1.4. Step 4: Install Basic Functions of Chatbots

4.1.4.1. General Settings

The bot is given a name and an avatar, and the basic functions of a regular chatbot are installed according to the instructions. Then set the default language, greeting, and questions.

4.1.4.2. Set-up for Chatbots

After applying the settings, different groups can be built at will. For example, teachers can group general information and group lessons. In each group, we can continue to build tags, including many types of images, text, audio, video, files, etc., depending on the format you want to upload to the data system. In each card, we can click the add button to add information for the created card. It can be an extra tag, a link, a phone number or a module.

4.1.4.3. Building Menus for Chatbots

For optimization, we should use a hybrid chatbot form in addition to exchanging by asking questions. Users can learn information according to the instructions. For example, a teacher who wants to orient students to study according to available lectures will set up a self-study section. In each menu, we can set the information by assigning created tags, links, or modules. For example, in the section “I want to self-study,” the lesson cards set up above were attached. Then when students use it, it will display the lessons available in the database.

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4.1.5. Step 5: Training the Chatbot

4.1.5.1. Chatbot-building Procedure

After a chatbot is completed in terms of interface and menus, the most important and time-consuming work is training the bot. Simply put, for the chatbot to interact with the users, the teacher needs to build a database large enough to meet the needs of the learners. For ease of data entry, we can divide it into different lessons, topics, chapters, etc. For each topic, we start entering the data for the chatbot. User questions need to be entered first, which can be a keyword, phrase or a complete question, and then the results that the chatbot will answer are entered. For example, when users want to ask about potential energy, they may ask "What is potential energy?", "Expression of potential energy", "I want to ask my teacher about potential energy." Based on the question/text entered in the chatbot, when a keyword appears, the chatbot will return relevant results. The results can be formatted as text or can be in the form of images, links, audio, video, etc., by linking to the tags created in step 3.

Following the above process, the instructor will train the chatbot to grow, become smarter, and answer many questions. The more data that is added to the Chatbot regarding the interaction between teachers and students in various situations, the smarter the Chatbot becomes. The teacher can use the chatbot to help students answer questions. Figure 2 illustrates the training process of the chatbot.

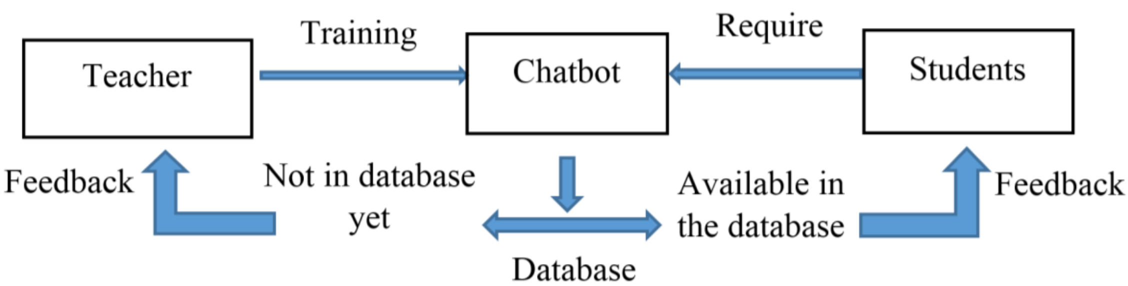

Figure 2. Working process of chatbot.

When students send a request to the chatbot, it will automatically give responses from the available database. If the request is beyond the scope of the bot, the teacher will collect new questions from the students and continue to train the chatbot.

The teacher has a great role to play to help the chatbot work effectively. To process the data quickly, the teacher can divide the knowledge array of the lesson content and train the chatbot according to the process outlined in Figure 3, which illustrates the segmented construction of educational content during the training of the chatbot.

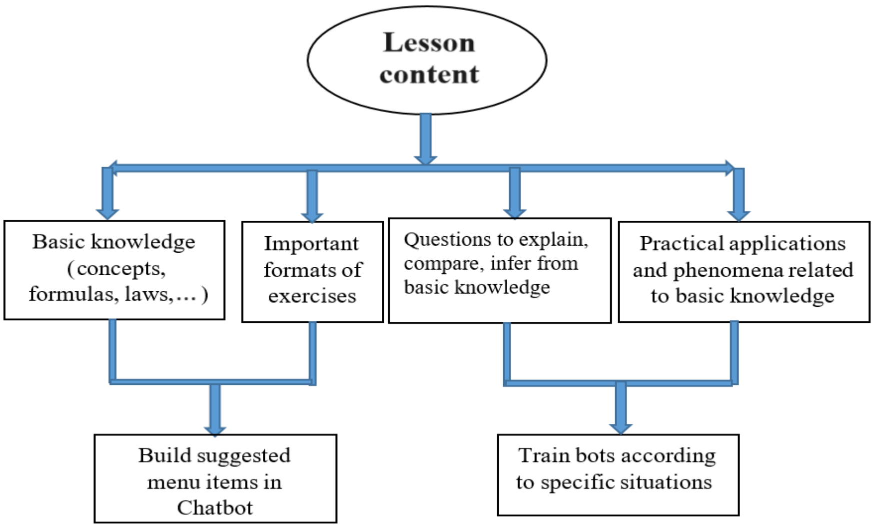

Figure 3. Fragmentation of knowledge for training the chatbot.

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Once the appropriate knowledge has been classified, the database construction becomes easier to complete. Teachers can consult experts so that the database covers the entire content of knowledge. However, questions posed by students can be diverse and there will be situations that teachers cannot anticipate. These questions will be collected, processed and added to the database. The chatbot will need to answer many questions from learners, so it needs to be equipped with a large enough amount of data to cover all the knowledge of the lesson. Due to the number of unanticipated questions, it is not possible to complete the system in a short period of time, but it will need to be constantly updated to include new knowledge, as described in Figure 4, which illustrates the database building process for chatbots.

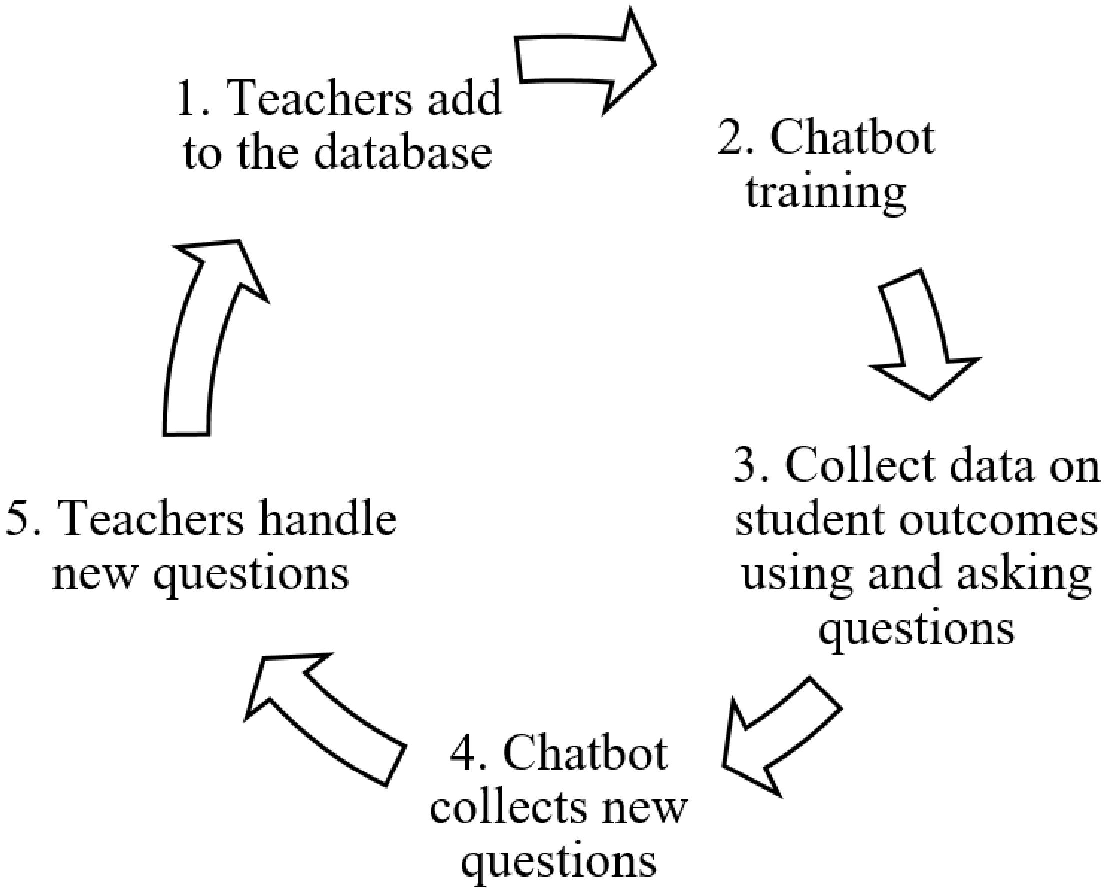

Figure 4. Database building process for chatbots.

- Step 1: The teacher studies and builds a foundational database system based on the lesson content by analyzing, learning, consulting experts, and reading documents.
- Step 2: Import the database into the platform to train the bot.
- Step 3: Let students use the chatbot and ask questions related to the lesson content.
- Step 4: The chatbot system will record questions that are not included in the data system.
- Step 5: The teacher synthesizes new questions, processes the information and adds it into the database.

After Step 5, the process will be repeated cyclically, and new questions will continue to be added to the database. Then the students of the next grade will inherit the knowledge base of the previous generation. Chatbots will continue to be trained and become increasingly intelligent and knowledgeable.

4.1.5.2. Using Chatbots to Guide Students to Self-Study the Laws of Conservation (Physics 10)

4.1.5.2.1. Building Items in the Chatbot Menu

- Key knowledge includes concepts, laws, and theorems about kinetic energy, potential energy, and mechanical energy.

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- Basic types of cards: kinetic energy, kinetic energy change, potential energy, conservation of mechanical energy.
- Basic formulas to memorize.

4.1.5.2.2. Training the Chatbot According to Hypothetical Situations

In addition to the background knowledge, the teacher learns the content related to the lesson, practical examples, applications in life, and phenomena that can be explained through knowledge of the lesson.

Table 1 represents the response content corresponding to various types of questions during the training process of the chatbot.

Table 1. Training questions chatbot.

Classify	Number	Question (Similar questions are separated by)	Answer
Concept question	1	Gravitational potential energy/Expression of gravitational potential energy/Formula of gravitational potential energy/Types of potential energy	Gravitational potential energy is obtained when an object is at a height above the reference object. The expression for gravitational potential energy is $W_t = mgh$
	2	What is potential energy/What is the expression of potential energy/Formula for potential energy/When does potential energy appear/Definition of potential energy	There are two main types of potential energy: elastic potential energy and gravitational potential energy. Gravitational potential energy is obtained when an object is at a height above the reference object. The expression for gravitational potential energy is $W_t = mgh$ Elastic potential energy is obtained when an object is elastically deformed. The expression for the elastic potential energy of the spring is $W_{đh} = \frac{1}{2}kx^2$ (x = spring strain)
	3	What is kinetic energy/Kinetic energy formula/When does kinetic energy appear?	The kinetic energy of an object is the energy obtained due to the object's motion and is equal to: $W_đ = \frac{1}{2}mv^2$
	4	The formula for the change of kinetic energy/The change in the kinetic energy of an object/The kinetic energy theorem	The change in kinetic energy of an object is equal to the sum of the work done by the external forces acting on the object. $W_{đ2} - W_{đ1} = A_{Externalforce}$
	5	Law of conservation of mechanical energy/State the law of conservation of mechanical energy	When an object is acted upon only by potential forces, the mechanical energy of the system is conserved: W = Const
	6	What is mechanical energy/What types of energy does mechanical energy include/Definition of mechanical energy/Concept of mechanical energy/Expression of mechanical energy	The mechanical energy of an object includes kinetic and potential energy. $W = W_{đh} + W_t + W_đ$
	7	What is elastic potential energy/Expression of elastic potential energy/Formula for elastic potential energy	Elastic potential energy is obtained when an object is elastically deformed. E.g., for a spring, the formula is: $W_{đh} = \frac{1}{2}kx^2$, where x is the deformation of the spring.
Questions to explain/ compare	8	Distinguish between kinetic energy and momentum/What is the difference between kinetic energy and momentum/Momentum is different from kinetic energy	The kinetic energy of an object is the energy obtained due to the object's motion and is equal to: $W_đ = \frac{1}{2}mv^2$. Momentum is a quantity that characterizes an object's ability to transmit motion. Momentum is a vector quantity.

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Classify	Number	Question (Similar questions are separated by)	Answer
			In terms of magnitude: $p = mv$
	9	Why does kinetic energy change after collision/On collision why does kinetic energy change?	When there is a collision, the object is subjected to a force according to Newton's second law. An acceleration occurs causing a change in velocity, thereby leading to a change in kinetic energy.
	10	Is potential energy negative? /Can potential energy be negative? /When potential energy is negative/Is gravitational potential energy negative? /Potential energy is negative	
	11	Can mechanical energy be negative? /When mechanical energy has negative value/Is there any case of negative mechanical energy?	Potential energy is a scalar quantity that depends on the location of the potential datum. So potential energy can be negative when the position of the object is lower than the position selected as the potential landmark. When an object moves in a gravitational field: $W = W_{đ} + W_t = mgh + \frac{1}{2}mv^2$. Kinetic energy is always positive, but potential energy depends on the location of the potential datum, so potential energy can be negative, resulting in mechanical energy being negative.
	12	What potential energy does an object have, and when does the object have mechanical energy?	Objects capable of doing work.
	13	Why does a compressed spring have potential energy/Why does a compressed spring have potential energy?	Because then the spring has the ability to do work.
Questions related to practice	14	When can the law of conservation of mechanical energy be applied? /Cases where the law of conservation of mechanical energy can be applied	The law of conservation of mechanical energy is used when an object is acted upon only by potential forces (e.g., elastic force, gravity, electric field force).
	15	Give an example of the change between kinetic and potential energy	Oscillating clock pendulum, swing, hammock swing.
	16	Example of converting kinetic energy into potential energy	Playing basketball, football, badminton, table tennis, long jump, throwing an object high, riding uphill.
	17	Examples of potential energy to kinetic energy	Waterfall flowing from above, athletes' archery, slides.
	18	Applications of mechanical energy in life/Applications of mechanical energy use/How mechanical energy is applied	This type of energy is widely used in modern life. The most obvious evidence is in: - Manufacturing moving objects, means of land, water and air transport such as bicycles, motorbikes, cars, trucks, airplanes, boats, and canoes. - In recreational activities such as golfing or bowling. - In the military, such as manufacturing guns. - In production to operate machinery, equipment C11 is automatic or manual. - Application in hydroelectric power plants.
	19	What is the energy when shooting arrows	When shooting an arrow, initially pulling the bowstring will give the object an elastic potential energy, then the potential energy will be converted into kinetic energy when releasing the arrow.
	20	Describe an athlete's movement when participating in skateboarding/Describe the conservation of mechanical energy when a skater skates/Describe a skateboarder's motion	When starting to skateboard, the athlete stands at the beginning of the chute, now the kinetic energy is zero, and the mechanical energy is equal to the maximum potential energy. When sliding to the bottom of the trough, the potential energy is 0, and the mechanical energy is equal to the maximum kinetic energy. When reaching the other end of the trough, the kinetic

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Classify	Number	Question (Similar questions are separated by)	Answer
			energy is 0, and the mechanical energy is equal to the maximum potential energy.
	21	Why do tsunamis cause havoc only when they hit an obstacle?	Tsunamis cause destruction only when they hit an obstacle because the destructive power of a tsunami is created by resonance when successive waves crash inland. When encountering obstacles, the waves crash more and more consecutively, leading to more destructive power.
	22	Why are tsunamis so much more destructive than normal waves?	Waves are usually created by the action of wind on the surface of the water creating the propagation of energy on the surface. Tsunamis are mainly caused by underground earthquakes or volcanic activity, giving the waves energy.
	23	In what form does the energy of waves exist?	The energy of the wave exists mainly in the form of kinetic energy.
	24	When it hits the earth, what kind of energy is a meteorite's energy converted into?	When hitting the Earth, the energy of a meteorite is converted into kinetic energy, forming craters on the Earth's surface.
	25	Why is the energy of meteorites so great compared to the energy of common objects?	The energy of meteorites is very large compared to the energy of common objects because: - A meteorite has a large mass. - Meteors move at great speed = great kinetic energy. - The distance from the meteorite to the Earth is very large. There is very large gravitational potential energy.
	26	When in flight/In what form does the meteorite's energy exist?	When in flight, the meteorite's energy exists mainly in the form of kinetic energy and gravitational potential energy, in addition to light and thermal energy.
	27	Please describe the operation of a glider/Why is it that when a roller coaster is at the top of the track its speed is slowest and vice versa?	The traction of the engine does the work of bringing the roller coaster to the top of the track, storing maximum potential energy. As the wagon slides down, its kinetic energy increases and at the same time its potential energy decreases. When reaching the bottom of the track, all the potential energy has been converted into kinetic energy, thermal energy and sound energy.
	28	Drop a ball from height h to the floor. What form of energy is the ball's kinetic energy converted into as soon as it hits the floor?	Most of the ball's kinetic energy is converted into potential energy causing it to bounce. A small portion of the kinetic energy of the ball is converted into heat (Heats the ball and the floor) and sound energy (Makes a sound when the ball hits the ground).
	29	An example of an object that has both kinetic and potential energy	When airplanes are flying, birds are flying, etc.

After building hypothetical scenarios for questions related to the topic, the teachers can train bots easily on the Messnow platform. When the chatbot database has been completed, the teacher guides students to self-study with the chatbot and the teacher collects questions that are not yet in the system. New questions will be announced again for teachers to add, and from these, additional related questions can be developed.

Table 2 presents the questions added to the chatbot's database by teachers based on student feedback.

Table 2. New data developed by teachers from student questions.

Number	Question	Answer
1	Why is gravity called a force?	Because the work of an object is only affected by force. It does not depend on the path format; it only depends on the position of the start and end points.
2	What are the types of forces?	Conservation forces, also known as potential forces, are forces that, when acting on an object, produce mechanical work whose magnitude does not depend on the form of the path, but only on the position of the starting and ending points. Potential forces include gravitational force and static force, because the work of an object is only affected by the force, independent of the shape of the path and only depending on the position of the beginning and the end; electric force, elastic force, constant force.

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Number	Question	Answer
3	What is elastic force? /Elastic force	Elastic force is produced when an object is deformed. With a spring, the elastic force has the expression: F = kx (x: strain)
4	What is electrostatic force?	Electrostatic force is the force of interaction between two stationary charge carriers. If two objects of the same sign repel each other, two objects of opposite signs will attract each other.
5	What is a constant force?	Force with constant magnitude and direction.
6	What is the work of force/work expression?	Work is understood as mechanical work. When a force acts on an object to move the object, we say the force has done work. Work expression: A = FScosα F: Applied force S: Distance traveled α: Angle between the direction of force and the direction of motion.

After researching more new questions, the teacher added the data source and trains the chatbot. Thus, the more knowledge sources are expanded, the more questions the students can answer.

4.2. Second Research Stage

4.2.1. Building Lessons Plans

In the first step, two lesson plans are developed. Both lesson plans are structured as tasks that learners need to undertake for self-study completion. Each learning task clearly specifies the learning outcome that students need to achieve and provides general, non-specific instructions to guide learners on how to accomplish the task. Both lesson plans allow the use of textbooks and common internet search tools to complete the learning tasks. However, for the experimental class, the lesson plan permits students to use the newly developed chatbot.

4.2.2. Development of Measurement Instruments

The first measurement instrument is a questionnaire consisting of six quantitative items and one item for collecting additional comments from students. These items are the main components when discussing students' attitudes after using the chatbot in self-study physics. Each quantitative item is divided into four levels for students to self-assess. The higher the level, the higher the agreement. A score of 1 indicates disagreement with the statement in the item, while a score of 4 indicates strong agreement with the statement.

The second measurement instrument is a physics content test. The 45-minute test consists of 30 multiple-choice objective physics questions with four options. The questions mostly cover key knowledge and topics where students often have misconceptions. The test results are converted to a 10-point scale. A score of 0 corresponds to answering all 30 questions incorrectly or not answering at all. A score of 10 corresponds to answering all 30 questions correctly.

4.2.3. Selection Research Samples

The research sample consists of tenth grade students at the High School for Gifted Students of VNU University of Sciences. The school has six classes of tenth grade students, with each class having between 35 and 45 students. The homogeneity of the two selected samples is based on two criteria: the scores achieved in the physics learning process, and the feedback from the physics teachers teaching those classes.

The scores of exams in Vietnam are graded on a scale of 10, where higher scores correspond to more correct answers. Based on the physics subject scores up to February 2023, two relatively homogeneous samples were selected. It was very difficult to choose two samples with exactly the same scores, so we chose five score ranges: 0–5, 5–6.5, 6.5–8, 8.5–9, and 9–10. Within each score range, we ensured that the number of students in both samples was equal.

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Next, we interviewed teachers to compare the physics learning abilities of students in each score group. If the teachers detected any anomalies, such as a student in a group with significantly superior or inferior physics proficiency, we would replace them with another student of equivalent proficiency.

The selected control group consisted of 50 students, denoted as 10A, and the experimental group also comprises 50 students, denoted as 10B.

4.2.4. Conducting the Pedagogical Experiment

The pedagogical experiment was conducted at the High School for Gifted Students, Vietnam. The experimental period was from February 13–24, 2023. The control group and the experimental group were given learning tasks. The self-study time for each group was 90 minutes. After the 90-minute self-study period, the control group underwent a 45-minute test. The experimental group then took a 45-minute test and completed a form.

We have built a chatbot, a test to assess the topic of kinetic, potential, and mechanical energy in grade 10 high school. The assessment of the effectiveness of chatbots and learners' interest is through student self-assessment questionnaires using specific criteria and a comparison of test results between the experimental group and the control group.

5. DISCUSSION AND RESULTS

5.1. Experimental Results

5.1.1. Evaluating Students' Attitudes After Using the Chatbot in Physics Learning

The effectiveness of the chatbot in helping students' self-study is based on the level of agreement through the survey. The assessment results are assigned according to the respective levels: 4 = very good, 3 = good, 2 = normal, 1 = not good. Table 3 presents the experiment results on the effectiveness of chatbots in helping students learn on their own.

Table 3. Experiment results on the effectiveness of chatbots to help students learn on their own.

Expression	4 (Very good)	3 (Good)	2 (Normal)	1 (Not good)
Are you excited to use chatbots during self-study?	36	8	5	1
Can chatbots help you find accurate information?	31	15	4	0
Can chatbots help you save time studying?	32	15	2	1
Can chatbots help you study more easily?	31	14	3	2
Do you think it is necessary to use chatbots in learning?	35	9	5	1
Can chatbots help you reduce stress while studying?	29	13	7	1

In response to "Are you excited to use chatbots during self-study?", 36 students (72%) felt very excited, and eight students (16%) felt excited, showing that most of the students felt excited when experiencing a chatbot application. This shows that chatbots have helped students learn effectively and easily by themselves. Not only is it interesting, but 88% of students think that the use of chatbots in teaching is necessary or very necessary, showing that the research, development, construction and use of chatbots in teaching is appropriate.

5.1.2. The Effectiveness of Using Chatbots in Physics Teaching

Based on the objectives of the original lesson, the two classes, 10A and 10B, were taught the same program and the content of knowledge on the topic of kinetic energy, potential energy, and mechanical energy was the same. The one difference was that the self-review process at home of the 10B students was further supported by chatbots. The two classes were assessed with the same test, consisting of 20 multiple-choice questions divided into four levels: know (4 questions), understand (10 questions), apply (4 questions) and highly apply (2 sentences). Figure 5 illustrates the comparison of the test score between the control group and the experimental group.

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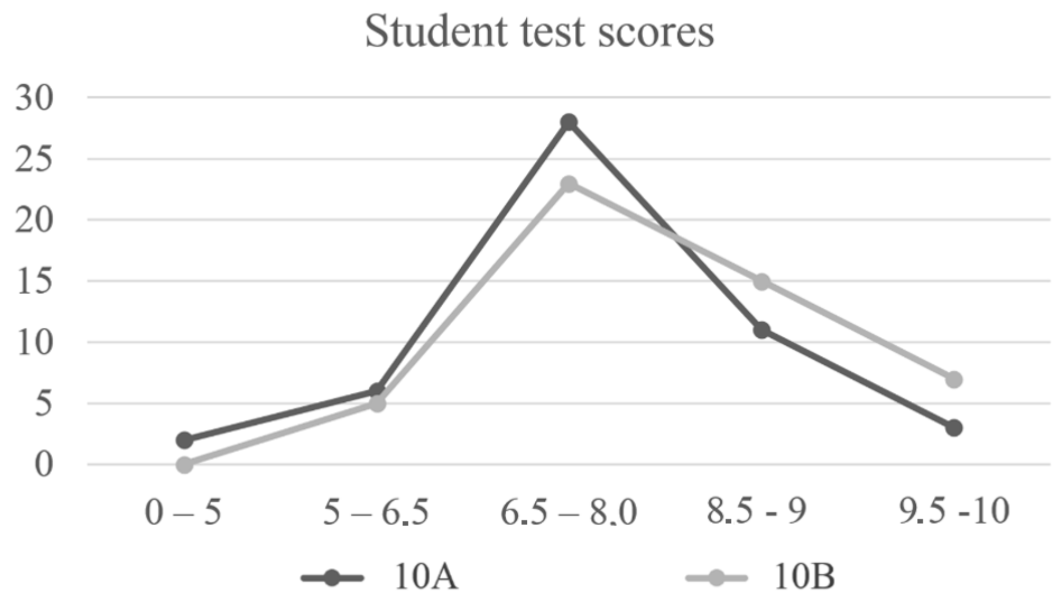

Figure 5. Comparison of test scores between the experiment and control classes.

The results show that the experimental class had five students and the control class had eight students with scores below 6.5. To achieve this score, students needed to be able to complete sentences at the level of knowing and understanding. When using a chatbot students will have better theoretical background knowledge. With scores between 6.5 and 8, accounting for the highest percentages in the two classes of 28 and 23 students, respectively, this score required students to complete all sentences at the level of understanding, knowing and being able to do a certain amount of work. There were 22 students in the experimental class and 14 students in the control class with scores above 8.5 (excellent). These students answered all of the application questions and some highly applied questions. This confirms that the chatbot had a positive impact on students' self-learning ability.

5.2. Discussion

5.2.1. Findings Derived from the Experiment Data

The research results presented show a significantly high level of student engagement and satisfaction with the use of chatbots in self-study sessions. The majority of the students responded positively to the questions, demonstrating strong enthusiasm for incorporating chatbots into their learning experiences. Specifically, the question related to excitement when using chatbots during self-study showed that 72% of the total respondents expressed high levels of excitement, and an additional 16% said they felt excited. This excitement underscores the effectiveness of chatbots in facilitating students' self-directed and effective learning experiences. Notably, the findings show that the chatbot not only enhanced the learning outcomes but also contributed to making the learning process more interesting and engaging.

Furthermore, the vast majority of students (88%) expressed their belief in the necessity and importance of integrating chatbots into teaching practice. This overwhelming consensus highlights the alignment between research goals and the perceived utility of chatbots in educational settings. It shows that researching, developing, building and using chatbots in teaching is not only appropriate but also necessary to enhance the overall learning experience.

The comparison of the test scores between the experimental class, which received additional support from a chatbot during self-assessment, and the control class, which followed a standard curriculum, provided valuable insights into the impact of integrating chatbots on student learning outcomes. The analysis of the test scores showed clear differences between the two classes at different score levels.

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With lower scores (below 6.5), the experimental class had a lower number of students (5) than the control class (8). This suggests that using chatbots can enhance students' underlying theoretical knowledge, thereby potentially reducing the number of students who struggle with basic concepts.

At the average score (6.5–8), both classes had a large number of students, with 28 students in the experimental class and 23 students in the control class in this range. This indicates equivalent levels of proficiency in understanding and applying knowledge between students in both groups.

Notably, regarding higher scores (over 8.5), the experimental class prevailed over the control class, with 22 and 14 students, respectively. These findings suggest that chatbot-assisted self-study can have a positive impact on students' ability to solve more advanced application-based questions, suggesting enhanced self-study ability in students exposed to chatbot support.

The results of this study highlight the potential of chatbots as an effective tool to enhance self-directed learning and improve learning outcomes. These findings provide compelling evidence supporting the integration of chatbots into educational practices to promote autonomous and engaging student learning experiences.

5.2.2. Comments from the Students

After using the chatbot to perform tasks, the students' feedback was mostly positive, but they also listed some areas that needed improvement. They emphasized the importance of enhancing the problem-solving ability of chatbots, which should have the function of guiding research sources or indicating referenced sources to ensure the reliability of answers. Additionally, students emphasized the need to integrate comparisons with responses on reputable professional forums. They argued that this will facilitate the creation of more appropriate solutions. Furthermore, the students recommended that the chatbot should have a function that allows the upload of documents to help the chatbot orient itself in finding and learning from the information in the included documents and drawing conclusions from the documents themselves. They also recommended that units of quantity should be combined, ensuring accuracy and clarity of responses. Furthermore, students called for a deeper expansion of the chatbot's knowledge base, particularly in specialized topics of disciplines. The students' perceptions reflect the enormous potential of chatbots as a learning aid if their ability is honed to provide nuanced, comprehensive, and accurate information that is contextually relevant, especially in the context of specific disciplines. Therefore, there is a need to increase chatbot integration across various academic fields, ensuring that students receive accurate, insightful and clear responses to their questions.

Incorporating students' feedback is crucial for refining and improving the efficacy of educational tools such as chatbots. Following their engagement with the chatbot for professional tasks, students offered valuable insights that highlighted its strengths and areas for improvement.

One key aspect emphasized by the students was the importance of bolstering the problem-solving capabilities of chatbots. They suggested that chatbots should possess functionalities that guide users toward relevant research sources or indicate references to ensure the reliability of answers. This aligns with the broader goal of fostering critical thinking and research skills among students, as it encourages them to verify information and seek out authoritative sources.

Additionally, students underscored the need for integrating comparisons with responses from reputable professional forums. By leveraging insights and perspectives from established professionals in the field, chatbots can offer more robust and nuanced solutions, enriching the learning experience for students.

Moreover, students advocated for the incorporation of a feature that allows the chatbot to access and analyze additional documents, thereby enhancing its ability to locate and derive insights from diverse information sources. This capability would not only facilitate a deeper understanding of the subject matter but also promote independent learning and information synthesis among students.

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The students also emphasized the importance of ensuring accuracy and clarity in the information provided by the chatbot, particularly in terms of unit conversions and data presentation. This highlights the need for meticulous attention to detail and precision in the development and maintenance of chatbot functionalities.

In addition, the students called for the expansion of the chatbot's knowledge base, particularly in specialized areas of various disciplines. This underscores the importance of continuous updates and additions to the chatbot's repository of information to ensure its relevance and usefulness across diverse academic fields.

The feedback underscores the immense potential of chatbots as learning aids, provided they are equipped with the capabilities to deliver nuanced, comprehensive, and contextually relevant information. To maximize the effectiveness of chatbots in education, there is a pressing need for their integration across various academic domains, accompanied by ongoing refinement and enhancement to meet the evolving needs of students and educators alike.

6. CONCLUSION

6.1. Enhancing Education Through Chatbot Integration

The integration of chatbot technology into the self-study process, particularly within the realm of physics education, emerges as not only necessary but also highly advantageous, aligning seamlessly with the educational landscape outlined in the 2018 general curriculum for Vietnam. This study has illuminated the significant benefits that chatbots bring to students, facilitating enhanced learning outcomes and fostering a deeper interest in the subject matter. Moreover, the positive feedback and constructive suggestions provided by the students further underscore the potential for ongoing research and development in this field.

The results obtained from the experimental implementation utilizing a meticulously crafted four-step method, provide compelling evidence of the efficacy of chatbots in augmenting students' self-study endeavors. Notably, the majority of the students exhibited a favorable response to the utilization of chatbot technology, with many expressing enthusiasm and engagement during the learning process. However, the short duration of the study prompts the need for further investigation to ascertain the long-term impact of chatbot integration on high school students' learning outcomes.

The insights gleaned from the students' comments highlighted areas for improvement and refinement in chatbot functionality. The emphasis on enhancing problem-solving abilities, ensuring the reliability of answers through research source guidance, and integrating comparisons with responses from reputable forums underscores the importance of continuously honing chatbot capabilities to meet evolving educational needs. Additionally, suggestions for expanding the knowledge base, particularly in specialized disciplines, highlight the untapped potential of chatbots as versatile learning aids.

This study not only affirms the feasibility and effectiveness of teachers constructing chatbots to aid self-learning but also underscores the transformative impact of the proposed 5-step chatbot development process. Through meticulous attention to lesson objectives and comprehensive knowledge acquisition, teachers can harness the power of chatbots to enhance student effectiveness and engagement in physics education.

In conclusion, the successful integration of chatbots into the educational landscape represents a significant step forward in advancing self-directed learning and enriching the teaching-learning experience. As we continue to explore the myriad of possibilities afforded by chatbot technology, it is imperative that educators and researchers collaborate to unlock its full potential across diverse academic disciplines, ensuring that students receive accurate, insightful and contextually relevant support in their learning journey.

6.2. Policy Proposals

The findings of this study highlight the potential of integrating chatbots into educational environments, especially in the areas of physics teaching and self-study. Based on the results and discussions presented, several

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policy recommendations can be proposed to improve the effectiveness and widespread adoption of chatbots in educational policies and practices:

Integration into the curriculum: Education policymakers should consider incorporating chatbot-powered learning modules into the curriculum, especially in subjects such as physics that require self-study skills and the ability to solve problems.

Teacher training and support: Policy makers should allocate resources to train teachers on how to use chatbots effectively in the classroom. Teachers need to be equipped with the necessary skills and knowledge to seamlessly integrate chatbots into their teaching activities.

Quality assurance and content authentication: It is imperative to establish quality assurance mechanisms to ensure the accuracy and reliability of content generated by chatbots. Educational institutions should collaborate with subject matter experts and educational technologists to validate the content provided by chatbots, especially in subjects such as physics, where accuracy and precision are key.

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