Development of an Educational Chatbot System for Enhancing Students' Biology Learning Performance

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Abstract

In traditional biology classrooms, teachers do not have enough class time to interact with students, and students often do not have the opportunities to raise questions in class. Therefore, out of class, students may not have sufficient ability to learn and review biology knowledge based on faulty foundations. To address the problem, it is important to provide suitable learning tools to support students conducting biology learning out of class. In recent years, chatbots have been adopted in various fields for providing instant interactions and supports to users. Therefore, by using chatbot technologies in biology education, students can interact with a chatbot out of class anytime and anywhere and further obtain instant learning supports. Bearing this in mind, the aim of this study is to propose a biology learning chatbot system that can support students to learn biology out of class. Moreover, a quasi-experiment was designed for a grade 7 biology course in a junior high school. 34 students were asked to participate in the experiment and divided into a control group and an experimental group. The experimental results indicated that the proposed chatbot system had a positive impact on students' learning achievements in traditional biology learning.

Keywords: Biology education, Chatbot, Learning achievement, Quality education

1 Introduction

Literatures indicated that grade 7 students may engage in frustration and unpleasant learning experiences in biology classes and get low learning performances, since biology classes are difficult for them [1-2]. In traditional classrooms, teachers and students must be in the same place at the same time, and the same teaching strategies and plans are adopted for students, no matter what their levels are. When students are unable to understand teaching contents in classes, it could have a negative impact on their learning activities and further lead them to get low learning motivation and learning achievement [3-4]. With the advancement of information and communication technology (ICT) and the change of learning mode, learning with technology and Internet is the current trend worldwide. In technology-enhanced online learning modes, students are not restricted by time and place, and they can obtain suitable learning subjects and materials based on their prior knowledge and learning status [5]. Literatures indicated that during the learning process, appropriate and immediate learning supports to students are important. Otherwise, students' learning motivation and achievement may have negative effects while encountering learning problems [6-7].

In recent years, with the social media rise, instant messaging applications have become more and more important, such as LINE, Facebook Messenger, WeChat, etc [8]. They provide users with a real-time and convenient way to exchange information. Thus, many service providers also use instant messaging applications to provide real-time information services to users. The interaction of instant messaging applications changes the software services from traditional interface operations to conversational interface operations. Based on the instant and convenient interaction and the rapid development of communication software, it has become a well foundation to promote the development of chatbots [9].

Based on instant messaging applications, chatbots break through the traditional interactive interface. Users can operate familiar instant messaging applications without downloading, installing, and learning additional and different software [10]. Moreover, chatbots can engage users in getting particular services through conversation-based interactions. Chatbots can help users to complete specific tasks entrusted to them at any time and place in the shortest time and enhance the user experience. In addition, chatbots can collect users' behaviors and preferences through conversation-based interaction processes, and then provide personalized services to each user [11]. Based on the above, chatbots have been adopted in many industries to expand the services in various fields, such as shopping consultation, financial advice, medical consultation, and personal assistant, etc [12]. However, the education field is still lacking of chatbot developments and applications.

As mentioned above, this study aims to develop a biology learning chatbot system to support grade 7 students' learning in biology classes. The proposed chatbot system can support students in conducting biology learning activities out of class. To explore the effectiveness of the proposed approach, 34 grade 7 students were divided into a control group and an experimental group. The students of the two groups were

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DOI: 10.53106/160792642023032402006

invited to learn biology in traditional classrooms and adopt two different learning approaches out of class (online biology discussion group and biology learning chatbot system). For investigating the effects of the proposed learning approach, the research questions of this study were proposed as follows.

(1) Could the biology learning with the chatbot system enhance students' learning achievement more than the biology learning with the online discussion group?

(2) Did students' prior knowledge influence their learning achievement while learning biology with the chatbot system and the online discussion group?

2 Literature Review

In traditional biology classrooms, teachers usually conduct lecture-based instructions during the course session and students receive the instructions passively [13]. Furthermore, in order to facilitate students' learning, teachers typically assign exercises as homework to students out of class [14]. Nevertheless, students generally meet difficulties to complete the assignments out of class [15].

The traditional biology teaching strategy make it difficult to engage students in learning abstract biology concepts during a 40-minute class [16]. During the learning process, teachers do not have enough class time to interact with students and students often do not have opportunities to raise questions in class [17]. Therefore, out of class, students may not have sufficient ability to learn and review relevant knowledge based on faulty foundations [18]. To address the problem, it is important to provide suitable learning tools to support students conducting biology learning out of class [19].

Thanks to the advancement of information and communication technology (ICT), it is feasible to promote students learning with technology-supported learning tools in biology education [20-21]. Literatures have indicated that ICT is a catalyst to benefit students' biology learning. For instance, scholars applied augmented reality (AR) technology to concretize abstract biology concepts and further enhance students' learning motivation and achievement [22]. Furthermore, teachers can also use ICT to promote student-centered learning activities in traditional biology classrooms [23]. Therefore, literatures have evidenced that ICT benefits students' biology learning in traditional classrooms.

However, out of class, students learn and review biology knowledge alone without teachers' and peers' interactions that is still lacking of suitable ICT supports. Literatures suggested that during the learning process, appropriate and immediate learning supports to students are important [24-25]. Otherwise, students' learning motivation and achievement may be negatively affected while encountering learning problems [6-7]. Previous studies indicated that chatbots are suitable technology to provide instant interactions and supports to users [26-28]. Therefore, by using the chatbot technology in biology education, students can interact with the chatbot out of class anytime and anywhere and further obtain instant learning supports [29-30].

3 Biology Learning Chatbot System

In this study, a biology learning chatbot system was proposed based on LINE messaging API to support grade 7 students' biology learning out of class. LINE is a popular and an international instant message application. Figure 1 shows the architecture of the biology learning chatbot system. LINE Messaging Server receives and responds to clients and manages the permissions of the LINE application. When the LINE server receives client-side messages, it forwards them to the biology learning chatbot system developed in this study. The system program was developed by PHP and deployed in the chatbot server. The chatbot server was built on Linux operating system with Apache web server and MySQL database. The database is composed of a learning materials database and a student information database. The learning materials database stores teaching materials from Junyi Academy and the student information database stores students' learning records.

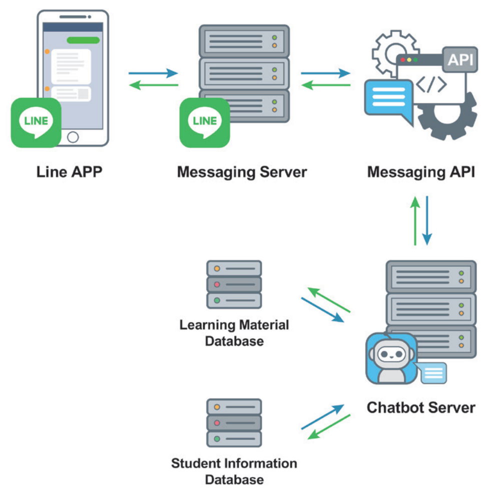

Figure 1. The architecture of biology learning chatbot system

The main functions and usage scenarios of the biology learning chatbot system are described as follows.

3.1 Add Friends

This system is a chatbot developed on the LINE platform. To use the chatbot system firstly, students have to use the LINE APP to add the biology learning chatbot as a LINE friend by scanning a QR code or entering an ID.

3.2 Getting Started Screen

After adding the proposed chatbot as a LINE friend, the start screen of the chatbot is shown in Figure 2. The Messaging API captures students' LINE user ID while students added the chatbot as a LINE friend. In addition, the proposed chatbot system would record students' LINE username, so that students can interact with the chatbot like a real person, just like a friend. At the bottom of the message window is a rich menu. This study designed four main functions in the rich menu for the proposed chatbot system that are Learning Video, Biology Assistant, Exercises, and Learning Record.

Figure 2. Screenshot of start screen and function menu of the biology learning chatbot system

3.3 Learning Video

When students click on "Learning Video" from the rich menu, the chatbot replies messages to guide them to select learning videos. All learning materials built in the chatbot system are referenced from Junyi Academy's secondary biology curriculum. After students select a learning video, the chatbot following replies a message to play the learning video to them, as shown in Figure 3. Moreover, the chatbot would record students' watch logs as their learning behaviours.

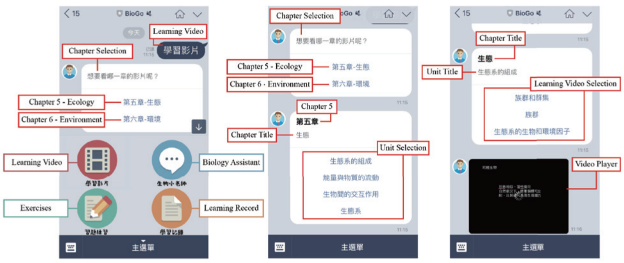

Figure 3. Biology learning chatbot learning video function

3.4 Biology Assistant

Biology assistant provides students with explanations of biology concepts. Students can use keywords to raise a question to the chatbot with regard to biology concepts. Following that, the chatbot can immediately reply a message to present the biology concepts and answer the question, as shown in Figure 4. Moreover, the chatbot would record students' keyword messages as their learning behaviours.

Figure 4. Biology learning chatbot biology teacher function

3.5 Exercises

The exercises function allows students to take assessments with the chatbot. When students select an unit, the chatbot would send messages to display a multiple-choice item and require students to answer the test item. Following that, the chatbot sends an instant message to show students' answer result and further ask them to take next item (as shown in Figure 5). To ensure the quality of the test items in the chatbot, all test items are referenced from Junyi Academy. If students do not understand the concepts with regard to the test item, they can use the learning video or biology assistant functions to review the concepts. In addition, the chatbot also records students' assessment logs as their learning behaviors.

Figure 5. Biology learning chatbot exercises function

3.6 Learning Record

When students send a learning record message to the chatbot, the chatbot would reply messages to show their learning records. The message information contains video watching records, query records, and assessment records, as shown in Figure 6. The query records can show nearly 10 queries that students have asked by using the biology assistant function, so that students can easily review the relevant concepts. The assessment records are to show students the test items that they answered correctly or missed in the exercises function to help them understand their weaknesses. If students do not understand a topic that they often make mistakes on, they can use the learning video function to review it again.

Figure 6. Biology learning chatbot learning record function

4 Experiment

To investigate the impact of the biology learning chatbot system on students' learning achievement, this study conducted a quasi-experimental design for a grade 7 biology course in a junior high school. The subject-matter area of biology in the experiment was focused on ecology and environment. The experiment had a length of 2 weeks.

A total of 34 grade 7 students and one teacher were asked to participate in the experiment. The average age of all students is 12.8. All students were divided into two groups. The first group of 17 students (7 males and 10 females) served as the control group. The second group of 17 students (9 males and 8 females) served as the experimental group. The two groups were supported by the traditional teaching strategy in the class. Out of class, the students in the control group were supported by a LINE discussion group to facilitate their learning. The students in the experimental group were supported by the biology learning chatbot system to facilitate their learning.

The overall procedure of this experiment is presented in Figure 7. Before the experiment, the students in the experimental group and control group were asked to take the second monthly examination to evaluate the equivalent of the students' prior knowledge of biology. During the process of the learning activities, the students in the control group and experimental group received theoretical concepts of ecology and environment from the teacher by using textbooks in the traditional classroom. After school, the teacher assigned homework to ask the students to complete it out of class. Furthermore, to assist the students of the two groups in learning and reviewing biology knowledge out of class, the teacher formed a LINE discussion group to the students of the control group and provided the proposed chatbot system to the students of the experimental group. After the experiment and learning activities, all students from the two groups took a post-test to measure their learning achievement. The pre-test and the post-test were administered as paper-and-pencil tests with a perfect score of 100. The KR-20 reliabilities of the pre-test and post-test were 0.749 and 0.757, indicating an acceptable internal consistency. Moreover, the mean difficulty indexes of the items in the pre-test and post-test were 0.56 and 0.68. The mean item discrimination indexes of the items in the pre-test and post-test were 0.43 and 0.38.

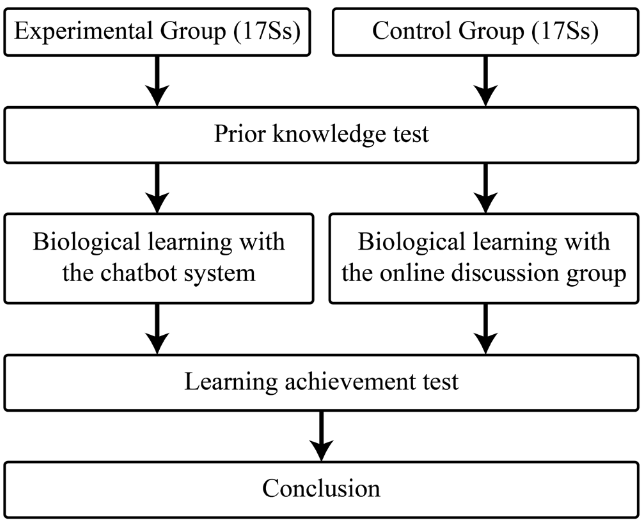

Figure 7. The experimental process

5 Results

The IBM SPSS was applied to analyze the performance of the students in the experiment, including the results of the prior knowledge test and learning achievement test.

With regard to the prior knowledge test, the mean value and standard deviation of the test scores were 64.35 and 18.36 for the control group and 59.64 and 16.25 for the experimental group. To evaluate the equivalent of the students' background knowledge with regard to biology before participating in the learning activities, an independent sample t-test was applied to analyze the prior knowledge test results between the two groups. Table 1 shows the independent sample t-test results of the prior knowledge test for the experimental group students and the control group students. The results showed that there were no significant differences between the experimental group and the control group before participating in the experiment (t = -0.791, p = 0.435 > 0.05).

Table 1. The independent sample t-test results of prior knowledge test for the two groups of students

Group	N	Mean	SD	t-test	
				t	p
Control group	17	64.35	18.36	-0.791	0.435
Experimental group	17	59.64	16.25		

$^*p < 0.05$

In order to further investigate the effect of the proposed approach on students' learning achievement, a one-way analysis of covariance (ANCOVA) was used to exclude the difference between the prior knowledge of the two groups. To conduct the ANCOVA, the learning achievement test results are set as the dependent variable and prior knowledge test results are set as the covariate. The results of the analysis in Table 2 show that there was a significant difference in the learning achievement test results between the experimental group and the control group students (F(1,31) = 9.821, p = 0.004 < 0.05, η^2 = 0.244). The students in the experimental group had better learning achievement test results than the students in the control group. The results show that the proposed chatbot system had a positive impact on students' learning achievements in traditional biology courses. Furthermore, the effect size η^2 was computed to measure the strength of the ANCOVA result. According to Cohen (1988), "η^2 = 0.01" indicates small effect size, "η^2 = 0.06" represents medium effect size, and "η^2 = 0.14" means large effect size [31]. In this result, the effect size (η^2) of learning approach was 0. 244, indicating a large effect size.

To further investigate the effects of the proposed approach on students' learning achievement, the students of the experimental group and the control group were divided into two parts according to the prior knowledge test scores respectively. By sorting the students' prior knowledge test scores of the control group and experimental group, the top 8 students with the highest prior knowledge test scores were assigned to the high prior knowledge group, and other 9 students were assigned to the low prior knowledge group.

Table 2. The ANCOVA results for the students' learning achievements

Group	N	Mean	SD	*Adjusted mean*	*SE*	*F*	η^2
Control group	17	72.47	17.30	70.66	1.72	9.82*	0.244
Experimental group	17	76.58	16.00	78.39	1.72		

*$p < 0.05$

A one-way ANCOVA was conducted to compare the scores of the learning achievement test for the two low prior knowledge groups. Table 3 shows that the adjusted mean and standard error of the experimental group were 71.07 and 3.58, while the control group was 57.81 and 3.58. The results of the analysis indicate that there was a significant difference in the learning achievement scores between the students with low prior knowledge from the experimental group and the control group ($F(1,15) = 8.999$, $p = 0.009 < 0.05$, $\eta^2 = 0.301$). Moreover, the effect size (η^2) was 0.301 for the variable, representing a large effect size [31]. Therefore, excluding the effect of prior knowledge test scores, it can be seen that the students with low prior knowledge used the proposed chatbot system to assist in traditional biology learning were more effective than the students with low prior knowledge who used the discussion group.

Table 3. The ANCOVA results of learning achievement test for the students with low prior knowledge from two groups

Group	N	Mean	SD	*Adjusted mean*	*SE*	*F*	η^2
Control group	9	60.44	14.88	57.81	3.58	8.999*	0.301
Experimental group	9	68.44	17.64	71.07	3.58		

*$p < 0.05$

In addition, a one-way ANCOVA was conducted to compare the learning achievement test scores of the students with high prior knowledge from the experimental group and the control group. As shown in Table 4, the adjusted mean and standard error of the experimental group were 85.23 and 1.33, while the control group was 86.26 and 1.33. The results of the analysis indicate that there was no significant difference in the learning achievement test scores between the students with high prior knowledge from the experimental group and the control group ($F(1,13) = 1.412$, $p = 0.256 > 0.05$, $\eta^2 = 0.022$). Therefore, excluding the effect of prior knowledge test scores, it can be seen that the students with high prior knowledge used the proposed chatbot system to support traditional biology learning were not significantly more effective than the students with high prior knowledge who used the discussion group.

Table 4. The ANCOVA results of learning achievement test for the students with high prior knowledge from two groups

Group	N	Mean	SD	*Adjusted mean*	*SE*	*F*	η^2
Control group	8	85.75	6.60	86.26	1.33	1.412	0.022
Experimental group	8	85.75	6.98	85.23	1.33		

6 Discussion

Applying the chatbot system proposed in this study to the junior high school biology classes had a positive impact on students' learning achievement. The past studies have pointed out that chatbots are instantly responsive and indicated that real-time feedback is an effective technology to engage learners [32-33]. Real-time feedback can create an effective learning environment based on student's learning status [34]. Thus, chatbots are an effective way to motivate students to learn, especially in a one-to-one learning environment [35]. In addition, the proposed chatbot system can effectively collect students' learning behaviors, which conforms to past studies. The studies suggested that collecting and presenting information about students' learning behaviors can support students to understand individual learning status in an online learning environment, thus enhancing their learning achievements [36-40].

Furthermore, through informal feedback from the students in the experimental group, several students reported that they were satisfied with their biology learning experience using the chatbot system. Moreover, they also indicated that they had a quality leaning experience on using the chatbot system. A different feedback from few students is that their parents may think they are chatting with friends while they are learning with the chatbot system. This phenomenon is consistent with the research findings [41-42]. Therefore, educational practitioners have to be able to provide appropriate guidance to stakeholders while implementing such learning approaches.

7 Conclusion

This study proposed a biology learning chatbot system to support traditional biology education. The chatbot system was proposed to assist students in learning and reviewing biology knowledge out of class. An experiment was conducted to evaluate the effects of the proposed approach on students' learning achievement. The results of this study indicate that the proposed approach was significant in improving students' learning achievement and had a significant positive effect on the learning achievement of students with low prior knowledge.

In summary, the main contribution of this study is to promote traditional biology education in junior high schools. In addition, some limitations should also be noted. First, as a result of junior high school semester considerations in Taiwan, this study did not conduct a random selection to distribute the students into the control and experimental groups. Second, the lack of generalizability is a limitation of the present data as the sample size was not large. Furthermore, since the number of samples is small in this study, the statistical power may be insufficient. Nevertheless, ANCOVA is still a robust approach to support the analyses in this study [43-44]. Future studies should implement large random selections and conduct various analyses when applicable. In addition, artificial intelligence and natural language processing technologies should be considered to integrate into the proposed chatbot system for enhancing the design of human-computer interactions.

Acknowledgements

This study is supported by the National Science and Technology Council, Taiwan, R.O.C. under grants NSTC 111-2410-H-153-012, NSTC 110-2511-H-153-002-MY3, and NSTC 108-2511-H-153-006-MY2. This study is also supported by the Ministry of Education, Taiwan, R.O.C. under grants MOE PEE1110245.

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Biographies

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