Using an Artificial Intelligence Chatbot in Scientific Inquiry: Focusing on a Guided-Inquiry Activity Using Inquirybot

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Received: 17 February 2023 | Revised: 10 May 2023 | Accepted: 15 May 2023

Abstract

This study aims to explore how to use an AI chatbot pedagogically in scientific inquiry by developing a guided-inquiry activity using an AI chatbot and applying it. The developed guided-inquiry activity consisted of designing and doing inquiry activities using the transmission of sound as the topic. In this activity, a chatbot, which was given the name Inquirybot, was designed with conversation flow and scripts for guiding the inquiry design process. By applying the developed inquiry activities and Inquirybot to fifth- and sixth-grade gifted students, we found several practical possibilities and challenges for using an AI chatbot in scientific inquiry. Based on the results, future tasks and educational implications are discussed in terms of efficiently adapting AI chatbots in scientific-inquiry activities.
Keywords

artificial intelligence – chatbot – guided-inquiry activities – pedagogical uses

Introduction

Recently, new technologies have been used in various educational settings (Martin et al., 2018; Riley, 2007). Technologies can be incorporated at different levels depending on their educational role in teaching and learning (Puente, 2010, 2012). This is also the case with artificial intelligence (AI), a form of technology that has recently received a great deal of attention. The new functions of AI have been greatly changing the picture of education (McArthur et al., 2005). AI, which judges the characteristics of learners on its own and provides automated responses or feedback, has been applied in various contexts, such as learning and evaluation. For example, AI has been used as an active support tool for learning, for example, by automatically scoring students' responses in writing and speaking assessments or learning vocabulary and practicing speaking with an AI chatbot (Benotti et al., 2017; Holotescu, 2016; Lee & Ha, 2020; Ha et al., 2019).

Among the many AI technologies, a chatbot is a type of software that can interact using texts or voices in a form like that of humans (Smutny &
For this reason, chatbots are useful in classroom situations where interactions frequently occur between the teacher and students or between students. Various chatbots have been developed, such as ChatGPT, DialoGPT, Replika, and JasperChat, and have started to be used in educational contexts (Khan et al., 2023). A well-known chatbot, ChatGPT, which can create amazing content in various fields, has had its possibilities discussed for use in education (Kelly, 2023). In addition, chatbots can provide individualized learning because they are based on an interaction method that is like human interaction and can give learning opportunities tailored to individual students’ levels or preferences (Holotescu, 2016; Pereira, 2016).

How can such educational possibilities and functions of AI chatbots be incorporated into science education? A few attempts to use AI chatbots in science education have been made so far. For example, a chatbot that provides additional information on exhibits in a science museum and one that classifies rocks based on learners’ observations and supplies relevant information have been developed (Busan Metropolitan City Office of Education, 2019; Kim et al., 2020). A study by Deveci Topal et al. (2021) during the COVID-19 pandemic, developed a chatbot that allows students to ask questions about the “matter and the changing states of matter” unit that they have studied online. This chatbot aimed to provide useful assistance in learning scientific knowledge. In this way, previous chatbots have tended to assist student learning through information delivery. Thus, more active pedagogical roles of AI chatbots need to be explored in various contexts of science learning. Based on the previous trials, we tried to focus on broadening the chatbot’s role of guiding students’ learning processes in inquiry activities beyond delivering information.

In this vein, the present study designed a scientific-inquiry activity using AI chatbots aimed at exploring ways of using AI technology in science teaching and learning. In inquiry activities in science classes, there is typically only one teacher who guides the inquiry problem and method by interacting with many students to carry out the inquiry (Bencze & Alsop, 2009; Kim & Tan, 2011). Teachers are generally expected to play the role of active facilitator, and students are expected to take the lead in performing the inquiry process (Kussmaul & Pirmann, 2021). However, in actual classrooms, it is difficult for a teacher to individually manage the questions of many students and to immediately answer students’ questions or give feedback. Chatbots could be used to solve these practical difficulties and redesign the learning environment in a more individualized and proactive way (Gupta & Chen, 2022).

Therefore, in this study, an AI chatbot called Inquirybot that supports inquiry activities in science classes was developed and applied in science lessons to give implications for science teaching and to learn with a view to
deriving practical implications for science teachers and science education researchers.

The research questions of this study are as follows:
1. What advantages can the chatbot provide in the guided-inquiry activities?
2. What difficulties did students face when applying the developed chatbot in guided-inquiry activities?

2 Background

2.1 Pedagogical Uses of AI Chatbot for Teaching and Learning

Attempts to use chatbots in teaching and learning have increased over the last several years (Colace et al., 2018; Cinglevue, 2017). Thus far, chatbots have been actively used in the field of language education, and the fields where they have been applied have been gradually expanding (Smutny & Schreiberova, 2020). Chatbots can be divided into various categories according to their characteristics, such as knowledge domains and communication channels (Adamopoulou & Moussiades, 2020), as shown in Table 1. The categories shown can help researchers in selecting and designing chatbots that match the focuses of their research and teaching and learning situations (Chang et al., 2021).

Many educational features and possibilities of educational chatbots have been reported. First, chatbots offer customized learning environments. For instance, a chatbot can play the role of an ideal teacher assistant while answering students’ individual questions and interacting with them. This shows that chatbots can provide learning opportunities at students’ appropriate levels and for students to be more proactive (Holotescu, 2016; Pereira, 2016). Second, a chatbot can immediately respond to learners at anytime and anywhere. The

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-category</th>
<th>Category</th>
<th>Sub-category</th>
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<tbody>
<tr>
<td>Knowledge domain</td>
<td>Generic</td>
<td>Response generation method</td>
<td>Rule based</td>
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<tr>
<td></td>
<td>Open domain</td>
<td></td>
<td>Retrieval based</td>
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<td></td>
<td>Closed domain</td>
<td></td>
<td>Generative</td>
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<td>Human aid</td>
<td>Human mediated</td>
<td>Communication channel</td>
<td>Text</td>
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<td>Autonomous</td>
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<td>Voice</td>
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<td>Image</td>
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Table 1 Chatbot categories (Adapted from Adamopoulou & Moussiades, 2020)
instantaneous responses and feedback of chatbots can provide various benefits to student learning (Smutny & Schreiberova, 2020). Third, mobile-based chatbots can supply more learning opportunities using online materials (Cinglevue, 2017). Holotescu proposed a chatbot that diagnoses the characteristics of learners and suggests the most appropriate online materials. Chatbots can connect students with abundant online materials that fit learners' interests and levels. Fourth, chatbots can be useful as teachers' assistants in offline classrooms. For example, in a classroom with a low teacher-to-student ratio, a chatbot can support the guidance and feedback of the teacher (Gupta & Chen, 2022). Chatbots can perform similar repetitive teaching activities on behalf of the teacher so that these tasks can be reduced, allowing teachers to do more work that directly supports students' learning. This study was also intended to incorporate these strengths of educational chatbots into guided-inquiry activities.

Although educational chatbots have various advantages and possibilities, intelligent chatbots developed for simulating human interactions have still been challenging to create for software developers. Huang et al. (2020) reported that there were still challenges in building open-domain dialog chatbots, although there have been substantial advancements thanks to neural approaches to natural language processing. For instance, Yin and Satar (2020) reported that high-level language learners were dissatisfied with text-based chatbots and that low-level language learners benefited from interactions with text-based chatbots. This implies that chatbots may not be helpful for all students, and the technical limitations such as unnaturalness and failed communications of chatbots may have a negative effect on high-achieving students resulting in low engagement. In addition, Gallacher et al. (2018) reported from a student survey that lack of emotion and visible cues were the major drawbacks of chatbots. This implies that chatbots are not yet intelligent enough to produce the emotional responses that humans can.

Given the advantages and disadvantages of using educational chatbots, educators should carefully consider both educational and technical aspects when designing chatbots. From the educational standpoint, it is important to design a flow of conversation that reflects the learning purpose, because a chatbot guides students' learning through conversations by transforming learning resources into a series of messages (Subramaniam, 2019). To design a chatbot's conversation, educators first need to determine the learning topic the student will explore when talking with the chatbot. In general, educational chatbots have often been grafted onto “guided learning” to complete predesigned tasks or practice skills (Hwang & Chang, 2021). Using a chatbot, students can learn a topic independently in space and time, such as learning sentence structure.
or vocabulary (Colace et al., 2018; Wang & Petrina, 2013). In science education, a text-based chatbot was developed and applied to acquire scientific concepts; however, it was reported that there was no statistical difference in students’ conceptual understanding between the experimental and control groups (Deveci Topal et al., 2021). However, few studies have developed chatbots that have involved learning activities such as inquiry activities (Hwang & Chang, 2021). Next, a scenario flow needs to be designed that considers students’ interests and preferences (Reyes et al., 2019). For example, a chatbot-based activity can provide students with the opportunity to select learning content depending on their preferences as a part of personalized learning (Yin et al., 2021). Similarly, a scenario flow can be dualized so that the desired topic can be selected, or additional in-depth material related to the learning topic can be presented.

After establishing a scenario flow for a chatbot, learning resources need to be specified. Chatbots can provide students with various resources and messages suitable for each learning stage (Wang & Petrina, 2013). The resources and messages provided by a chatbot can include cognitive feedback that corrects students’ incorrect answers (Clarizia et al., 2018) and affective feedback, such as praise or encouragement, that increases students’ confidence, motivations, and learning effectiveness (Yin et al., 2021). The feedback or information provided by a chatbot can be presented in various modes, such as texts, images, and sounds (Colace et al., 2018; Yin et al., 2021). The chatbot’s pedagogical function of providing various materials, information, and messages has also been used as support for classes with large numbers of students where it is challenging for teachers to simultaneously deal with the questions and responses of many students (Reyes et al., 2019).

Several types of information related to students’ learning can be collected through a chatbot and its platform (Vladova et al., 2019). For example, students’ answers to the chatbot’s questions can enable teachers to identify which students understand well and which do not (Wang & Petrina, 2013). Online records and usage data can allow teachers to monitor learning processes and classroom situations (Reyes et al., 2019; Renz & Vladova, 2021). As learning indicators, the various data produced in a chatbot platform can be another convenience of using educational chatbots.

Another practical consideration of using chatbots is that educators need to determine which context of teaching and learning is suitable for using a chatbot (Chang et al., 2021). There have been cases where chatbots have taken charge of automated scoring and customized feedback, which are part of the overall learning process (Benotti et al., 2017). Educational chatbots have also been used together with other existing pedagogical tools (Smutny & Schreiberova,
For example, there have been cases where chatbots have diagnosed the characteristics of learners to connect them with various massive open online course (MOOC)-based materials (Holotescu, 2016). Chatbots have usually been combined with other educational resources to form an integrated learning environment. Therefore, it is necessary to clarify the overall context and goals of the learning activities to which a chatbot is applied and to consider the educational role of the chatbot in these activities.

Meanwhile, in terms of technological aspects, it is necessary to consider the technical difficulties experienced by teachers and students when they use chatbots. Chatbots can be developed in programming languages but can also be developed easily using platforms supplied by companies. Recently, platforms such as Google Dialogflow, where even non-experts can easily develop chatbots without coding, have been launched. From a long-term perspective, such platforms can be more useful for teachers who are not technical experts so that they can more easily design chatbots and use them in educational settings. Similarly, students who use chatbots deal with technical issues (Pereira, 2016). Students are also required to have basic skills, such as handling chatbot platforms and writing texts to chatbots, and these skills may vary according to their age and degree of experience with technologies in their everyday lives. Therefore, educational chatbots should be designed in a way that both teachers and students can easily access and use them in educational settings.

2.2 Guided-Inquiry Activities in Science Classrooms

Scientific inquiry has been defined as all practices of observing, reasoning, interpreting, explaining, predicting, arguing about, and modeling scientific phenomena (Duschl, 2008; Giere, 1991). Even though scientific inquiry involves conceptual, social, and epistemic aspects of science (Duschl, 2008), we narrowed down our focus of scientific inquiry into inquiry activities that are partially guided. This is because it is not easy to fully achieve a whole process of open-ended scientific inquiry with the limited functions available in the present technology of AI chatbots. In this context, this study developed and adapted the AI chatbots the context of guided-inquiry activities, which means small-sized inquiry activities that are partially guided by a teacher or other facilitators (the other facilitator in this study being an AI chatbot).

In general, guided-inquiry activities provide students with the tested procedures to arrive at a predetermined but unspecified outcome (Schoffstall & Gaddis, 2007). Unlike open-inquiry activities, guided-inquiry activities provide students with inquiry problems and design processes. Students’ interest and participation can be increased even in inquiry problems not directly designed by students by including unexpected elements in the inquiry process.
Guided-inquiry activities are useful in that they can offer an experience for learners who are not familiar with the entire inquiry process, such as elementary students, to develop activities step by step (Arslan, 2014; Margunayasa et al., 2019).

In a guided-inquiry activity, the teacher is an active facilitator (Kussmaul & Pirmann, 2021). While students carry out the inquiry, the teacher continuously monitors its progress, supports groups who are having with problems with content or processes, and leads discussions. Teachers can identify groups that are struggling and give appropriate help and can find confusing parts and correct them. In guided-inquiry activities, students do not design the inquiry problems themselves; rather, the inquiry process must be led by the students and sufficiently supported by the teacher.

However, it is not easy for teachers to get students to actively participate in guided-inquiry activities because students tend to follow the method proposed by the teacher and remain passive participants (Sadegh & Zion, 2009). Many methods have been discussed to encourage the active participation of students. One suggestion has been that the teacher should continuously monitor the activity process, respond appropriately to the various issues faced by the students, and give feedback (Kapucu, 2016; Kussmaul & Pirmann, 2021). However, a teacher's support can be limited when there are too many students to teach. As another alternative, unexpected elements can be included in guided-inquiry activities to increase student participation (Schoffstall & Gaddis, 2007).

This study took notice of the educational use of chatbots to promote student participation and teachers' supportive environments in guided-inquiry activities. We tried to increase meaningful learning opportunities and high-quality interactions between teacher and students by introducing learning topics and methods and providing feedback on the questions that were expected to be repeatedly asked and checking using chatbots. We also left room for students to decide on the inquiry method themselves so that chatbots could be used effectively in designing scientific-inquiry learning in a way that increased students' initiative.

3 Research Method

3.1 Research Context and Design

This study used a single case study (Yin, 2011) to explore how to use a text-based chatbot in inquiry activities for elementary school students. As an exploratory case study, this study aimed to describe the educational supports and difficulties that students and teacher experienced when a chatbot was used.
in scientific inquiry activities. Given that the technical level of the Korean text-based chatbot was not still high enough to have complicated conversations, we selected inquiry activities at the elementary school level in which students could construct comparatively simple discourse structures. To describe a rich contextual event within a specific boundary, we tried to provide insight into the research topic rather than suggest generalized claims (Mitchell, 1983). That is, the aim of this this single case study was to describe the process of developing and applying a chatbot within the boundary of a chatbot-based inquiry activity for elementary school students and provide insight into the pedagogical strategies for using chatbots in an inquiry activity.

3.2 The Participants
The guided-inquiry activity participants in this study were fifth and sixth grade students and their teacher in a science gifted education program operated by a university in Korea. Considering the research context, we selected gifted students in fifth and sixth grade who were familiar with both inquiry processes and mobile phone use. The 18 participants in the study were 11 fifth graders and 7 sixth graders, 15 of whom were male and 3 of whom were female. The participant students were learning science activities in a 1-year science gifted program run by the university. These gifted students voluntarily participated in various science activities for 3 hours every other Saturday. These features of the students indicate that they generally had interest, scientific literacy, and inquiry skills that were higher than average students’.

The participant teacher was one of the researchers who designed and conducted this study. She was an elementary school teacher with 12 years of experience and had a doctoral degree with a high level of understanding of the purposes and teaching strategies of science inquiry. In a guided-inquiry activity, the teacher needs to support students’ inquiry activities as an active facilitator (Kussmaul & Pirman, 2021). Therefore, the participant teacher encouraged the students to solve various problems that occurred in designing and practicing inquiry activities. The teacher also led group and class discussions to promote inquiry thinking when students faced challenges in the inquiry process.

3.3 Selection of the Chatbot Tool: Inquirybot and Its Platform (Kakao I Open Builder)
This study selected the Kakao I Open Builder chatbot, developed by the Kakao Corporation in South Korea, as a platform for developing Inquirybot. The educational chatbots that have been widely used recently, including both voice-based virtual agents (e.g., Siri from Apple, Alexa from Amazon, and Assistant from Google) and text-based chatbots (e.g., Facebook Messenger
bot, Lex from Amazon, and Skype bots), have mostly been English-based chatbots (Smutny & Schreiberova, 2020). Smutny and Schreiberova evaluated the quality of the existing text-based educational chatbots based on the criteria of teaching, humanity, affect and accessibility, showing that about 46% of text-based educational chatbots lacked natural conversation skills, and most used button-based browsing or linkage with external data. In addition, voice-based chatbots were reported to be more effective than text-based chatbots in improving students’ speaking skills and interest in language education (Kim, 2016); however, voice-based chatbots’ lack of speech recognition technology can produce more complex technical errors than occur in text-based chatbots (Wang & Petrina, 2013).

A Korean text-based chatbot was selected as the basis for the Inquirybot in this study because delivering clear meanings is more important than improving speaking skills in guided-inquiry activities. In developing a Korean text-based chatbot, the researchers considered that the chatbots used in existing studies did not have enough Korean-related data (Chang et al., 2021). The Kakao chatbot was also convenient for designing because it was developed by Kakao I Open Builder, which enables non-experts to design Korean-language chatbots simply. Additionally, considering that KakaoTalk is a local messaging app in South Korea with the highest share in the country (Jeong & Jeong, 2020), a Kakao I Open Builder-based chatbot had the advantage of high accessibility for students. Therefore, Kakao I Open Builder was selected to create the chatbot in consideration of the fact that Korean language-based data were insufficient in other chatbots and that this chatbot was accessible and convenient for chatbot users and developers.

The Kakao chatbot used in this study combined both rule-based and AI chatbot approaches. It was primarily rule based and used machine learning to improve its performance to train the chatbot to recognize patterns in user input and to make better predictions about how to respond. Natural language processing was used to analyze user input and identify the intent behind it, and natural language generation was used to generate responses to user input based on predefined rules and scripts. The chatbot in this study used a text-based automatic response method in accordance with the Kakao chatbot system. The chatbot designed for this study, Inquirybot, can be classified as a domain-specific chatbot to be used in the context of guided-inquiry activity.

### 3.4 Lesson Plans Using Chatbot for Guided-Inquiry Activities

The guided-inquiry activity developed in this study consisted of three lessons that dealt with two main experiments related to sound transmission using tuning forks and a paper-cup phone. Over three lessons, students were asked to
observe phenomena related to sound transmission, conduct the related experiments with the guidance of Inquirybot, and then scientifically explain them. The detailed activities of each lesson are shown in Table 2.

In Lesson 1, the students constructed their understanding of sound transmission by explaining how the vibration of a tuning fork is transmitted through the air. The participant students observed the vibration of a tuning fork when it came into contact with water and explained the process in which sound occurs and is transmitted through vibration. Using the vibration concept of sound transmission that was constructed in Lesson 1, the students performed their own inquiry activities in Lessons 2 and 3. The main activities of Lessons 2 and 3 were to design and conduct an inquiry about sound transmission through a paper-cup phone. Concretely, in Lesson 2, the students in each group designed an inquiry process and materials for the guided-inquiry topic while talking with the Inquirybot. In Lesson 3, the students carried out the inquiry in a group, then recorded the results of the inquiry on worksheets and shared the results with the entire class. The teacher asked the students to write the results on a blackboard and guided classroom talks to draw conclusions.

Addressing what a chatbot can do to facilitate inquiry activities and how it can facilitate them, we concretized the pedagogical roles of the Inquirybot by planning the overall flow of the chatbot-based learning activity. The Inquirybot supported the students’ designing and conducting the experiments in Lessons 2

<table>
<thead>
<tr>
<th>Lesson topics</th>
<th>Main activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Establishing foundation knowledge about sound transmission</td>
<td>Observing the vibration of a tuning fork when it is hit Explaining how the sound of a tuning fork is transmitted through air</td>
</tr>
<tr>
<td>2 Designing inquiry</td>
<td>Designing an inquiry with Inquirybot</td>
</tr>
<tr>
<td>3 Inquiry practices</td>
<td>Doing an investigation in each group Recording and sharing the data from the inquiry Discussing and drawing conclusions about the experiment</td>
</tr>
</tbody>
</table>
Inquirybot, designed to lead text-based conversations, was positioned to introduce the topic and ask the students about the experiment materials and specific methods, such as controlling variables. To construct an activity that promoted students’ inquiring minds rather than followed a cookbook-style experiment, the researchers designed the guided-inquiry activity to include unexpected elements (Schoffstall & Gaddis, 2007). For example, students were asked to predict and discuss the inquiry results before carrying out the inquiry. The inquiry methods were also left open, which let students decide on some of the methods themselves. Each group of students was asked to have a group discussion to decide the length of the string used for the paper-cup phone and how to examine the sound characteristics. Table 3 shows the learning activities of Lesson 2, including the sub-strategies related to the use of Inquirybot.

### Table 3: Learning activities in Lesson 2

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning activities in Lesson 2</th>
<th>Lesson time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introducing Inquirybot to students</td>
<td>5 minutes</td>
</tr>
<tr>
<td>2</td>
<td>Designing an inquiry activity with Inquirybot in each group</td>
<td>15 minutes</td>
</tr>
<tr>
<td></td>
<td>Planning and determining the inquiry method and resources through conversation with Inquirybot</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Predicting the results of the inquiry activity</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Doing the inquiry activity in each group</td>
<td>20 minutes</td>
</tr>
</tbody>
</table>

#### 3.5 Designing Inquirybot for Guided-Inquiry Activities

After establishing the pedagogical roles of Inquirybot in the lessons, the conversation flow of Inquirybot was designed appropriately to its roles. Designing the conversation flow was implemented in two phases: (1) a flow diagram for the Inquirybot was constructed and (2) conversation scripts to be presented by the chatbot were written. In the first phase, the conversation flow diagram for the Inquirybot was developed (see Figure 1). Given that a flow diagram should be designed for a specific learning goal (Reyes et al., 2019), the conversation flow was constructed to ask the students what they needed and what variables should be made different or the same (Step 2 or Steps 4 and 5 in Figure 1). In addition, the students were guided to decide the methods for examining the features of the sound transmitted through the paper-cup phone (Step 3 in Figure 1). Based on the conversation flow, Inquirybot guided
the students to explore scientifically possible ways for investigating sound and conduct an experiment with the method found.

In the second phase, based on the conversation flow in Figure 1, the conversation script was written for how the Inquirybot would respond. The script was written in consideration of the technical capabilities of the chatbot being used. The Kakao interface combines both rule-based and AI chatbot approaches. In the rule-based interface used in this study, the chatbot can present choices (as shown in the red boxes in Figure 2) to select the conversation item in the next stage in the form of buttons. In the Kakao interface, which combines both rule-based chatbots and AI chatbots, the user can proceed to the next stage of the conversation by texting their responses or clicking the buttons in the red boxes presented in Figure 2.

The Inquirybot was designed to proceed with the conversation by using the expected answers and partially closed-ended questions based on a rule-based system of chatbot. A generative chatbot such as ChatGPT is not suitable for leading and facilitating the process of guided-inquiry activities because it is difficult to limit the topic and structure of the conversation. Therefore, a rule-based chatbot method was adopted for setting up Inquirybot to lead a conversation within a given topic. At the same time, to provide more natural
conversation situations, the students’ ideas were asked in each process of the conversation. For example, in this experiment, questions were asked such as what independent variable (the type of string) should be set differently.

When writing a conversation script for an AI chatbot, the persona of the chatbot should be considered (Mendoza et al., 2020). A persona is a character or personality that is created to represent the chatbot. The persona can reflect various characteristics such as gender and age. Two characteristics were emphasized for the persona of the Inquirybot. First, we tried to give familiarity to students. Therefore, words frequently used by students were sometimes included to create a sense of familiarity. Second, it was emphasized that the Inquirybot was a student who had started to learn Korean. This was in consideration of previous studies indicating that Korean-based chatbots make many technical errors, giving students emotional fatigue during the learning process. With its identity as a student, the fact that the Inquirybot may not understand the conversation because it does not know many words was set as a persona.

The Inquirybot design was reviewed by three elementary education experts in Korea. In the reviewing process, visual materials were added to the Inquirybot’s dialogue. The experts commented that some meanings may not be clearly understood since the Inquirybot delivers science content only as text. Therefore, given the level of development of elementary school students, science content needed to be presented with related pictures and photos. The
Inquirybot was therefore modified to present text-related visual representations, as shown in Figure 3. In addition, the means of accessing the Inquirybot was improved so that it could be accessed efficiently by clicking a URL address or by scanning a QR code. Figure 3 shows the addition of visual representations to the Inquirybot’s texts.

### 3.6 Data Collection and Analysis

In this study, the quantitative and qualitative data were collected while designing and applying the guided-inquiry activity using a chatbot. First, we collected the qualitative data including the teacher’s reflective notes, the contents of the researchers’ meetings, video of all the lessons, lesson materials, worksheets, and student questionnaire results. In the reflective records, the teacher recorded her experiences and thoughts on the entire process of planning the activity. In applying the activity, the videos of the lessons, teaching materials (e.g., PowerPoint presentations, video, and experimental material), student worksheets, and group worksheets were collected. We also investigated the participating students’ thoughts about their experiences. Through an open-ended survey, the students discussed their experiences of designing an inquiry process using the Inquirybot. The main questions were as follows: “What did you like when you were talking with the Inquirybot?” “What was the most difficult thing when you were talking with the Inquirybot?” and “Do you have any ideas about what needs to be improved or is necessary in designing the inquiry process with the Inquirybot?” The students responded to the above questions after completing three lessons, and all responses were transcribed.

Second, quantitative data were also collected based on the results of interactions between students and the developed chatbot. We obtained statistical results on the number of times users accessed the system, the number of button...
clicks, and the number of user responses at each step as the conversation with the chatbot progressed (see Table 4). The collected data were provided as part of a service for chatbot operators on the Kakao I Open Builder platform. We were able to collect the following statistical data: the number of times users accessed the system, the number of button clicks, and the number and ratio of user responses at each step as the conversation with the chatbot progressed. The number of times users accessed the system means how many times a participant student accessed the Inquirybot during a lesson. In the Kakao platform, one access is considered terminated if there is no further utterance for more than 10 minutes after the user’s final utterance. For example, in this study, a total of 16 accesses occurred while nine student groups were designing their inquiry with the Inquirybot. Next, the number of button clicks refers to how many times the participant students clicked each button provided in the Inquirybot (see Figure 2). The number of user responses shows how many times a response occurred at each step, and the ratio shows the proportion a given response accounted for out of all responses at that step. The information produced during the usage of the chatbot allowed us to understand the students’ participation patterns and to identify the stages that required more guidance (Hobert, 2019).

From the qualitative data, we extracted the episodes and responses that were considered helpful in student learning. The episodes and responses that showed the difficulties experienced by students while using the chatbot were also extracted. Analyzing the frequency of quantitative data and the pattern of change over time allowed investigation of whether the chatbot was used in a way that was helpful to students’ learning. To secure the validity and reliability of the analysis, the researchers conducted a triangular verification of data using various sources of data. In addition, to avoid any distortions in the interpretations among the researchers, the features extracted independently by the researchers were compared with each other to discuss, correct, and supplement points with differences.

4 Findings

4.1 Educational Possibilities: Supporting Students’ Personalized Inquiry at Their Own Pace

We could see that the Inquirybot helped students proceed with their inquiry at their own pace. One case showed that when the students’ inquiry pace was faster, they were able to move forward using the Inquirybot. Another showed that even if the students’ inquiry pace was slow, they could get help by asking the Inquirybot repeated questions. Detailed cases are described below.
4.1.1 Students Could Move Forward Their Inquiry Using the Inquirybot

Each group of students discussed and made their own decisions about the lengths of string connecting the two paper cups and how to examine the sound. The students in each group conducted their inquiry activities based on the conversation with the chatbot and group members; at the same time, the teacher individually checked each group’s inquiry process and provided experimental materials or feedback for them as follows:

The teacher saw Group 3 students’ experiment with the thread loose and made comments to them.
Teacher: To hear sound well through a paper-cup phone, how taut did you need to keep the thread?
Group 3: We need to keep the thread taut.
Teacher: You are right. Can you tell me how taut you kept the thread when you heard the sound well through the paper-cup phone?

**LESSON 2 TRANSCRIPT, 20:30**

While the teacher gave feedback to Group 3, other groups of students continued to conduct their inquiry activities talking with chatbots and group members. Instead of spending time explaining or guiding the inquiry process to all students, students were able to conduct their inquiries at their own pace, and the teacher was able to give individualized feedback to the students for the amount of time saved. That is, the participant students proceeded with their inquiries smoothly, having multiple interactions with their teacher, group members, and the chatbot. After each group did the inquiry in their own way, every group shared their methods and inquiry results with the entire class. Figure 4 shows how the individual groups shared their own inquiry results on a whiteboard.

The groups measured and reported the features of sound in various ways, as shown in Figure 4. Some groups quantitatively measured the sound...
volume (dB) with a sound measurement application (e.g., Students I and J and Students A and K), and others qualitatively described the characteristics of the sounds they heard (e.g., Students B and L and Students G and Q). Meanwhile, one group found the sound characteristics using the waveform generated when recording the sound with a cell phone. The teacher discussed each method of investigating sounds as follows.

Teacher: Even though we conducted the same experiment, the ways of investigating sound were slightly different from each other. Each way has different characteristics. How did Students I and J investigate?

Student I: We used a [sound measurement] app.

Teacher: Yes. The group that used the app can show the volume of sounds accurately in numerical values, and the group that explained what they heard can know characteristics such as “the sound is reverberating or clear.” They all have their pros and cons.

LESSON 3 TRANSCRIPT, 46:30

In this way, the teacher gave the opportunity to share different measurement methods and examine the advantages and disadvantages of each method. This case shows that even if students conduct a guided-inquiry activity with the Inquirybot on the same topic, it is possible to create an inquiry environment in which more scientific and persuasive methods can be compared and discussed. Depending on how an activity is constructed through the conversation flow of an AI chatbot in a guided-inquiry activity, it is possible for students to conduct various inquiry activities depending on their preferences or levels.

This case also implicates the teacher’s role is still critical in implementing AI-adapted lessons. In the above case, the teacher’s intervention helped students understand the epistemic aspect of inquiry, such as learning various methods of comparing the volume of sound and comparing the advantages and disadvantages of each method. As this case shows, when teachers partially utilize chatbots in the classroom, teachers need to design the activities and discussions that come before and after the students’ chatbot-based activities.

4.1.2 Students Could Look Backwards at Their Inquiry Processes Using the Inquirybot

When students were asked the advantages in designing inquiries together with the Inquirybot, students responded as follows:
– Allowing students to ask questions repetitively (5 responses):
  The Inquirybot answered well even if I asked the same thing multiple times. (Student L)
  If I don’t know, I can ask the Inquirybot. If I don’t remember, I can click again to see the resources. (Student B)
– Feeling more comfortable than asking the teacher face to face (4 responses):
  I liked it because it was much more comfortable than raising my hand to ask the teacher. (Student C)
  It doesn’t require talking face to face. (Student J)
– Providing immediate answers to students’ questions (3 responses):
  The Inquirybot responded right away. … (Student P)
  The Inquirybot answered immediately. (Student A)
– Explaining the inquiry method well (7 responses):
  The step-by-step explanation enacted by the algorithm was easy to understand. (Student D)
  The Inquirybot was good at explaining. (Student F)
  I thanked the Inquirybot for explaining it in detail. (Student I)

As shown in the example answers above, the students said that they could lessen the feeling of being burdened by direct interactions with the teacher. For example, talking to the Inquirybot reduced students’ emotional burden of asking the teacher the same question again or raising their hands in a face-to-face mode. Also, since the Inquirybot is a robot, it was able to respond immediately to individual questions from students. The responses show that the Inquirybot helped students efficiently grasp and understand the presented inquiry topic and method.

4.2 Educational Possibilities: Allowing Teachers to Understand Students’ Ideas Occurring in the Inquiry Activity of Each Group

Since conversations between the Inquirybot and students are stored as data, teachers can check how students answered questions from the Inquirybot and their understandings. This function of the Inquirybot can be helpful for teachers to understand students’ ideas in the inquiry activity of each group.

For example, the Inquirybot asked students what preparation materials they needed and what variables they had to control. The students’ responses to the Inquirybot’s question, “What preparation materials are necessary?” are shown in Table 4.

Since the Inquirybot developed in this study included a rule-based system, the choices that the user could click to proceed during the conversation were presented at the same time. The parts shown in Table 4 that had buttons
provided were the choices presented by the rule-based interface, which could be clicked on by the students. For example, in Table 4, the response “thread” occurred 17 times, or 20.48% of all responses at Step 1, which asked which materials were needed for the inquiry activity. Other examples of responses were “thread,” “paper cup,” “awl,” and “copper wire.” This information provided in the chatbot platform allowed us to understand students’ ideas at each step of their learning with the chatbot.

It is very common to receive students’ thoughts statistically and instantly through an online-based survey tool in lessons. However, in the context of this study, it is worth noting that we were able to collect students’ thoughts and possibly track the changes generated in their intermediate processes of group inquiry activities while conversing with the chatbot. Since teachers cannot interact with all groups at once, it is not easy to track the development or change processes of group activities. Thus, the above functions of Inquirybot can give us some possibilities to bridge the interaction gap between teachers and students in group activities.

### 4.3 Educational Challenges: Technical Limitations in Natural Conversations

The difficulties that came from the technical limitations of the rule-based method used with an AI-based method were due to the lack of Korean-based science-related data. To operate and react, rule-based chatbots rely on scenarios designed in advance by the developer. The Inquirybot used this type of system led only to conversations with the designed flow, so the conversations were perceived to be unidirectional by the students. In cases where the answers were not expected, the Inquirybot was designed to reply, “I’m sorry,

<table>
<thead>
<tr>
<th>Student response</th>
<th>Number of responses (%)</th>
<th>Student response</th>
<th>Number of responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[a button provided] If you cannot remember what to prepare.</td>
<td>35 (42.17%)</td>
<td>[a button provided] Check preparation materials.</td>
<td>2 (2.41%)</td>
</tr>
<tr>
<td>Thread</td>
<td>17 (20.48%)</td>
<td>Thread, paper cup</td>
<td>3 (3.61%)</td>
</tr>
<tr>
<td>Paper cup</td>
<td>12 (14.46%)</td>
<td>Cup</td>
<td>2 (2.41%)</td>
</tr>
<tr>
<td>Awl</td>
<td>8 (9.64%)</td>
<td>Copper wire</td>
<td>2 (2.41%)</td>
</tr>
</tbody>
</table>
I don’t understand.” Therefore, the students saw the Inquirybot’s Korean language skills as being poor. The following are the comments of students about this aspect of the Inquirybot.

- Capability of the Inquirybot to comprehend students’ words was poor (10 responses):
  - The Inquirybot’s level of understanding was poor, so it was difficult to talk [due to its lack of Korean language skills]. (Student R)
  - The Inquirybot has many words that it doesn’t understand. (Students C, I, and H)
  - If I answer, the Inquirybot says I don’t understand. (Student M)
  - When I asked Inquirybot about something I was wondering about, I didn’t get the right answer. (Student J)

- One-sided communication (5 responses):
  - Communication with the Inquirybot was difficult. (Student B)
  - The Inquirybot kept saying the same thing over and over. (Student N)
  - The Inquirybot pushes [the conversation] too much in one direction. (Student O)

As discussed earlier, several systems of operating chatbots have different technical strengths and weaknesses in adapting them to learning activities. For example, as in the case of this study, a rule-based way of Inquirybot allowed us to set the topic and flow of inquiry activities; however, it had limited ability to recognize what students said, as shown in the above data. In this sense, designing the lessons using chatbots needs to entail both selecting a chatbot that fits the goal, direction, and structure of the learning activity and considering how to manage the technical limitation of selected chatbots.

4.4 Educational Challenges: Increasing Clicking on Buttons and Decreasing Writing

Another educational challenge that occurred in applying a rule-based chatbot was that the response rate, which means the ratio of students who wrote down their thoughts, gradually decreased as the conversation progressed. The researchers analyzed these students’ participation patterns based on the information provided in a chatbot platform. The information in Table 5, provided in the Kakao I Open Builder platform, showed that the change in the ratio of students who clicked on the buttons that had been provided to have a conversation gradually increased over time. In other words, the participant students had conversations while writing down their thoughts for the chatbot at first, but over time, they increasingly went through by clicking rather than having a conversation.
The phenomenon shown in Table 5 is related to the technical problem of chatbots. Since it was difficult for the students to communicate with the chatbot, it seemed that toward the end of the conversation they proceeded by only clicking the buttons presented by the chatbot rather than talking to it. Table 5 shows that the students’ concentration on the conversation with the chatbot decreased due to repeated technical errors. This trend was also confirmed through the above student interview data.

These challenges can be solved with the technological development of chatbots. However, with the current level of technology, it is necessary to prepare auxiliary devices to reduce such difficulties. For example, in this study, the teacher was able to directly help the students to continue the conversation with the chatbot in the classroom, and the persona of the Inquirybot was set as a student. In other words, despite some technical errors, the students conducted their inquiries smoothly through multiple interactions with their teacher, group members, and the chatbot. The students in each group proceeded with their inquiry activities based on conversations with both the chatbot and group members, while at the same time, the teacher individually checked the group processes and provided materials and feedback for each group. Technical errors made students decrease text-based interactions with the chatbot; however, the errors did not interfere with the overall inquiry process of the groups as they had additional support. In the long term, it is necessary to continue efforts to develop a chatbot that leads more natural conversations by constructing a corpus of Korean-based science terms and concepts and grafting it onto the AI chatbot (Chang et al., 2021).

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Ratio of responses involving buttons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Asking which materials are needed for the inquiry activity</td>
<td>44.58%</td>
</tr>
<tr>
<td>2</td>
<td>Asking how to design the inquiry activity in detail</td>
<td>83.78%</td>
</tr>
<tr>
<td>3</td>
<td>Asking how to examine the features of sound</td>
<td>92%</td>
</tr>
<tr>
<td>4</td>
<td>Asking which factors need to be set differently</td>
<td>94%</td>
</tr>
<tr>
<td>5</td>
<td>Asking which factors need to be the same</td>
<td>100%</td>
</tr>
</tbody>
</table>
5 Discussion and Implications

In this study, with the aim of effectively integrating AI chatbots into inquiry activity, a guided-inquiry activity using an AI chatbot was developed and applied. The guided-inquiry activity let students design and carry out an inquiry process with the topic of sound transmission. The lessons were designed so that students could use the chatbot, named Inquirybot, in the inquiry design process in the second of three 40-minute lessons. We focused on a more robust use of the chatbot in ways that would coincide with the educational purpose beyond just using the chatbot as a substitute for existing teaching tools (Puentedura, 2010). This study noted the educational roles and direction of Inquirybot use that coincided with the values and goals of science education while applying a guided-inquiry activity to fifth and sixth grade gifted students.

We found that the chatbot could have educational possibilities for responding immediately to the learner’s questions, talking individually to each learner in their own situation and at their own pace, and providing the same information multiple times. In addition, teachers could check and track students’ ideas that were stored in the data from their conversations with the chatbot. While the teacher individually checked and provided feedback on each group’s activity, the other groups continued to proceed with their inquiry activities while talking with the chatbot. In cases where there were parts that were not understood well, the participant students comfortably asked questions while feeling less of a burden and were instantly provided with information about the question by the chatbot. Similar results had been found in language learning research. Fryer and Carpenter (2006) reported that chatbots may help students feel less shyness when they practice language than when they practice with a human partner. That is, the chatbot functions were appropriately grafted to contexts where guidance and checking of the inquiry activity were required by that step of the inquiry.

Because we found that inquiry can be individualized through the use of the Inquirybot as described above, we believe that it is possible to develop a chatbot for guided inquiry with more openness or customized inquiry that considers the levels and preferences of individual students. For instance, Figure 5 shows an example of a customized inquiry activity that includes two different inquiry activities for a single topic: (1) comparing the sounds transmitted depending on the type of string connecting two paper cups and (2) comparing the sounds transmitted depending on the connection method between the paper cup and the string. As shown in Figure 5, this conversation flow can play the role of supporting individual students or groups to select and design an experiment.
that fits their preferences by asking students to select the topics they want and leading conversations while asking about the preparation materials needed to carry out the inquiry and how to control variables.

However, at the same time, this study illustrated the challenges and limitations of using a chatbot and how these challenging issues could be dealt with. First, as shown in the responses of the students, communication with the chatbot was not as natural as everyday conversations with people. Therefore, the teacher monitored the progress of the students and supported them to solve problems that occurred when communication with the chatbot did not go smoothly. In addition, by setting the persona of the chatbot, the students were
enabled to understand the roles and capabilities of the chatbot to some extent. Second, additional educational interventions were established together with chatbot-based activities to create a supportive and meaningful inquiry environment. Students were informed about the interventions in the guided-inquiry activity, the inquiry topic, and the overall inquiry process, but they were asked to determine detailed inquiry methods themselves. For example, the chatbot guided the students to decide how to investigate the characteristics of sound through small-group discussions. The students investigated the characteristics of sound in their own way, and this led to discussions about the pros and cons of each method. This example shows that even if the flow and direction of the conversation in chatbot-based activities are determined to some extent, the activities that expand students’ options can be sufficiently designed. A series of pedagogical instructions for chatbot-based activities need to be carefully designed, such as expanding students’ options in activities and establishing supportive preliminary activities to encourage students’ interest and participation.

More widely, the results of this study have the following implications in using chatbots in general science classroom situations. First, by developing and using AI chatbots such as the Inquirybot in activities that include questions and feedback that need to be given to students repeatedly and routinely, such as guided-inquiry activities in science classrooms, opportunities for students to interact individually with teachers can be created. It is technically not very difficult to develop a chatbot that can be used in a classroom situation. Various educational chatbots that are teaching oriented rather than service oriented have already been actively used in educational contexts such as language education (Huang et al., 2022; Xu et al., 2021). For instance, a voice chatbot was used for college students studying English as a foreign language to practice English while talking about specific topics (Kim, 2016), and text chatbots have also been used (Yin & Satar, 2020). A chatbot that students can access for help when they encounter problems regarding learning activities was also developed (Wang et al., 2017).

Similarly, in guided-inquiry activities conducted in a general science classroom, students also need appropriate help along with continuous monitoring by teachers or facilitators (Kussmaul & Pirman, 2021). Some of these activities require fairly standardized and repetitive feedback, while others need to be supported specifically according to the students’ responses and levels. In a large class situation where teacher support may be limited, the use of an AI chatbot that can offer routine and standardized guidance and answer questions in a timely manner can be a good way to create synergy in teaching activities in a classroom setting. In this study, the chatbot gave students points that
must be considered in inquiry design and answered questions they had while designing their inquiry (see Figure 1).

In addition, the use of AI chatbots in guided-inquiry activities can provide opportunities for students’ individualized inquiry activities. Although their use may be limited even in general teaching and learning, AI chatbots can support students’ carrying out of inquiry activities in ways that appropriately fit their pace. In this study, students used the immediate answers given by the Inquirybot when designing an inquiry. In the inquiry process, students came to have numerous questions and issues for which decisions should be made. If such issues are not resolved in a timely manner, it may be difficult to perform the inquiry effectively within a limited time. If simple questions are easily and immediately resolved through the AI chatbot, an environment where students can participate in the inquiry more independently will be created. In addition, as with the Inquirybot, questions routinely presented in the inquiry process can be quickly given so that a more supportive and student-centered inquiry environment can be created.

In summary, this case study explored how to utilize the benefits of an AI chatbot in guided-inquiry activity by developing and applying its protocol. As an exploratory case study, there are limitations in generalizing the findings reported here to a more general use of chatbots. For example, depending on which chatbot platform is selected, the data that teachers or researchers can collect may vary. Pedagogical ways of using chatbots also rely on the services and infrastructure provided by the selected platform. These technical differences and limitations need to be taken into consideration as an important variable when designing and applying chatbot-based activities in other contexts. This study illustrated a concrete case of how to deal with these types of technical limitations. To decrease the technical problems of the current chatbot, we constructed closed questions and a persona for the Inquirybot, and the teacher helped the group activity as a facilitator. However, because these results were reported based on an exploratory case involving primary-level students, further study is needed to statistically verify the effects of the chatbot-based inquiry activity and learning environment.

Although chatbots still have technical limitations such as in natural language processing (Huang et al., 2022), their use has been extensively considered and provided for education (Cinglevue, 2017; Clarizia et al., 2018; Sinha et al., 2020). The demand for exploration of how to use AI technology in science education is not only unavoidable but is also likely to continue to increase because AI has already deeply penetrated our lives, and the number of fields where AI is being used is increasing tremendously. In this vein, the practical
strategies and trials reported in this study can serve as a basis for the effective use of AI chatbots in the future.

Funding

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (NRF-2018R1C1B5086374).

Ethical Consideration

Informed consent was obtained from all participants.

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References


