

## **Using Chatbots as Smart Teaching Assistants for First-Year Engineering Students**

### **Dr. Sherif Abdelhamid, Virginia Polytechnic Institute and State University**

Dr. Sherif E. Abdelhamid served as an Assistant Professor of Computer Science at the College of Computing and Information Technology (CCIT). Before joining CCIT in 2018, he was an Infrastructure Software Engineer at the Center for Open Science, Virginia, USA.

He obtained his Ph.D. and MSc in Computer Science from Virginia Tech and his current research work lies at the intersection of computation and education. In particular, he is interested in building and evaluating software systems that enrich the students' learning environment and promote their success.

### **Dr. Andrew Katz, Virginia Polytechnic Institute and State University**

Andrew Katz is an assistant professor in the Department of Engineering Education at Virginia Tech.

# Full Paper: Using Chatbots as Smart Teaching Assistants for First-Year Engineering Students

## Abstract

As the artificial intelligence (AI) field advances, more research areas within AI are emerging including machine learning, neural networks, fuzzy systems, and much more. In the last decade, chatbot technology has emerged as a new area of AI. Chatbot use-cases are surfacing across various sectors including banking, customer services, medicine, and e-commerce. Recently, chatbots have begun being used in education, and the potential advantages are notable. In this paper, we are reviewing related literature and presenting a mobile application system, named Alpha, that utilizes chatbots as smart teaching assistants. The system consists of an artificially intelligent (smart) chatbot, cloud-based database, speech recognition, and web services. We conducted a student survey and a usability assessment of the implemented system. We have integrated our system into a first-year engineering course, and more courses will be added in the future. The system aims to support students' learning processes and engagement in addition to providing real-time 24/7 assistance to students.

## 1 Introduction

### 1.1 Background and Motivation

According to one study [1], 95 percent of undergraduate students own a laptop or a smartphone and 78 percent of students say that their phones have an above moderate contribution to their academic success. Another study [2] showed that 70 to 79 percent of students use their smartphones in at least one class. In the last few years, chatbots have become increasingly used because they are based on natural language processing (which has seen big advances) and user conversation interfaces that are very common in messaging apps on smartphones. The ubiquity of smartphones and potentially significant role in supporting student learning motivated us to conduct this study and build a smartphone application-based chatbot, named Alpha.

### 1.2 Contributions

Our major contributions are: 1) an exploratory study of how students use chatbots and perceive their roles in education, 2) a multi-tier chatbot system design and implementation, and 3) a usability survey assessment and evaluation of the implemented system.

## 2 Chatbots Overview

Chatbots are programs or systems that emerged within the artificial intelligence field and use natural language processing to create natural conversations with users. Applications of chatbots span various areas including e-commerce, information retrieval, automatic answer machines, banking, ticket reservations, health, and entertainment [3][4][5].

In the last decade, the applications of chatbots in education are growing. Chatbots are not intended to replace the human role in teaching but instead provide adequate aid and assistance

not only to students but also to instructors and university administrators. According to [6], the teaching process will involve a close collaboration between humans and machines, and instructional roles can possibly be disseminated amongst multiple chatbots.

Chatbots use natural language conversation which increases flexibility and engagement for students. Additionally, when provided with questions, chatbots can provide students with a step-by-step guide to the final solution. Chatbots can be well suited to the student-centered learning approach. Instead of having the instructor hand-down information to students, students can cognitively construct knowledge and meaning through their new experiences and interactions, as opposed to memorization. Chatbots can facilitate the interactions between students and instructors, and students and peers, leading to an enhancement in dialog-based learning. According to Wegerif [7], chatbot-based interactions consist of three ingredients: initiation, response, and feedback (IRF). An additional discussion ingredient can be integrated (IRDF) representing the collaborative discussion (D) amongst students and their interactions with the chatbots.

### **3 Literature Review**

The roles of chatbots within the university can have educational and non-educational purposes. Non-educational roles include university admission services [8], library services [9], academic advising [10], and student time management [11]. Chatbots have also been used to support students' emotional and mental health. In a recent study [12] conducted by Stanford University, they found that the students who had up to 20 sessions with a chatbot, named Woebot, reported notable reductions in anxiety and depression. Woebot uses Cognitive Behavioral Therapy (CBT), a therapy that changes the way students think and behaves by reframing the negative thoughts into positive ones. Another study [13] discussed the concept of Education 4.0, where artificial intelligence applications including chatbots, are integrated with education. The paper proposed a new chatbot named eduAssistant that provides reporting capabilities and student data tracking and analysis. Another research work [14], found that most students prefer chatbots due to their convenience in comparison to other communication methods. In another study [15], the effect of chatbot use on high school students' engagement and retention was measured and researchers found that most indicators of engagement (task completion, participation, enthusiasm, and self-reported interest) increased when using a chatbot. Likewise, [16] found that around 65% of students feel that the chatbot made the course more personal, and around 84% of students indicated that push notifications helped them to work better on course requirements.

### **4 Exploratory Student Survey**

The survey aims to investigate the familiarity of students with chatbot technology, how they perceive chatbots as teaching assistants, their role in education, and what features they are looking for. The survey took a questionnaire form. The questions followed either a Likert or a rating scale, in addition to yes/no and open-ended questions. The survey was conducted in a college of engineering at a university located in Egypt. There were 42 participants, with ~48% female and ~52% male students. From the survey, we found some interesting findings. More than 80% of students are chatting most of the time using different messaging apps. More than

75% of students indicated they have used a chatbot service or similar system before. Twenty-four percent of students have used chatbots to learn about or search for a specific topic, and 15% used chatbots for online booking. Fifty percent of students said they seek help from their teaching assistants most of the time. However, 71% of the students mentioned that they have difficulty meeting with their teaching assistants due to various reasons.

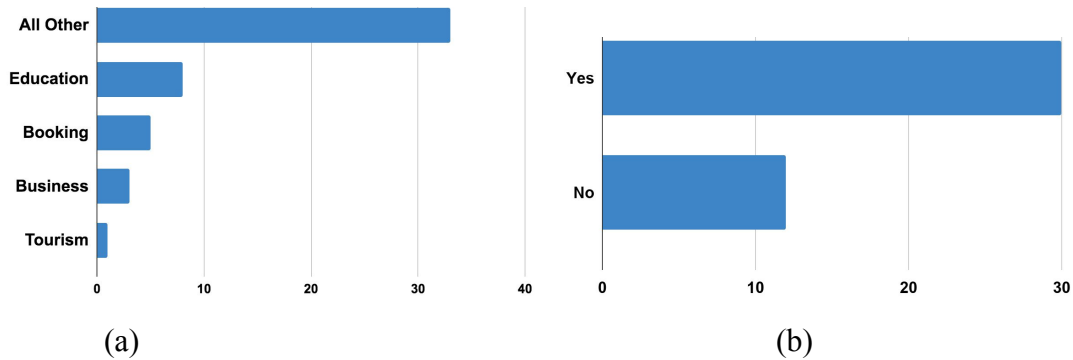


Figure 1. (a) Areas or sectors where students used chatbots, (b) Number of students having difficulties meeting with their TAs.

More than 95% of students said that the presence of a chatbot will be helpful to answer some of their questions (FAQ) and around 85% agreed that chatbots will save their study time. Results also showed that around 80% of students believe that chatbots will improve their learning environment, and more than 65% totally agree that finding key terms and information using a chatbot is much faster compared to manually searching their paper-based textbooks.

## 5 System Design and Implementation

### 5.1 System Components

The implemented System consists of six main components: **1)** a mobile application that handles user interactions and forward students' requests to the system, **2)** a chatbot service implemented using Dialogflow framework that handles conversations with students, **3)** a predefined rules engine that use machine learning to extract intentions/meanings from students' conversations and guide the chatbot service to take the appropriate action or response, **4)** a cloud-based database, implemented using Google Firestore, that stores the parsed learning material and responds to the chatbot's queries in real-time, **5)** a parsing service implemented using Python programming language that parses and imports the learning resources into the database, and **6)** a speech/text two-way conversion service that converts students' speech to text before sending to the chatbot and synthesizes natural-sounding speech from the returning text from the chatbot to students. An illustration of the system components is shown in figure 2.

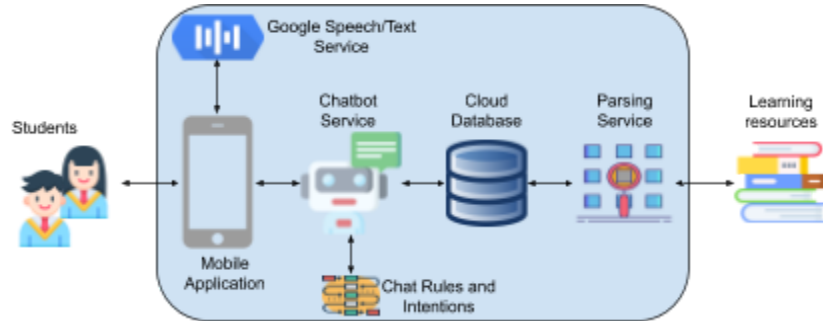


Figure 2: System main components

### 5.2 Mobile Application User Interface

The mobile application interface is designed to enhance the students' experience and minimize the learning time to use the chatbot service. The interface consists of two main screens: 1) a help screen that provides information and guidance to students along with sample questions the chatbot is expecting and 2) a student-chatbot interaction screen where students use the mic to have speech-based natural language conversations with the chatbot, respond to chatbot quizzes, and receive immediate feedback to their answers.

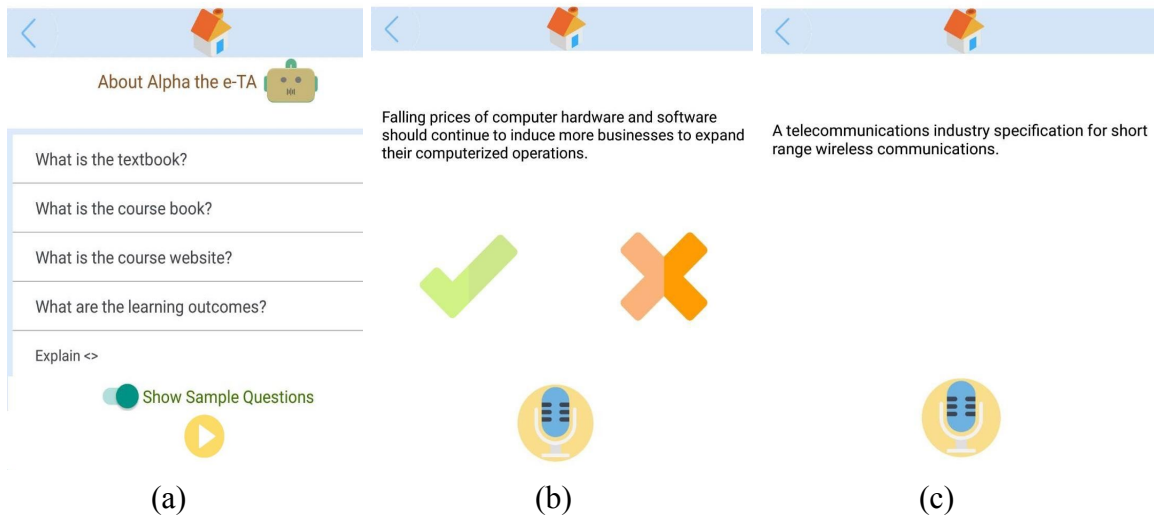


Figure 3: (a) Help screen showing examples of questions that can be recognized by Alpha, (b) Interaction screen showing a generated MCQ quiz by Alpha, (c) Alpha's response to a student inquiry on key term "Bluetooth" definition. Alpha provides both voice and text responses.

### System Usability Evaluation

This part of the study is to evaluate the usability of the chatbot system. Eleven students participated in the evaluation. The students are selected based on their enrollment in the first-year engineering course titled "Introduction to Information Systems - IS171". The course material was integrated with our system. The participants took the SUS questionnaire which was chosen for different reasons: (i) it has been widely used and proven to be reliable even with relatively small numbers of participants [17], (ii) SUS can interpret Alpha's usability rank among

other systems using Sauro's benchmark database [18], (iii) SUS can address both usability and learnability [19], and (iv) it has shown better performance when compared with other questionnaires (e.g. Questionnaire for User Interface Satisfaction, Computer System Usability Questionnaire, and Words (adapted from Microsoft's Product Reaction Cards)) [18]. Finally, we calculated the individual SUS and the average SUS scores. The percentile rank was determined based on the work by Sauro [18]. The average SUS score is seventy-seven which translates into an 80% percentile rank. This means that Alpha is more usable than 80% of the products that were evaluated in the Sauro Database.

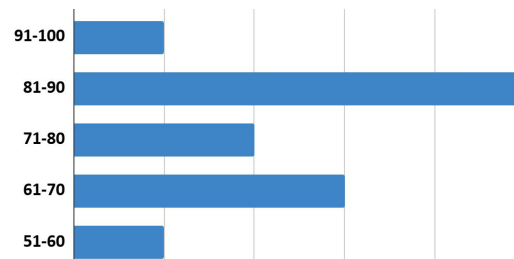


Figure 4: Distribution of the raw SUS scores with an average score equals to 77.

## System Performance Monitoring

System performance (measured by response time, payload size, and success rate) is continuously monitored using Google backend analytics and admin dashboard services. Additionally, a manual monitoring process will be conducted through periodic user surveys to collect students' feedback and report existing issues.

## Conclusion and Future Work

The increasing use of chatbots in everyday life is evolving and changing the way students learn and acquire information. In this paper, we discussed related literature and found an increasingly diverse use of chatbots in education. We conducted an exploratory survey to understand the students' needs and how they perceive the use of chatbots. Finally, we implemented a chatbot system, named Alpha, and conducted a usability assessment which revealed that students consider the new system highly usable and easy to learn.

In the future, we will consider and assess the degree of humanness and proactivity in our chatbot design, in addition to its ethical dimensions. Currently, course information is uploaded to the chatbot in a semi-automated manner, implementing a fully automated process can be more productive and easier for educators and admin users. To improve our chatbot, a new feature will be added allowing students to provide their feedback on chatbot responses based on relevancy. This will allow us to measure how much student inquiries were successfully resolved.

## References

- [1] D. C. Brooks and J. Pomerantz, "ECAR Study of Undergraduate Students and Information Technology, 2017," p. 41, 2017.

- [2] S. Adams Becker, M. Cummins, A. Davis, A. Freeman, C. Hall Giesinger, and V. Ananthanarayanan, NMC Horizon Report: 2017 Higher Education Edition. New Media Consortium, 2017.
- [3] D. Coniam, "The linguistic accuracy of chatbots: usability from an ESL perspective," *Text & Talk*, vol. 34, no. 5, pp. 545–567, Sep. 2014, doi: 10.1515/text-2014-0018.
- [4] M.-C. Ko and Z.-H. Lin, "CardBot: A Chatbot for Business Card Management," in *Proceedings of the 23rd International Conference on Intelligent User Interfaces Companion*, Tokyo Japan, Mar. 2018, pp. 1–2, doi: 10.1145/3180308.3180313.
- [5] D. Madhu, C. J. N. Jain, E. Sebastain, S. Shaji, and A. Ajayakumar, "A novel approach for medical assistance using trained chatbot," in *2017 International Conference on Inventive Communication and Computational Technologies (ICICCT)*, Coimbatore, Mar. 2017, pp. 243–246.
- [6] M. Fuertes, "Briefing paper: chatbots in education." <http://elc.blogs.uoc.edu/briefing-paper-the-chatbots-in-education/> (accessed Mar. 06, 2020).
- [7] R. Wegerif, "The role of educational software as a support for teaching and learning conversations," *Computers & Education*, vol. 43, no. 1–2, pp. 179–191, Aug. 2004.
- [8] H. Agus Santoso et al., "Dinus Intelligent Assistance (DINA) Chatbot for University Admission Services," in *2018 International Seminar on Application for Technology of Information and Communication*, Sep. 2018, pp. 417–423, doi: 10.1109/ISEMANTIC.2018.8549797.
- [9] D. Allison, "Chatbots in the Library: is it time?" Faculty Publications, UNL Libraries, Oct. 2011.
- [10] C. Chun Ho, H. L. Lee, W. K. Lo, and K. F. A. Lui, "Developing a Chatbot for College Student Programme Advisement," in *2018 International Symposium on Educational Technology (ISET)*, Jul. 2018, pp. 52–56, doi: 10.1109/ISET.2018.00021.
- [11] C. Toxtli, A. Monroy-Hernández, and J. Cranshaw, "Understanding Chatbot-mediated Task Management," *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, pp. 1–6, 2018, doi: 10.1145/3173574.3173632.
- [12] S. Crown, A. Fuentes, R. Jones, R. Nambiar, and D. Crown, "Ann G. Neering: Interactive Chatbot To Motivate And Engage Engineering Students," presented at the 2010 Annual Conference & Exposition, Jun. 2010, pp. 15.181.1-15.181.13.
- [13] K. K. Fitzpatrick, A. Darcy, and M. Vierhile, "Delivering Cognitive Behavior Therapy to Young Adults With Symptoms of Depression and Anxiety Using a Fully Automated Conversational Agent (Woebot): A Randomized Controlled Trial," *JMIR Mental Health*, vol. 4, no. 2, p. e19, 2017.
- [14] Fernoagă, Vlad, et al. "Intelligent education assistant powered by Chatbots." *The International Scientific Conference eLearning and Software for Education*. Vol. 2. "Carol I" National Defence University, 2018.
- [15] L. Benotti, M. C. Martínez, and F. Schapachnik, "Engaging high school students using chatbots," in *Proceedings of the 2014 conference on Innovation & technology in computer science education*, Uppsala, Sweden, June. 2014, pp. 63–68, doi: 10.1145/2591708.2591728.
- [16] S. Carayannopoulos, "Using chatbots to aid transition," 2017, doi: 10.1108/IJILT-10-2017-0097.
- [17] T. S. Tullis and J. N. Stetson, "A Comparison of Questionnaires for Assessing Website Usability," *Usability professional association conference*. Vol. 1. 2004.
- [18] Sauro, J., and Lewis, J. R. "Quantifying the user experience: Practical statistics for user research," Elsevier, 2012.
- [19] J. R. Lewis and J. Sauro, "The Factor Structure of the System Usability Scale," in *Human Centered Design*, Berlin, Heidelberg, 2009, pp. 94–103, doi: 10.1007/978-3-642-02806-9\_12.