A Pilot Study Integrating an AI-driven Chatbot in an Introductory Programming Course

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***Abstract*— As AI software tools become more commonplace, their potential to transform the student experience has greatly increased. By integrating these tools into a course, students can begin to receive real-time, around the clock, instructor moderated support. The potential benefits for students are significant. In addition to increasing their ability to work constructively on their schedule, it has the potential to engage students who might otherwise avoid directly interacting with another person. Before these tools can be meaningfully actualized into a course, work must be done to build a knowledge base about the course.**

For this research, the team sought to develop an intelligent chatbot interface for an introductory computer programming course. The interface had an initially limited knowledge base with the intent that it would be populated based on students' interactions with the chatbot. This model allowed the bot to evolve with the needs of the students.

This paper seeks to present the methodology for how the chatbot was developed and integrated into the course, how the knowledge base was developed, the usage during the pilot, and the next steps for improving the chatbot's interface. Additionally, the paper will discuss the mechanisms added to handle issues such as false-positive responses and how faculty may be able to integrate such tools into their own courses as supplementary assistance.

Keywords—Chatbot, Innovative Pedagogy

I. Chatbots

A chatbot is a software platform that simulates an interaction between a user and the computer using natural language [1]. These tools are applied across many contexts with the purpose of the software answering users' questions within a specific domain of knowledge [2]. With the recent emphasis on personalized learning, as directed by the National Academy of Engineering Grand Challenges [3], platforms such as these, when standing alone or integrated with intelligent tutoring systems (ITS), have the potential to enhance student learning. When using the lens of social constructivist theories, the use of conversational dialogue (i.e., the back-and-forth nature of a chatbot interface) is a means of knowledge creation [4].

The ability for students to ask questions is a critical aspect of learning and can lead to increased student outcomes [5, 6]. A summary by Harper et al. [6] has shown that giving student the opportunity to ask question led to improved study skills, improved problem solving, and better retention of course material. Despite this, there is evidence that students do not readily ask questions due to fear of negative reactions from the teacher [7]. When designed and implemented appropriately, a chatbot has the potential to allow students to ask questions without fear of social perception and allow them to develop skills associated within the specific domain.

A. Research Questions

This exploratory pilot study examines the usability of a chatbot when applied in the context of a first-year engineering programming course through the following research questions:

RQ1. How do students interact with a chatbot in a first-year programming course?

RQ2. What are student perceptions regarding the opportunity to use a chatbot in a first-year programming course?

II. Chatbots in Educational Contexts

Chatbots are commonly seen in the context of banking, e-commerce, and business as tools for customer support and engagement [8]. Within educational settings they have been implemented in online and distance courses [4, 9]. They have been especially useful for learning foreign languages [10], providing simulated experiences with historical figures within a domain (i.e. Freud [4]), and to teach computer science concepts [11, 12].

Across these implementations, the main issue with the development of a chatbot exists in the development of the knowledge database from which the answer to the questions can be drawn and the linguistic nature of the response. Approaches to the creation of the knowledge base have relied on the use of wikis, forums, and open student questions as a starting point for database creation.

In the context of engineering-centric implementations, one study presents Dr. Anne G. Neering. [13] To develop the database, students were initially tasked with authoring the knowledge database through the use specifically designed assignments. In later iterations of the chatbot, students could ask it a question and if there was no response, then the student could attempt to generate one. This response could then be rated and evaluated by other users of the chatbot. If the student did not generate a response, the question would remain unanswered until either another student asked and answered it, an instructor answered it, or it was assigned as homework. Anne G. Neering was implemented across several semesters in seven engineering courses. During that time, the chatbot received 5680 questions with 55% of the questions receiving responses at some point

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(though the authors do not discuss the validity of those responses).

Similar response rates were seen in the implementation of Freudbot (61%) [4], a chatbot designed to explain Freud's theories and ideas to distance education psychology students. Unlike Dr. Anne G. Neering, Freudbot's database was populated, not by students, but with responses developed by the authors based on a dictionary-like list of terms and a biography of Freud.

III. EduBot

An AI-based Chatbot, named EduBot, was developed by the authors as a plugin to the Canvas Learning Management System [14]. As shown in Fig. 1, EduBot appeared as a link in the sidebar menu allowing students to click on the link at any time to ask the bot a question.

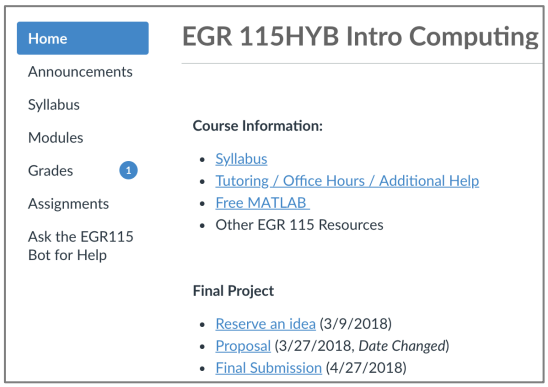

Fig. 1. EduBot Link in Canvas LMS

When users asked EduBot a question, the AI sought an answer from a Question & Answer (Q&A) database. If an answer could not be found, EduBot would automatically reply that an answer could not be found and that the professor had been notified. An email would be automatically sent to the professor with the question and a link to a response page. On that response page, the professor could simultaneously respond to the student (in the form of an email back to the student addressing their question) and update the Q&A database with a new response. Using this workflow, the intent was to improve EduBot's ability to correctly answer the question and to ensure that all questions received validated feedback, resulting in a 100% response rate, as compared to the 55% for Dr. Anne G.Neering and the 61% for Freudbot.

If an answer was identified, it was delivered back to the user. To help combat false-positive responses (where EduBot found an answer but it was not helpful in addressing the student's question), all responses included a button to indicate that "This answer is not helpful". Clicking the button initiated the same sequence of events as if EduBot had not found an answer at all.

The back-end of EduBot leverages the IMS-Global LTI Integration Standard [15] to interact with the Canvas LMS [14] and the Microsoft QnA Maker [16] to handle the AI processing. All other interactions are handled using a custom-built PHP interface designed to manage the EduBot workflow.

IV. Methods

A. Course Integration

EduBot was integrated into three sections of an Introduction to Computing for Engineers course taught by two instructors at a STEM+Business-only institution in the Southeast. The course focuses on problem solving and computer programming using MATLAB. A total of 67 students had access to EduBot. EduBot was announced early in the class and periodically mentioned as one of the many options for obtaining assistance with course content but was not featured heavily as a primary resource for students – they were typically directed to the more traditional avenues of teaching assistants and instructor office hours.

B. Data Collection and Analysis

Throughout the academic term, all interactions between the students and EduBot logged in a database. The interactions were then reviewed by the authors and categorized based on their perceived question purpose, as shown in Table I. EduBot's responses were also classified based on the author's perceived accuracy at addressing the question (Table II). The authors familiarity with the course content and structure allowed for classifications to be based partly on the contextual alignment of the questions. For example, the question "does it matter if the prompt of the input function is longer than the limit line" was classified as a course specific interaction. As MATLAB provides no errors or warnings about long lines, it was assumed that this question is more likely asking if the instructor cares about long lines versus if they are technically allowed. Likewise, when a specific function existed for a task, such as flipping an array, that was classified as being function specific question seeking the name of the function rather than a more general matrix/array question.

In the final week of the academic term, a focus group was conducted with each of the classes that had access to EduBot. The focus group questions focused on two conditions: those who used EduBot and those who did not use it. Users of EduBot were asked "why did you use it?", "How useful was EduBot at answering your question?" and "What could be improved?". Non-users were asked "Why did you not use EduBot?" and "What would make you more likely to use EduBot?". Responses were categorized into common themes.

V. Results

A. EduBot Usage

EduBot was used for 48 interactions by 21 unique users (31% of possible users) in 33 different usage sessions. Six of the 21 unique users initiated more than one session, with the other 15 only using the chatbot once. A majority of these interactions occurred within the first third of the academic term (Figure 2)

The initial knowledge database for EduBot was only populated with common MATLAB functions used in the Introduction to Computing for Engineers course. As a result, it was expected that there would be a high percentage of "No-Answer Found" responses from EduBot. Overall, these responses comprised 33.3% of the chatbot's responses.

TABLE I. INTERACTION CATEGORIZATION

Interaction Category	Number of Interactions	Example Interactions
Function Specific Help	16	• How do I use the mod function? • How do I flip arrays • str2double
Course Specific	6	• What if the video link is not working • Does it matter if the prompt of the input function is longer than the "limit line"? • when are office hours
Loops & Conditionals	6	• Can I use a string as a condition in a while loop • How do I use a loop to count things • How do you use for loops?
Nonsense	5	• Hi bot • Thanks! Bye
Algorithm Development	4	• how do i make someone input a whole number • how can I error check a string • error checking strings
Programmer Defined Functions	4	• using a programmer defined function • How do I call a programmer defined function • How do I use a created function
Basic Computer Usage	2	• How do I save the matlab file as a pdf? • how do i download matlab,
Matrices	2	• how do i splice matrices • How do I separate arrays by columns,
Unclear Question	2	• How can I shorten my lines?
Error Message Interpretation	1	• What do i do when matlab tells me 'Matrix dimensions must agree

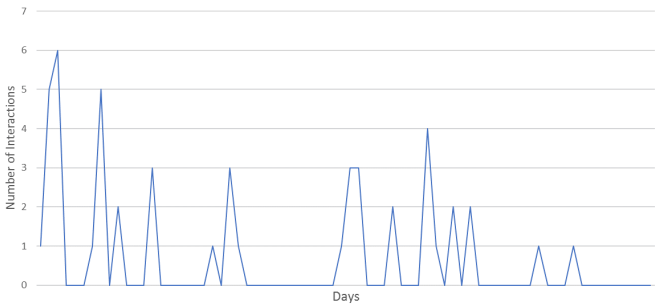

Fig. 2. Usage of Edubot over the duration of the term.

TABLE II. EDUBOT RESPONSE ACCURACY

Response Category	#	%
Response Clearly Addressed Question	8	16.7%
Response Tangentially Addressed Question	4	8.3%
Student Clicked Response Not Helpful – Prof. Emailed	5	10.4%
No Answer Found – Prof. Emailed	16	33.3%
Student Rephrased Question	6	12.5%
Response was not helpful and not asked again	9	18.8%

B. *Student Perceptions of EduBot*

The focus groups revealed that the initial interest in EduBot (seen in Figure 2) was largely based on curiosity. Student users wanted to see what type of response they would receive from the chatbot. However when they did not receive an immediate response they became disengaged and decided that there were other resources (i.e. Google, MATLAB help functions) where they could receive an answer more promptly rather than waiting for the instructor to reply. A few users of the chatbot noted that they asked a question later in the term to see if the knowledge base had been built up to support their more recent question. However, when they received the "no answer found" they decided to not use EduBot further.

Non-users of EduBot indicated that they felt they could receive better information from Google and the MATLAB help directory or doc files than they could from EduBot, a perception that may or may not be accurate. They also indicated that, when they had very specific questions, they thought it was easier to talk to the instructor rather than write their question to EduBot. Other non-users indicated that they simply forgot that the chatbot functionality was available throughout the course.

When questioned about the potential for EduBot within the context of the introductory programming course, students overwhelmingly indicated that the chatbot would be better served answering questions that are related to the contextual application of programming concepts, providing examples that are relevant to the course information, and providing direction to course specific resources. These recommendations were identified by the students as knowledge that they could not easily obtain through internet searches and internal MATLAB support because these sources were either too general in their responses or were not contextually relevant to the course materials.

VI. CONCLUSIONS AND FUTURE WORK

Chatbots have the potential to encourage student questions from students who may be fearful or inhibited to participate in a regular class session. They can also potentially provide an opportunity to offer contextually relevant responses to student questions in comparison to those they can find in general internet searches [16]. Despite lower than expected usage, EduBot was developed with these "contextually relevant responses" in mind to address where students could have course specific questions answered outside of traditional class times and without fear of judgment regarding what they were asking.

The development utilized a similar framework to Crown et al. [13], but rather than having students develop responses, EduBot relied on the instructor responses to ensure validity in the responses. While the author's initial expectation was that responding to all bot interactions might increase the instructor's time commitment, they acknowledged that this increase might also be offset by the fact that the most commonly used alternative to the bot was still to email the instructor. By using the EduBot workflow, responses to one student's question could now be given to all students. Unfortunately, the lack of student involvement in the process led to decreased use of the chatbot. The usage and feedback from students notes a need for a more

comprehensive development of the chatbot database before implementation rather than developing the knowledge base simultaneously.

Future work on EduBot will address the creation of a more comprehensive database, through the use of multiple sources including student question databases. Additional analyses will begin to examine the depth of questions in order to begin to develop a chatbot that can encourage students to ask more meaningful questions.

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REFERENCES

[1] Shawar, B. A., & Atwell, E. (2007). Chatbots: are they really useful?. In *Ldv forum* (Vol. 22, No. 1, pp. 29-49).

[2] Bii, P. (2013). Chatbot technology: A possible means of unlocking student potential to learn how to learn. *Educational Research*, *4*(2), 218-221.

[3] National Academy of Engineering Website, http://www.engineeringchallenges.org/, accessed April 10, 2018.

[4] Heller, B., Proctor, M., Mah, D., Jewell, L., & Cheung, B. (2005, June). Freudbot: An investigation of chatbot technology in distance education. In EdMedia: World Conference on Educational Media and Technology (pp. 3913-3918). Association for the Advancement of Computing in Education (AACE).

[5] Shodell, M. (1995). The question-driven classroom: student questions as course curriculum in biology. The American Biology Teacher, 57(5), 278-281.

[6] Harper, K. A., Etkina, E., & Lin, Y. (2003). Encouraging and analyzing student questions in a large physics course: Meaningful patterns for instructors. Journal of Research in Science Teaching, 40(8), 776-791.

[7] Dillon, J. T. (1981). A norm against student questions. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *55*(3), 136-139.

[8] Brandtzaeg, P. B., & Følstad, A. (2017, November). Why people use chatbots. In *International Conference on Internet Science* (pp. 377-392). Springer, Cham.

[9] Kerly, A., Hall, P., & Bull, S. (2007). Bringing chatbots into education: Towards natural language negotiation of open learner models. Knowledge-Based Systems, 20(2), 177-185.

[10] Jia, J. (2004). The study of the application of a web-based chatbot system on the teaching of foreign languages. In *Society for Information Technology & Teacher Education International Conference* (pp. 1201-1207). Association for the Advancement of Computing in Education (AACE).

[11] Benotti, L., Martínez, M. C., & Schapachnik, F. (2014, June). Engaging high school students using chatbots. In *Proceedings of the 2014 conference on Innovation & technology in computer science education* (pp. 63-68). ACM.

[12] Shaw, A. (2012, April). Using chatbots to teach socially intelligent computing principles in introductory computer science courses. In *Information Technology: New Generations (ITNG), 2012 Ninth International Conference on* (pp. 850-851). IEEE.

[13] Crown, S., Fuentes, A., Jones, R., Nambiar, R., & Crown, D. (2010). Anne G. Neering: Interactive Chatbot to Motivate and Engage Engineering Students. In *American Society for Engineering Education*. American Society for Engineering Education.

[14] "Learning Management System | Canvas by Instructure," 2018. [Online]. Available: https://www.canvaslms.com/.

[15] IMS Global Learning Consortium, *Learning Tools Interoperability v2.0 Final Specification*. Lake Mary, FL: IMS Global Learning Consortium, 2013.

[16] Microsoft, "QnA Maker," 2018. [Online]. Available: https://qnamaker.ai/. [Accessed: 21-Apr-2018].