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Using Chatbots to Teach STEM Related Research Concepts to High School Students

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Abstract: Research or capstone subject is not in the curriculum of ICT strand, but it is only offered in the Academic track. However, given the current technology trends, it can be deduced that research is also essential to help the students become active and creative professionals in their respective fields in the future. In this paper, we present the use of chatbots for teaching research concepts to senior high school students. The students were tasked to create chatbots for the different domains that they were interested in through the use of Dialogflow. This paper also discusses the teaching methodology that was used to deliver the course.

Keywords: Conversational agents, natural language dialogue, STEM learning, Pedagogy

1. Introduction

The standard duration of acquiring basic education as recognized by most countries around the world is 13 years from Kindergarten to Grade 12 (K-12). The Philippines is the last country in Asia that implemented the K-12 program and is previously one of the only three countries worldwide that requires 10 years of basic education before going to university. With the intention to equip the students with the standard knowledge, skills, and competencies that are essential for college, the K-12 program was implemented last 2011 with the first batch of Senior High School students (i.e. Grade 11 - 12) accepted last 2016 (The K to 12 Basic Education Program, 2013). With the K-12 program in its early stage, several preparations are needed to be done to cope up with the worldwide standards for basic education.

In the K-12 program, the students may choose between the following tracks: Academic, Technical/Vocational, Sports, Arts and Design, etc. This research will focus on Information and Communications Technology (ICT) strand which is under the Technical/Vocational track (Sarmiento & Orale, 2016). Perusing the curriculum guide of the Department of Education, ICT strand does not have a research or a capstone. However, looking at the possible career paths of the ICT graduates, it can be deduced that research is necessary and beneficial in some of the jobs or degrees listed. Hence, the participating school of this research believes that the students must experience research or capstone for at least a term.

In this research, the process of creating a chatbot is used to simulate the research process in a short period of time. This approach can also be used in STEM to give them an early exposure to research methods so that they can be ready to a higher level of research.

2. Related Work

2.1 Chatbots for Education

Ranoliya, Raghuwanshi, & Singh (2017) created a chatbot that could be used by any university to provide answers to questions that students frequently ask, in an interactive manner. It provides information such as rankings, availability of services, university environment, other academic information and many more They used a combination of Artificial Intelligence Markup Language (AIML) and Latent Semantic Analysis (LSA) to provide accurate answers for any query based on the FAQs dataset. AIML was used to handle template based and general questions like greetings. LSA was used provide responses to other service-based questions.

Another chatbot created by Argal, et al. (2018) was designed to answer user queries in the travel domain. They implemented their chatbot on the Amazon Echo platform to trigger Alexa, which is Amazon's own chatbot. They then used a backup server hosted by Amazon Web Services for processing the requests. They also used their deep neural network engine, which implements the Restricted Boltzmann Machine, to generate responses.

Chatbots can also be used in the field of health informatics as shown in the work of Madhu, Neeraj, Sebastian, Shaji, & Ajayakuman (2017). Their chatbot acts as a personalized medical assistant by predicting diseases based on symptoms and by giving a list of available treatments. It can also give information about different medicine and their uses.

2.2 Chatbots for Different Domains

Chatbots have been used in tutoring systems for teaching many courses and not just Computer Science. Some of these systems include the work of Kerly, Hall, & Bull (2007). Oscar is another chatbot that is an adaptive online intelligent tutoring system. It is capable of leading tutoring conversations and adapt to the learning styles of students. AutoTutor is another chatbot that was designed to mimic a human tutor by conversing with learner in natural language. Over a dozen experiments were conducted using AutoTutor to teach concepts on Newtonian Physics and computer literacy.

The work of Benotti, Martinez, & Schapachnik (2018) presented their own software platform Chatbot which was designed to introduce Computer Science concepts to high school students. Their work differs from the usual model of using a chatbot as an intelligent tutoring system because in Chatbot, the students have to program their own chatbots and learn the concepts by programming and not by chatting with the chatbot. A few other researchers like Keegan, Boyle, & Dee (2012) and Shaw (2012) also used chatbot programming as a method to increase engagement in Computer Science. They used to teach artificial intelligence concepts and to explain the Turing Test. Bigham, et al. (2008) conducted a workshop for blind students, wherein they were tasked to create personalize instant messaging chatbots. They designed this course in order to inspire blind students to take up Computer Science.

3. Course Design and Implementation

3.1 Course Outline Design

The research or capstone project course is intended as a specialized course for the Science, Technology, Engineering, and Mathematics (STEM), Humanities and Social Sciences (HUMSS), and Accounting, Business and Management (ABM) strands under the Academic Track. The ICT track is under Technical, Vocational, and Livelihood track; thus, it does not have a course about research or capstone project. In this regard, the contents of the course are adapted from the sample syllabus of the Capstone project course of the Academic Track.

In the Capstone course, the students are introduced to the research process and are guided by an adviser throughout the whole capstone process to produce a scientific paper to be presented as an output. The course is taught in the second year of Senior High School and runs for the whole academic year. The contents of the course are the following: scientific problem, scientific literature, hypothesis, methodology, data collection, data analysis, conclusions, recommendations, and scientific paper (K to 12 Basic Education Curriculum, n.d.).

Since it is not supposed to be part of the specialized courses of ICT track, the participating school decided to reduce the duration from 1 academic year to only a term or a total of 4 months. The instructors adapted the software development life cycle, specifically waterfall, in teaching the students about the research process since the two processes are similar. The waterfall model focuses on early and detailed planning which reduces issues in the design later on. It is similar to research wherein the scientific problem, scientific literature, and hypothesis stages are done early as it is crucial in the whole process.

The waterfall model can be mapped to the content of the research course. It has 5 steps: requirements definition, system and software design, implementation and unit testing, integration

and system testing, and operation and maintenance (Munassar & Govardhan, 2010). Refer to Table 1 for the mapping of the steps in research/capstone to the waterfall model.

The scientific problem focuses on identifying a scientific problem or question and determining if the research problem is applied or basic. The scientific literature focuses on reviewing, analysing, comparing, and setting relevance criteria of other studies related to the research problem. The hypothesis focuses on formulating possible outcomes of the investigation or solutions to the research problem. These three stages are equivalent to requirements definition of waterfall which includes determining the expected functionalities that could solve a problem.

The methodology and implementation focus on designing the concrete steps to be taken to implement the solution. This is equivalent to system and software design, and implementation and unit testing wherein the major components of the solution and their interaction are defined and programmed.

The data collection includes gathering data and determining whether the data collected is sufficient. The data analysis involves drawing insights from the data collected. Its equivalence is integration and system testing which focuses on gathering insights from testers if the system follows the system requirements.

The conclusions and recommendations include drawing conclusions from the data that were gathered and making suggestions that could improve the study. Its equivalent is operation and maintenance which focuses on coming up with the list of issues and/or enhancements that can be applied for the improvement of the system.

With this, the research/capstone course for the ICT strand entails a small-scale research and/or project development. The proposed course outline is patterned after the waterfall model. Table 2 shows the proposed course outline and its mapping to each step in the waterfall model.

3.2 Course Activities Implementation

Since the students are not yet knowledgeable in programming a software and the course is taught for 4 months only, they are tasked to create a chatbot instead of creating a software from scratch. Students are first introduced to the concept of chatbots. They are then asked to choose a domain that they would like to work on. Although all the students were on the ICT track, there was still a lot of variety in terms of what they wanted to take up in college so they were allowed to choose a domain that piques their interests. Since conversations can be about almost anything, the chatbot creation allows the students to learn research while focusing on conversations about the topic that they like.

Table 1
Proposed Course Outline mapped to Waterfall

Waterfall	Lecture Topics/Activities
Requirements Definition	Introduction to Research and Systems Development Ethics in Research and Software Engineering
Requirements Definition	Requirements Engineering • Problem Analysis • Requirements Specification
System and Software Design	Design • User Interface
Implementation and Unit Testing	Project Implementation
Integration and System Testing	Validation • End user testing

3.2.1 Requirements Engineering

From the chosen domain, they identified a research problem that can be solved through the use of a chatbot. After identifying the research problem, they had to do requirements analysis in order to identify the components and requirements of their solution. They are given the task to research usual conversations about the topics that they used. They can check different mobile and web applications

where they can infer the information that they need in the construction of the conversations. For example, if their solution is a chatbot for medical diagnosis, the students can check the contents of a medical website to derive the common questions of people who visit that website and analyze what questions they can ask the user to arrive at a diagnosis. Their output for this phase is a software requirements specification that contains the possible flow of conversations and the possible responses of the users.

3.2.2 Design

After they have finalized the software requirements specifications, they are tasked to design the user interface of the chatbot. The user interface must match the topic that they chose to engage the users in the conversation. For example, if their solution is a chatbot for travel planning, they can show images of the scenic spots instead of just plain text or for the fitness chatbot, they had to show the meal plans in a format that would make it appetizing.

3.2.3 Project Implementation

The students used Dialogflow to create their chatbots. Dialogflow is an end-to-end development suite by Google, for building conversational interfaces for websites and mobile applications. It can be used to create interfaces, such as chatbots, that are capable of natural and rich interactions. It uses machine learning to recognize the intent and context of what a user says thus allowing the chatbot to give accurate responses. Natural language understanding enables it to recognize a user's intent and it is also capable of extracting pre-build entities such as time, date and numbers. Developers can train their agents to identify custom data types and they can also use pre-built agents as a template. Dialogflow supports more than 20 languages and it has integrations with over 14 different platforms such as Google Assistant, Viber, Facebook Messenger and more (Dialogflow Enterprise Edition, n.d.). After creating their chatbots, they integrated it to Facebook Messenger by creating their own app and page so that users can chat with the chatbot that they created.

3.2.4 Validation

The students validated the performance of their chatbots through a survey from at least 30 participants. They formulated survey questions to draw out whether the responses of the chatbots are convincing for the users. Then, they recorded the conversations of the participants with the chatbot. They have gathered the responses on the survey questions afterwards.

4. Results

There were 19 students in the class and they were split into six groups. They created chatbots for the following domains: travel, university applications, fitness, games, restaurants and shopping.

After creating their chatbot, they integrated their chatbots to Facebook Messenger so that it could be accessed by anyone with access to their page. A screenshot of a sample chatbot is shown in Figure 1 showing a dialog between a student and the university chatbot.

They were asked to present their work to a panel composed of four university professors from the College of Computer Studies of De La Salle University. The rubric in Table 3 was used to evaluate the students' chatbots and their work throughout the whole research process. The evaluation criteria were designed to evaluate the chatbot as well as the output of each step in the software development lifecycle.

Table 2
Evaluation Criteria

Evaluation Criteria	Description
Problem Definition	Stated the research problem clearly, providing motivation for undertaking the research

Literature and Previous Work	Demonstrated sound knowledge of literature in the area and of prior work on the specific research problem
Content	Clearly defined the topic and its significance; Supported the research and key findings with an analysis of relevant and accurate evidence; Provided evidence of extensive and valid research with multiple and varied sources; Provided evidence of complex problem solving Combined and evaluated existing ideas to form new insights
Solution Approach	Applied sound research methods/tools to solve the defined problem and has described the methods tools effectively.
Results	Analyzed and interpreted research results/data effectively.
Language Use and Delivery	The student communicated ideas effectively; Effectively used eye contact, speaks clearly effectively and confidently using suitable volume and pace; Fully engaged the audience; Used rich and varied words for context and correct grammar.
Organization and Preparation	Introduced the topic clearly and maintained clear focus on the topic; Effectively included smooth transitions to connect key points; Ended with a logical, effective and relevant conclusion.
Question and Answer	Demonstrated extensive knowledge of the topic by responding confidently, precisely and appropriately to all questions and feedback.
Chatbot Design	The chatbot is logically well designed; The flow of conversation is well designed; The chatbot has convincing, satisfying and natural interactions; Uses well-designed functionalities like the use of rich text formatting, images and provides navigation tools to help users navigate the layout makes tasks more fun and interesting or entertains and enables participants to enjoy the interaction.
Chatbot Functionality	The chatbot displays correct output with no errors Interprets commands accurately and able to respond to specific questions; Executes requested tasks and can detect meaning or intent; General ease of use Gives conversational cues. Robustness to unexpected input; Contains breadth of knowledge and is flexible in interpreting it.

Table 4 shows the average score for each criterion. Each criterion is rated using a scale of 1-5, with 5 being excellent, 4 very good, 3 acceptable, 2 needs improvement and 1 needs significant improvement. The evaluation criteria with the highest average grade was the one for the problem statement. This is because the problems they chose to work on were relevant to their interests so it was easy for them to identify the gaps or problems with the current applications that they used in the particular domain that they chose. It also helped them in identifying the requirements and which features to include since they knew what was needed in the system as they are the prospective users as well. They also had a high score for the literature and previous work because of the same reasons. On the other hand, they had low scores for the results criteria. This could be because the model used was the software delivery lifecycle and although they were taught how to do test cases, the instructors did not discuss how to create and evaluate a survey. Most of the groups conducted surveys to evaluate their chatbot in a quantitative manner but they did not include open-ended questions in order to get the reasons for the scores given by the participants of the survey. This would have been discussed in a regular research class. Another reason could be the lack of time. Since the students only had four months to do research and to create the chatbot, they had very little time to do their testing and evaluation and to write about the results as well.

Table 3
Average scores for each evaluation criteria

Stat	Mean
Problem Definition	4.416667
Literature and Previous Work	4.041667
Content	3.625
Solution Approach	3.458333
Results	2.75
Language Use and Delivery	4.166667

Organization and Preparation	4.083333
Question and Answer	3.375
Chatbot Design	3.416667
Chatbot Functionality	3.458333

5. Conclusion

Chatbot projects can help introduce research concepts to students with the flexibility of allowing them to choose the domain based on their interests, and at the same time it also introduces them to basic concepts in Computer Science. Overall, the implementation of the course was a success and the school officials from the high school where we offered it, wanted to offer the same course again for the next batch. For future work, we recommend that the course must include a module for teaching how to collect and analyse data. We would also like to recommend comparing the output produced by students and their experience when using chatbots versus other modes of teaching research.

References

Argal, A., Gupta, S., Modi, A., Pandey, P., Shim, S., & Chang, C. (2018). Intelligent Travel Chatbot for Predictive Recommendation in Echo Platform. *IEEE 8th Annual Computing and Communication Workshop and Conference*, (pp. 176-183).

Astros, E. A. (2018, Feb 6). *Is ICT strand getting more SHS enrollees*. Retrieved from Pressreader: https://www.pressreader.com/philippines/panay-news/20180206/281788514509189

Benotti, L., Martinez, M., & Schapachnik, F. (2018). A Tool for Introducing Computer Science with Automatic Formative Assesment. *IEEE Transactioins on Learning Technologies*, (pp. 179-192).

Bigham, J. P., Aller, M. B., Brudvik, J. T., Leung, J. O., Yazzolino, L. A., & Ladner, R. E. (2008). Inspiring blind high school sstudents to pursue computer science with instant messagin chatbots. *39th SIGCSE Technology Symposium Computing Science Education*, (pp. 449-453).

Dialogflow Enterprise Edition. (n.d.). Retrieved from Google Cloud: https://cloud.google.com/dialogflow-enterprise/

K to 12 Basic Educatioin Curriculum. (n.d.). Retrieved from Department of Education: http://www.deped.gov.ph/k-to-12/about/k-to-12-basic-education-curriculum/

Keegan, M., Boyle, D., & Dee, H. M. (2012). Turi: Chatbot software for schools in the turing centenary. *7th Workshop Primary Secondary Computer Education*, (pp. 153-154).

Kerly, A., Hall, P., & Bull, S. (2007, March). Bringing chatbots into education: Towards natural language negotiation of open learner models. *Knowledge Based Systems*, pp. 177-185.

Madhu, D., Neeraj, J., Sebastian, E., Shaji, S., & Ajayakuman, A. (2017). A Novel Approach for Medical Assistance Using Trained Chatbot. *International Conference on Inventive Communcation and Computational Technologies.*

Munassar, N., & Govardhan, A. (2010). A Comparison Between Five Models of Software Engineering. *International Journal of Computer Science Issues*, 94-101.

Ranoliya, B. R., Raghuwanshi, N., & Singh, S. (2017). Chatbot for University Related FAQs. *International Conference on Advances in Computing, Communications and Informatics*, (pp. 1525-1530).

Sarmiento, D. H., & Orale, R. L. (2016). Senior High School Curriculum in the Philippines, USA, and Japan. *Journal of Academic Research*, 12-23.

Shaw, A. (2012). Using chatbots to teach socially intelligent computing principles in introductory computer science courses. *IEEE 9th International Conference in Information Technology*, (pp. 850-191).

The K to 12 Basic Education Program. (2013). Retrieved from Official Gazette: http://www.officialgazette.gov.ph/k-12/