AC 2010-1726: ANN G. NEERING: INTERACTIVE CHATBOT TO MOTIVATE AND ENGAGE ENGINEERING STUDENTS

Stephen Crown, University of Texas, Pan American

Arturo Fuentes, University of Texas, Pan American

Robert Jones, University of Texas, Pan American

Rajiv Nambiar, University of Texas, Pan American

Deborah Crown, San Jose State University

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Abstract

Student motivation and engagement are essential ingredients to academic success. Although the relationship is clear, the challenge is finding what pedagogical methods and context motivates students and engages them to a point where they become active participants in the learning process. An effective approach to discovering what will motivate and engage students is to focus on student's interests, goals, aspirations, and values. With a better understanding of students it is possible to develop an effective learning environment or activity that is embraced by students, leads them to a deeper level of learning, and entices them to become lifelong learners. This approach was the starting point in the development of an online artificial intelligence or "chatbot" named Anne G. Neering (EnGiNeering). The chatbot is a computer program delivered on course websites that serves as a text based conversational agent. The purpose of this interactive online learning environment is to encourage students to think reflectively on course fundamentals. Although providing students with access to a complex artificial intelligence focused on course fundamentals is a valuable byproduct, the greatest value lies in the student motivation and engagement associated with development of the knowledge base. Student involvement in the process of building Anne's knowledge base has proven to be instructional and fun. The knowledge base is built from individual and cooperative student interactions. As part of assigned coursework students formulate questions based on their perceptions of course fundamentals and attempt to provide responses that are consistent with their own knowledge and in a way that other students would relate to and clearly understand. An evaluation mode uses student interaction to assess the accuracy of student responses and provides an interesting environment for open ended student interaction on course concepts. The development and assessment of the knowledge base is primarily the work of students but is somewhat hidden from the users. The "chatbot" is currently being tested by four engineering professors and one business professor with seven undergraduate courses. The paper outlines the response of students to this learner centered environment and its impact on student motivation, engagement, and ultimately academic success. The success of this learning environment is also explained in terms of its relationship to the four dimensions of the HPL learning environments and the STAR Legacy cycle.

Introduction

Student motivation and engagement are essential ingredients to academic success. One of the challenges facing faculty is how to relate to students who are often very different from their teachers and who may best learn and process information differently than previous generations. One of the driving factors in this change is new technology that is having a significant impact on society and the average college student. One of the recent changes popular among students is the prevalence of online chat and text messaging. Students are comfortable with communication based short text-based exchanges of information. Leveraging the popularity of this mode of communication may provide another mechanism to interest students in engineering and possibly

serve as a significant platform for instruction. Many chat web sites exist that allow students to interact with other individuals or even with simulated intelligent being called chat-bots. Most of these chat-bots are simply built for the entertainment of users. The authors have developed a chat-bot whose purpose focuses on engineering education. In the past, among other course related technologies, the authors have had some success effectively introducing asynchronous computer based instruction into the learning environment[1-7].

The purpose of the engineering chat-bot site is to build an online artificial intelligence named "Anne G. Neering" that is a useful aid to students in their courses. Student involvement in the process of building Anne's knowledge base is intended to be both fun and instructional. Students are encouraged to inject some personality into the responses while remembering that other students are learning from the responses and evaluating their accuracy. The chat-bot gives students an opportunity to express course content in their own words and from a student's point of view that may communicate more effectively than the text or lecture content alone to other students.

Students can ask Anne a question by simply typing "What is your name?" in the text box and she will respond. In the context of an engineering course students are encouraged to interact with Anne and learn about specific course content. If they ask a question that she does not have a response to she will give them an opportunity to provide her with a response. If they provide Anne with a response she will give them credit as the author each time she is asked that question. Anne records the number of times that their question has been asked so that they can track how their response has been a benefit to other students.

Development of an Online Engineering Artificial Intelligence

The first implementation of the Anne G. Neering engineering chat-bot was simply to train one of the existing chat-bots to properly address engineering questions. There are several different chat-bot platforms available online that are hosted on remote servers or that can be downloaded and hosted on a local server. Several different versions and content editors were tested with most relying on an existing AIML (artificial intelligence markup language) brain such as Alice (http://alicebot.blogspot.com) but which also include tools for developing new content. AIML is a structured format that uses the XML file structure to define responses to predefined questions. These files can be imported into chat-bots to provide basic responses for common questions giving bots a personality aside from content specific engineering questions.

The first version of Anne G. Neering used with engineering students was created as a pandorabot on www.pandorabots.com. A limited amount of engineering content related to temperature measurement was developed by Dr. Crown and delivered to students in a measurements and instrumentation lab. Students responded positively to the platform however the time investment required for the instructor to create content for an entire course was determined to be prohibitive. In the process, however, it was observed that the development of the content was very instructional. In the following summer a group of high school students were employed to teach the chat-bot basic algebra to study the possibility of using students in the process of training the chat-bot. The students enjoyed working on the project, gained a better understanding of algebra,

and created a significant database of responses for questions about algebra. However, the students struggled with some of the complex structure of AIML beyond one for one matching of responses to algebra questions. Furthermore, the students had difficulty with the online teaching interface for the chat-bot.

Based on the positive response of students to the chat-bot and the difficulties encountered in using the available training utilities, a new platform for the chat-bot was developed by Dr. Crown (www.crown.panam.edu/chat) as shown in Figure 1. The new Anne G. Neering chat-bot was developed to interpret a majority of questions and responses given in existing AIML files. This would enable the engineering chat-bot to build onto one of several chat-bot personalities available such as Alice. It was determined that much of the needed capability of the chat-bot could be accomplished with a simplified set of AIML commands and that existing AIML files could be filtered to remove particular questions that make use of infrequently used commands. The functionality of the developed engineering chat-bot includes the ability to respond to predefined questions, use variables in questions and responses, map multiple questions to a common response, ask follow-up questions, learn from user input, identify predefined topics and respond accordingly, and provide random responses for common questions. With this limited set of capabilities a majority of standard AIML files could be used with limited filtering.
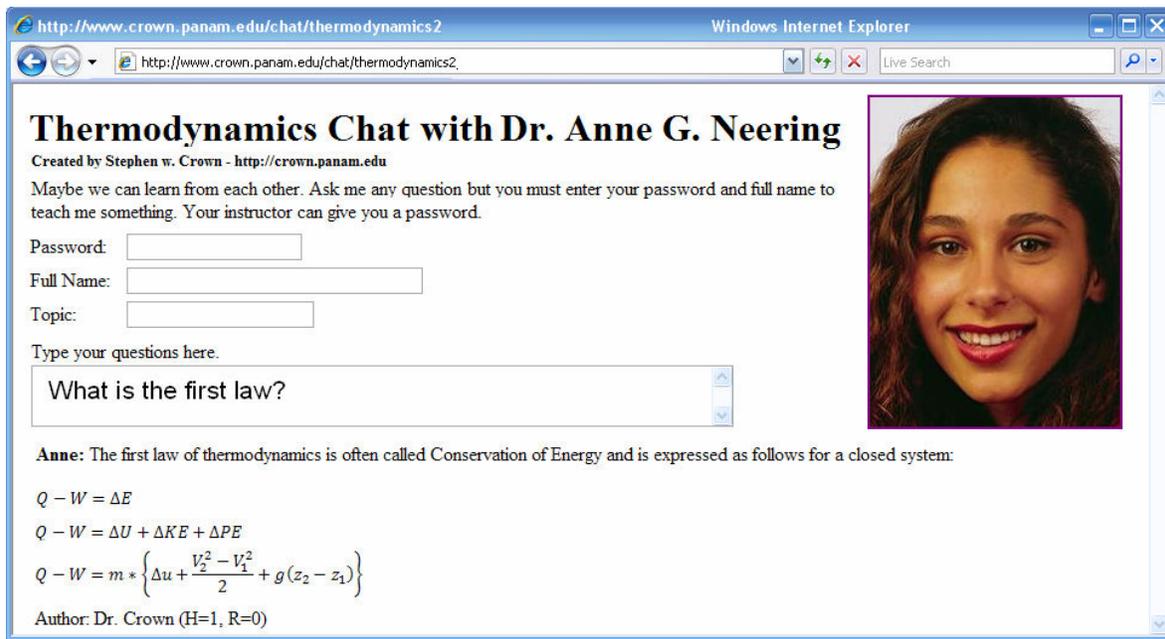

Figure 1: The Anne G. Neering (Engineering) Chat-Bot

The developed chat-bot is able to set and make use of any number of defined user variables such as user name, location, age, major, current classes, areas of interest, etc. to make the interactions more personal and targeted to specific learning needs. The list and use of these defined user variables is flexible by design so that new variables may easily be added as their usefulness becomes apparent. An example of Anne using the variables "user name" and "topic" during interactions is illustrated below.

You: What is your name?
Anne: My name is Anne G. Neering (my parents had a sense of humor). What is your name?
You: My name is Steve. {Anne learns user name - Steve}
Anne: Nice to meet you Steve. Are you an engineering student?
You: Yes. I am studying mechanical engineering. {Anne learns topic – mechanical engineering}
Anne: What mechanical engineering courses are you taking this semester?

Questions can be asked in a variety of ways and the training of the chat-bot is simplified if multiple questions can be mapped to a single response. The following questions could all be addressed with a common response.

You: What is the first law of thermodynamics?
You: What is the first law?
You: What is the law of Conservation of Energy?
You: Do you know what the first law is?
You: * first law *?
Anne: The first law of thermodynamics, often called the law of conservation of energy, states that energy cannot be created or destroyed but can change forms. We use this law to keep an accounting of where energy is going in various processes. The equations used depend on the nature of the system.

The above response is assigned to the single question "What is the first law of thermodynamics?" The other questions must simply refer back to this question. The final form of the questions listed above uses a wild-card which is used to match any question that has the words "first law" in it such as "Tell me about the first law." Anne would simply respond to the question "What is the first law of thermodynamics?" unless the actual question perfectly matched another predefined question.

The program learns from the interactions with the user and keeps track of previous questions and responses to better identify a match between the users question and the appropriate response. If a question from the user prompts a question posed by Anne, the response must be handled accordingly. If Anne asks the questions "What is your name?" the next question from the user must be interpreted as a response to Anne's question and the result mined for the user's name. Similarly, if the user asks "What is the first law of thermodynamics?", the program assumes that the topic is now the first law and questions specific to this topic can be addressed. If the user then asks "What is the equation?" the appropriate response would be to provide an equation for the first law as shown below.

You: What is the first law of thermodynamics?
Anne: The first law of thermodynamics, often called the law of conservation of energy, states that energy cannot be created or destroyed but can change forms. We use this law to keep an accounting of where energy is going in various processes. The equations used

depend on the nature of the system. {Topic set to the first law}
You: What is the equation?
Anne: The simplest form is Q-W=ΔE but it depends on the details of the system such as whether it is a closed or an open system.

The response to the question "What is the equation?" would only make sense if a topic of conversation was already understood. This question would then need to be appropriately defined for each topic. If the user simply asked "What is the equation for the first law of thermodynamics?" then the above response could be given since the topic was explicit in the question. The ability of the chat-bot to follow topics and seemingly track with a conversation, along with remembering information about the user and providing random responses, gives the user the sense that the chat-bot has some human characteristics and is more interesting to interact with and learn from. The challenge is then to combine this engaging personality with the knowledge base of course content required so that they could serve as a tutor. Teaching Anne the course content is a formidable task that would either require a significant investment of time or a large number of instructors.

Using Students to Train an Online Engineering Artificial Intelligence

Students and faculty who participated in the initial training of the chat-bot recognized the opportunity for learning in this task. As a trainer thinks through what are the likely questions a student may ask about a particular subject matter they must consider the stages of learning that students travel through and what concepts they find challenging. Students generally have little opportunity to express course content in their own words and using their own examples to illustrate concepts. Involving students in this teaching process brings students to a deeper understanding of the course content[8-11]. Involvement in the training project is enhanced by the fact that they are playing a role in the development of a tool that will be used by other students. As Anne's capabilities progress it is expected that usefulness of the tool will also progress as students interact as both trainers and users.

In 2008 Anne G. Neering was introduced in a number of large engineering classes where her training in specific course content was carried out through various assignments and projects. Although the capabilities of the developed engineering chat-bot give Anne a personality that is engaging as she instructs and interacts with students, the mechanics of this personality were problematic for training with multiple instructors. It was determined that Anne's capabilities must temporarily be limited for such a training environment where training is simultaneous and conducted by novice programmers. The chat-bot program was rewritten to allow for any number of users to simultaneously create new content for the engineering chat-bot. The development of a new platform allowed for the inclusion of tools specific to the delivery of engineering content and the support of students as content developers. Several tools were developed to assist in the learning process of students as they participated and in the management of providing credit and motivation for those involved.

The engineering classes and instructors that have participated in the development of Anne's understanding of engineering concepts are shown in Table 1. The total number of unique student

questions entered into the database for each course is show in the table. In the combined database of Thermodynamics I and II, students have entered 3141 unique questions and provided associated responses for 1755 of them. The totals for several of the courses represent a growing database developed over several semesters. The database manages the entry of new questions and ensures that all questions are unique.

Table 1: Courses Involved in the Engineering Content Training of Anne G. Neering.

Course Title	Instructor	Database Questions	Responses
Measurements and Instrumentation	Dr. Stephen Crown	1168	847
Thermodynamics I	Dr. Stephen Crown	3141*	1755*
Thermodynamics II	Dr. Stephen Crown	3141 (*shared database)	1755*
Mechanical Vibrations	Dr. Arturo Fuentes	645	184
Manufacturing Processes Lab	Dr. Rajiv Nambiar	139	70
Engineering Materials	Dr. Robert Jones	571	311
Engineering Composites	Dr. Robert Jones	16	10

Students train Anne by simply interacting through a textbox on her website. If a student asks Anne "How does a solar panel work?", they will get an informative response since that question had been addressed previously by another student as shown in Figure 2. If the question has not been asked before Anne will prompt the user to provide a response for the question. If the student provides a response Anne will record the response in the database and track the evaluated accuracy (ranking) of the response and the frequency that it is viewed (hits) by other students. If the student does not provide a response for the question it is stored in the database as an unanswered question and the frequency that the question is asked is tracked. The instructor is able to view the database in a report format and identify repeated student questions.

The top five unanswered questions at the beginning of the semester for some of the courses are shown in Table 2. These questions could be answered by the instructor, answered by future students who ask the questions, or assigned to students as homework. Over time the list of top questions give the instructor insight to the course topics that interest or are confusing to students. Several of the questions are personal questions for Anne and make the interactions more engaging and may make help the student relate the course content to areas outside of the structured course content. In thermodynamics, the first assignment given to students is to provide a response for five to ten questions on any topic. This helps to build Anne's individual personality that relates to students and gives students a simple introduction to Anne and to the procedures for creating responses. When Anne is demonstrated in class students are surprised that she can respond to many of their seemingly random personal and content related questions. After a few semesters of interactions, Anne gives a response for many of the student's questions. Studies of chat-bots that discuss general topics show that most conversations can be addressed with as few as 10,000 responses. The authors have discovered in the development of other online instructional material that most student questions are repeated and that significant assistance is provided by simply addressing repeated questions.

Thermodynamics Chat with Dr. Anne G. Neering

Created by Stephen w. Crown - http://crown.panam.edu

Maybe we can learn from each other. Ask me any question but you must enter your password and full name to teach me something. Your instructor can give you a password.

Password: ●●●●●

Full Name: Jorge O

Topic: Thermodynamics Project

Type your questions here.

How do solar panels work?

Anne: Solar panels collect solar radiation from the sun and convert that energy to electricity. The sun generates photons which give out energy. When this energy strikes directly on the surface of the solar panel, it allows electrons to change direction and be released, then the electric fields in the solar cells pull the free electrons in to form a current. From there, metal contacts in the solar cells generate electricity. In other words the more solar cells in the panels, the more energy will be produced. A more simple explanation is that the solar panels receive sun rays and makes them in an electric current that is sent to a charge controller, then to a battery system and then sent to a DC power or it could go to the inverter and then to the AC power. ">
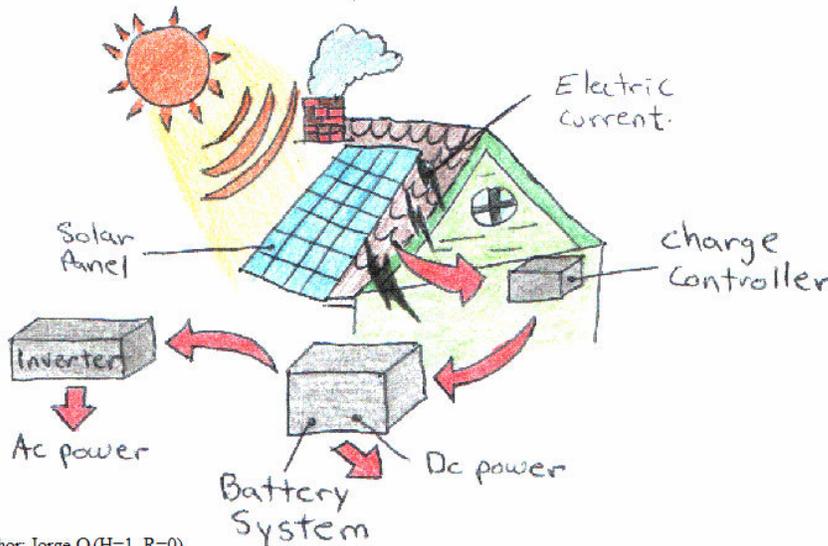
Author: Jorge O (H=1, R=0)

Figure 2: A Sample Question and Response with the Anne G. Neering Chat-Bot

Table 2: Top Five Unanswered Questions Posed by Students in Various Engineering Courses

Mechanical Vibrations	Engineering Thermodynamics	Engineering Materials
Do you have a boyfriend?	What is your favorite restaurant?	What is diffusion coefficient?
What is a natural frequency?	Do you know Russian?	How can the phenomenon of diffusion be demonstrated?
What are vibrations?	What is heat transfer?	With the use of a diffusion couple?
What is a vibration?	What is your favorite beer?	How do you calculate planar density?
What is frequency?	What school did you attend for your bachelors degree?	What are point defects?

Over the course of several semesters students have provided a response for 3170 questions in Anne's database. The majority of these responses address content specific questions for seven different engineering courses. Each question with a response in the database is tracked for its accuracy (ranking) and the frequency that it is viewed (hits) by other students. Evaluated responses that have a ranking of three are entered into an approved list of responses in the database. A negative student review will cause the ranking to go to a maximum of negative three. This information may be used by students as feedback for updating erroneous responses and as motivation as they see that other students are viewing their responses. The ranking and hits could be used as a method for assigning points for homework. The authors have discovered that the public posting of student's work is motivational and encourages students to be concerned about the quality of their work. Examples of the top ten questions for the mechanical vibrations course are listed in Table 3. Selected questions from the top ten questions in other courses are listed in Table 4. Where appropriate, many of the responses also include formatted equations and student generated images as shown in Figure 1.

Table 3: Top Five Questions by Hits from the Mechanical Vibrations Question Database.

Hits	Rank	Name	Question	Response
56	0	Vanessa	What is a trifilar suspension system?	A trifilar suspension system is an apparatus with a platform suspended by three wires. It is used for measuring the moment of inertia of irregularly shaped objects by measuring the period of oscillation of the system.
52	2	Lariza	What is coulomb damping?	Coulomb damping is a damping mechanism caused by sliding or dry friction.
51	0	Michael	What are the elementary parts of a vibrating system?	A vibrating system can have a means to store potential energy, a means to store kinetic energy, and a means by which vibrational energy is gradually lost.
50	0	Vanessa	What is the physical explanation of vibration?	The physical explanation of vibration concerns the interplay between potential and kinetic energy.
50	0	Daniel	What causes oscillation of a system once excited to attenuate?	Damping.

Table 4: Questions and Responses from the Anne G. Neering Database for Selected Courses

Hits	Rank	Course	Question	Response
20	3	Thermo	How do i interpolate?	When looking in a table for value x given value y, and value y lies between two known values. To find the value of x simply use the following equation. x = [(y-y1)/(y2-y1)]*(x2-x1)"plus"x1, where y2 and y1 are the values in which y falls between and x2 and x1 are the values that x will fall between.
35	1	Thermo	Where are you from?	Mato Grosso, Brazil
15	0	Materials	What is a vacancy?	A normally occupied lattice site from which an atom or ion is missing.
14	0	Materials	What is a dislocation?	A dislocation is a linear or one-dimensional defect around which some of the atoms are misaligned.
6	0	Processes	What is manufacturing processes lab?	It is a lab that demonstrates the different processes to manufacture materials as discussed in the lecture. It provides students with hands-on experience with the different tools and equipment.
4	1	Processes	What is surface finish?	Surface finish describes the geometric features of surfaces.
10	1	M & I	What is a thermistor?	A thermistor is a ceramic-like semiconductor that uses the relationship between resistance and temperature to take precise temperature measurements.
9	3	M & I	What is an A/D converter?	Converts an analog signal to a digital signal

Refining the Interface for Faculty and Students

Through interaction of the students and faculty who have interacted with Anne as part of a course, the interface has been refined to include functionality that simplifies the management of content both in maintaining quality and assigning credit. In the classroom students are typically assigned a task of creating a certain number of questions. As students generate questions they can type "List my questions" and a numbered list of the questions that they have submitted will appear. The list also shows the number of hits and the rating of their question and their response which can easily be edited as a response to negative feedback.

As students generated content it quickly became apparent that the faculty would not be able review and correct all of the responses. A mechanism was developed that allows the students to evaluate each other's responses and to give credit for involvement in this activity. Students

simply type "Quiz me" to randomly evaluate other student's questions and responses, which will also helps them learn the course content. They simply respond "Correct" or "Incorrect" and the feedback is sent to the author of the question. The collective evaluation of other students is used to give a ranking for each question. Once a question receives a positive ranking of three it enters an approved list of responses which can also be reviewed selectively. Students who use the site are challenged to use the information responsibly and not simply accept everything they read. This questioning of information is often absent in the educational process, especially in engineering, and can help students develop a deeper understanding of the content. Anne keeps track of the number of questions that students have evaluated which is easily viewed by the students and the instructor. The instructor can then assign students a homework task of evaluating ten questions which can easily be accomplished in 5 to 15 minutes.

Many student questions posed on the site are best addressed with an equation, worked out example, or figure. The capability was added to simply add equations, figures, and external hyperlinks to the responses as shown in Figures 1 and 2. To add an image, equation, or hyperlink to the response, students click on Anne's picture and select the image or equation that they want to insert. Students can upload additional equations and images to the web site or link to external files depending on the preference of the instructor. The ability to create responses and link images is password protected to help maintain the integrity of the site.

Discussion of Anne G. Neering's Results

The success of the chat-bot project may be explained in terms of how the development incorporated aspects of proven pedagogical methods. The most obvious connection is with respect to learner centered teaching environments. The "How People Learn" (HPL) environments provide a philosophical framework for the development of successful learning environments[12]. Elements of the all HPL environments dimensions (learner centered, community centered, knowledge centered, and assessment centered) are present in the chat-bot environment. The learner centered environment is one that tries to understand where the student is at and building on their current knowledge and interests to take them where they need to be. The interactive Chatbot helped in establishing content competence and personal engagement. The interactive Chatbot is uniquely learner-centered because it treats students' questions as a source of issues to verify or investigate. The engineering chat-bot environment forces students to evaluate new knowledge with what they already know since they are never certain that what they are being taught is absolutely correct. The teacher in this case may need to do some learning with the student and the students will be an active participant in that process. The gap between the student and the teacher is perceptibly narrower than between the student and the professor.

The community of students working on developing both the capacity and accuracy of Anne's responses and the feedback through the evaluation process engages students in a large ongoing community project. Most of the community interaction involves current students but even extends to students who posted questions several semesters back. Anne is also a participant in this community as she represents the combined personality of all students especially when personal discussions are involved. These collaborative learning strategies usually have positive

results including improved academic performance and communication skills, and increased student satisfaction with their learning experience.

The interactive Chatbot is knowledge centered in its use of authentic engineering questions and topics as the principal engagement and interaction source. Furthermore, the knowledge centered aspect of the chat-bot is most apparent as students reflect on what it is that they and other students find important and/or difficult in the course and then consider how to relate that in a set of questions and replies.   Furthermore, the interactive Chatbot is an assessment centered since it may be focus on what students know from both a formative and summative perspective. Specifically, as an assessment centered tool there are several ways that students can measure their contribution to Anne's development, such as by typing "List my questions" and that the instructor can assess and grade these contributions.

Connections between Anne G. Neering and the legacy cycle as an implementation of HPL were also considered in the development. The idea of developing an artificial intelligence for the course content that students are engaged in is a perfect environment for creating STAR-Legacy Cycle[13] challenges. Students have an opportunity to view the work of "experts/students" and gain multiple perspectives. The "research and revise" phase is simulated with the evaluation tools. The "go public" phase is addressed with the opportunity for students to post their responses on a public website that cites their name and evaluation of their work. These connections with elements of the Legacy Cycle provided direction in the development of a teaching tool and reasons as to why the project has been a success with the student learning process.

Conclusions

The initial positive response of students to the Anne G. Neering chat-bot, as evidenced by the quick growth of the question database, suggests that an engineering content chat-bot may have a useful role in supporting engineering education. The student learning associated with the training of the chat-bot shows that using students in this process is a practical way to begin development of a course content artificial intelligence program that benefits student learning. As students interact with the interactive Chatbot, the facets of knowledge-, learner-, community-, and assessment-centeredness are present.   The successful implementation of the chat-bot in several engineering courses ranging from sophomore to senior level courses demonstrates that the program can be used in a variety of settings. The more complex functions of a chat-bot that allow for random responses, the learning and use of user variables, contextual questions, and the use of wild-cards can be developed and maintained by expert users while the formulation of single question/reply entries may be effectively developed by students.   The development of a chat-bot built on student's questions and understandings and perceptions of course content provides the instructor with a unique look onto the minds of students. With the oversight and direction of the instructor and with the aid of students a true content specific engineering artificial intelligence may be created. Through this process we may better understand the complex learning process of our students.

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