Jill Watson: A Virtual Teaching Assistant for Online Education

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Abstract

MOOCs are rapidly proliferating. However, for many MOOCs, the effectiveness of learning is questionable and student retention is low. One recommendation for improving the learning and the retention is to enhance the interaction between the teacher and the students. However, the number of teachers required to provide learning assistance to all students enrolled in all MOOCs is prohibitively high. One strategy for improving interactivity in MOOCs is to use virtual teaching assistants to augment and amplify interaction with human teachers. We describe the use of a virtual teaching assistant called Jill Watson (JW) for the Georgia Tech OMSCS 7637 class on Knowledge-Based Artificial Intelligence. JW has been operating on the online discussion forums of different offerings of the KBAI class since Spring 2016. By now some 750 students have interacted with different versions of JW. In the latest, Spring 2017 offering of the KBAI class, JW autonomously responded to student introductions, posted weekly announcements, and answered routine, frequently asked questions. In this article, we describe the motivations, background, and evolution of the virtual question-answering teaching assistant.

1. Motivations: Learning Assistance in Online Education

Massively Open Online Courses (MOOCs) are rapidly proliferating. According to Class Central\(^1\), in 2016 more than fifty eight million (>58,000,000) students across the world together registered for more than six thousand and eight hundred (>6,800) MOOCs offered by more than seven hundred (>700) institutions. Further, these numbers continue to grow rapidly. Today MOOCs cover almost all disciplines and education levels, and the students cut across most demographics groups such as gender, age, class, race, religion, nationality, etc.

However, the effectiveness of learning in many MOOCs is questionable, and the student retention ratio typically is less than 50% and often less than 10% (Yau and Powell 2013). Although there are several reasons for the low student retention, a primary reason is the lack of interactivity in MOOCs (Daniel 2012). Thus, one of the principle recommendations for improving the effectiveness of learning in MOOCs, and thereby also improving student retention, is to enhance the interaction between the teacher and the students (Hollands & Tirthali 2014).

\(^1\) https://www.class-central.com/report/mooc-stats-2016/
As an example, consider Georgia Tech’s recently launched online section of CS 1301: Introduction to Computing\(^2\) based on the Python programming language. This online section is in addition to traditional, residential sections of the Introduction to Computing class. The online class itself has two sections. In Spring 2017, the accredited section is available only to forty five selected Georgia Tech students who have access to three teaching assistants (TA) in addition to course materials provided by the instructor. The three TAs provide several kinds of support to the online students, such as answering questions, tutoring on the course materials, evaluating student progress, etc. The open and non-credited section of the online Introduction to Computing class – the MOOC – currently has more than forty thousand registered students. The students in the MOOC have access to all the same course materials as the students in the other online section. However, the forty thousand MOOC students do not have access to any TA (or the instructor, except indirectly through the standard course materials). Given that computer programming is a technical skill that many students find difficult to master on their own, it is unclear what percentage students in the MOOC section will successfully complete the course. It seems safe to say the percentage of students who successfully complete the MOOC section without any teaching assistance will be significantly lower than the students in the online section with teaching assistants.

Of course most humans are capable of learning some knowledge and some skills by themselves. However, reliable estimates of autodidacts with the capacity to learn advanced knowledge and complex skills are not readily available. For the purposes of the present discussion, let us posit that a vast majority of learners can benefit from learning assistance: perhaps more than 90% of the fifty eight million students taking a MOOC worldwide may need or want some learning assistance and perhaps as many as 99% may significantly benefit from learning assistance. If we assume just one teaching assistant (TA) for fifty students for a typical MOOC, then we need at least one million TAs for supporting the fifty eight million students registered for a MOOC! It is highly doubtful that anyone can organize or afford such a large army of human TAs. The Georgia Tech CS 1301 MOOC itself will need about eight hundred TAs to support the forty thousand students, more than the number of TAs in all other Georgia Tech classes in computing combined. This raises a profound problem: how can we provide meaningful learning assistance to the tens of millions of learners taking MOOCs?

In response to this question, MOOC teachers, researchers, and service providers are building on several technologies for automated or interactive learning assistance such as E-Learning (e.g., Clark & Mayer 2003), interactive videos (e.g., Kay 2011; Koumi 2006), intelligent books (Chaudhri et al. 2013), intelligent tutoring systems (e.g., Azevedo & Aleven 2013; Polson & Richardson 2013; VanLehn 2011), peer-to-peer review (e.g., Faltchikov & Goldfinch 2000; Kulkarni, Berstein & Klemmer 2015), and autograding. Of course many of these technologies were developed prior to the start of the modern MOOC movement with the Stanford University’s MOOC on artificial intelligence in 2011 (Leckart 2012; Raith 2011). Nevertheless, MOOCs too are extensively developing and deploying these technologies to assist the online education.

\(^2\) http://www.cc.gatech.edu/academics/degree-programs/bachelors/online-cs1301
One strategy for improving interactivity in MOOCs is to use virtual teaching assistants to augment and amplify interaction with human teachers. In this article, we describe a virtual teaching assistant called Jill Watson for the Georgia Tech OMSCS 7637 class on Knowledge-Based Artificial Intelligence. Jill Watson (JW) has been operating on the online discussion forums of different offerings of the KBAI class since Spring 2016. By now some 750 students and some 25 (human) TAs have interacted with different versions of JW. In the latest, Spring 2017 offering of the KBAI class, JW autonomously responded to student introductions, posted weekly announcements, and answered routine, frequently asked questions. Thus, JW is a partially automated, partially interactive technology for providing online assistance for learning at scale. In this first scientific article on JW, we describe the motivation, background and evolution of the virtual question-answering teaching assistant, focusing on what JW does rather than how she does it.

2. Background: An Online Course on Artificial Intelligence

In January 2014, Georgia Tech launched its Online Masters of Science in Computer Science program (OMSCS for short). OMSCS is a fully accredited Georgia Tech graduate degree offered to highly selected students from across the world. The online courses are developed by Georgia Tech faculty in cooperation with Udacity staff, offered through the Udacity platform, and supported by a grant from AT&T. The goal of the OMSCS program is to offer the same courses and programs online that are offered through the on-campus Masters program while maintaining equivalent depth and rigor (Joyner, Goel & Isbell 2016). In Spring 2017, the OMSCS program currently has enrolled an order of magnitude more students (approximately 4500) than the equivalent residential program (approximately 350) and costs almost an order of magnitude (approximately $7000) less than the residential program (approximately $30,000) (Carey 2016; Goodman, Melkers & Pallais 2016). By now a few hundred students have successfully completed the OMSCS program, and the diploma awarded to them does not mention word “online” anywhere anyhow.

As part of the OMSCS program, in 2014, we developed a new online course called CS7637: Knowledge-Based Artificial Intelligence: Cognitive Systems (KBAI for short). The first author of this article (Goel) had been teaching an earlier KBAI course on Georgia Tech campus for more than a decade. While the online KBAI course builds on the contents of the earlier on-campus KBAI course, we rethought the course for the new medium and developed many of the course materials from scratch (Goel & Joyner 2016). The second author (Polepeddi) took the online KBAI course in Summer 2015 and was a TA for the course in Spring 2016.

The online semester-long KBAI course consists of 26 video lessons developed from scratch that help teach the course material (Ou et al. 2016), a digital forum where students ask questions and participate in discussions as illustrated in Figure 1, a learning management system through

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3 http://www.omscs.gatech.edu/
5 https://www.omscs.gatech.edu/cs-7637-knowledge-based-artificial-intelligence-cognitive-systems
which students submit assignments and receive grades, a proprietary peer feedback tool developed at Georgia Tech where students read and submit feedback on each other’s assignments, and a proprietary autograder tool developed by Udacity that helps grade the source code of programming projects. The course is administered by the instructor (typically Goel), who is assisted by a small team of TAs. The TAs typically answer questions and facilitate discussions on the digital forum, and grade assignments, projects, and examinations.

Figure 1. While the video lessons in the OMSCS KBAI course are like a textbook, the class forum is like a virtual classroom where students ask questions, discuss ideas, and give feedback. Here, a student asks a question about whether there is a word limit on an assignment.

Since Fall 2014, we have offered the OMSCS KBAI course each fall, summer and spring term. Initial enrollment in the class has ranged from about 200 to about 400 students each term so that by now about 2000 online students have enrolled in the course. For the most part, student surveys of the online KBAI course have been very positive (Goel & Joyner 2016; Ou et al. 2016). In addition, in the fall terms of 2014, 2015 and 2016, we have offered the same KBAI course to residential students at both graduate and undergraduate levels. The performance of the online students on the same set of assessments using blind grading has been comparable to that of the residential students (Goel & Joyner 2016, 2017). The retention ratio in the online section has been 75-80%, only slightly lower than the 80-85% in the residential sections.

The OMSCS KBAI course has provided us with a research laboratory for conducting experiments in pedagogy for online education. For example, we have experimented with

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programming projects based on real AI research to promote authentic scientific practices (Goel et al. 2013) as well as use of peers as reviewers and TAs as meta-reviewers (Joyner et al. 2016). We also developed and deployed about a hundred nanotutors for teaching domain concepts and methods (Goel & Joyner 2017). A nanotutor is a small, focused AI agent that models students’ reasoning on a particular problem engaging a domain concept or method to be learned. Given a student’s answer to the problem, a nanotutor first classifies the answer as correct or incorrect, and then provides an explanation on why the answer is (in)correct.

3. A Challenge in Scaling Online Education: Responding to Student Questions

Teaching the OMSCS KBAI class in the Fall 2014 and Spring 2015 terms revealed a new challenge for the teaching staff: the discussion forum for the online class was very active and thus took a large amount of staff time to monitor and respond. Table 1 provides the data from the discussion forums for the online and residential sections from Fall 2016. As Table 1 indicates, the discussion forum for the online section had >12,000 contributions compared to <2,000 for the residential class. One obvious reason for this six-fold increase is that online class had three times as many students as the residential class. Another, perhaps less obvious reason is that discussion forum acts as the virtual classroom for the online class (Joyner, Goel & Isbell 2016). It is on the discussion forum that the online students ask questions and get (and give) answers, discuss the course materials, learn from one another, and construct new knowledge.

Table 1: The level of participation of online students in the OMSCS KBAI class on the digital forum is much higher than that of residential students. Table 1 compares four participation metrics between online students and on campus students during the Fall 2016 offering of KBAI class.

<table>
<thead>
<tr>
<th></th>
<th>Residential (Fall 2016)</th>
<th>Online (Fall 2016)</th>
<th>+x</th>
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<tbody>
<tr>
<td>Number of students</td>
<td>117</td>
<td>356</td>
<td>+3x</td>
</tr>
<tr>
<td>Total threads</td>
<td>455</td>
<td>1201</td>
<td>+2x</td>
</tr>
<tr>
<td>Total contributions</td>
<td>1,838</td>
<td>12,190</td>
<td>+6x</td>
</tr>
</tbody>
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While the abundant participation on the discussion forum of the online class likely is an indication of student motivation, engagement and learning, and thus is very welcome, the higher levels of participation create a challenge for the teaching staff in providing timely, individualized, and high quality feedback. On one hand, the quality and timeliness of TAs’ responses to students’ questions and discussions is an important element of providing learning assistance and thus plays a part in the success of student learning and performance. On the other, given the high rate of student participation on the discussion forum, the TAs may not have time to respond to each message with a high quality answer in a timely manner.
4. A Potential Answer: Virtual Teaching Assistants

In reading through the students’ questions on the online discussion forums of the OMSCS KBAI class in Fall 2014 and Spring 2015, we recognized (as many-a-teacher has done in past), that students often ask the same questions from one term to another, and sometimes even from one week to another within a term. For example, questions about length and formatting of the assignments, allowed software libraries for the class projects, and class policies on sharing and collaborating have been asked in different ways every semester since January 2014. Perhaps more importantly that from the online discussion forums of the Fall 2014 and Spring 2015 OMSCS KBAI classes, we had access to a dataset of questions students had generated and the answers TAs had given.

Thus, in summer 2015, we wondered if we could construct a virtual teaching assistant that could use the available dataset to automatically answer routine, frequently asked questions on the online discussion forum? We posited that if we could create a virtual TA that could answer even a small subset of students’ questions, then it would free the human TAs to give more timely, more individualized, and higher quality feedback to other questions and the human TAs may have more time to engage in deeper discussions with the students.

Our thinking about the virtual teaching assistant was also inspired by IBM’s Watson system (Ferruci 2012; Ferruci et al. 2009). Independently of the OMSCS KBAI class, in Fall 2014, IBM had given us access to its Watson Engagement Manager\(^8\) for potential use in support of teaching and learning. We successfully used the Watson Engagement Manager for teaching and learning about computational creativity in a residential class in Spring 2015 (Goel et al. 2016). Building on this educational experience with the Watson Engagement Manager, in Fall 2015, IBM gave us access to its newer Bluemix\(^9\) toolkit in the cloud. Thus, we were familiar with both the paradigm of question answering and some of the Watson tools.

5. Jill Watson and Family

Starting in Fall 2015, we have developed three generation of virtual teaching assistants. We have also deployed these virtual teaching assistants in the discussion forums of the online KBAI classes in Spring 2016, Fall 2016, and Spring 2017, as well as the residential class in Fall 2016. All actual experiments with the virtual teaching assistants have been in compliance with an IRB protocol to safeguard students’ rights and to follow professional and ethical norms and standards.

We call our family of virtual teaching assistants Jill Watson because we developed the first virtual teaching assistant using IBM Watson APIs. However, the names and tasks of specific virtual teaching assistants have evolved from generation to generation as described below. More importantly, starting with the second generation, we have used our own proprietary software and open-source libraries available in the public domain instead of IBM Watson APIs.

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(or any other external tool). We made this shift to cover a larger set of questions as well as a larger set of tasks.

5.1 Jill Watson 1.0

5.1.1. Design

In January 2016, we deployed the first version of Jill Watson, Jill Watson 1.0 (or JW1 for short) to the Spring 2016 offering of the OMSCS KBAI class. Although we included JW1 in the listing of the teaching staff, initially we did not inform the online students that JW1 was an AI agent. As noted above, we built JW1 using IBM Watson APIs. JW1 is essentially a memory of question-answer pairs from previous semesters organized into categories of questions. Given a new question, JW1 classifies the question into a category, retrieves an associated answer, and returns the answer if the classification confidence value is >97%.

Initially, we deployed JW1 on the discussion forum with a human-in-the-loop; if she was able to answer a newly asked question, then we would manually check that her answer was correct before letting her post that answer to the class forum in reply to the question. In March 2016, we removed the human-in-the-loop and let JW1 post answers autonomously.

Every 15 minutes between 9am and 11pm, JW1 checked the discussion forum for newly asked student questions. We chose this time interval to mimic the working hours for most human TAs as well as to monitor to JW1’s performance throughout the day. If there was a question that JW1 could answer and that another human TA had not already answered, she would post an answer.

5.1.2. Performance

Figures 2, 3, 4 and 5 illustrate some of JW1 interactions with the online students on the discussion forum of the OMSCS KBAI class in Spring 2015. (Note that we have blackened some portions of the exchanges to maintain student confidentiality.)

Figure 2. In this question about a class project with a coding component, the student asks whether there is a limit to their program’s run time. Jill Watson 1.0 correctly answers that there is a soft 15 minute run time limit.
Figure 3. In this question about a class assignment involving a writing component, the student asks whether there is a maximum word limit. Jill Watson 1.0 correctly answers that there is no strict word limit. Another student then has a follow up question asking for elaboration, which a human TA handles. After this exchange, one student in the class speculates whether Jill Watson is human.

Figure 4. In this question about submitting a class project, a student asks about re-submitting with the correct file. Jill answers the question as if the student was asking about submitting the class project for the first time. However, the student accepts the answer and asks for further instructions.
We found that while JW1 answered only a small percentage of questions, the answers she gave were almost always correct or almost correct. We wanted to both increase the range of questions covered by JW as well as the task she addresses. The latter goal led us to develop the next generation of Jill Watson.

### 5.2. Jill Watson 2.0

#### 5.2.1. Design

In the first week of the KBAI class, we ask students to introduce themselves on the discussion forum by posting a message with their name, their location, why they're taking KBAI this semester, other OMS classes they've taken, activities outside of school, and one interesting fact about them. Human TAs then reply to each student, welcoming him/her to the class. However, it is time consuming to respond individually to 200-400 students within one week. Thus, we built the second generation of Jill Watson, Jill Watson 2.0 (or JW2) to autonomously respond to student introductions.

Unlike JW1 that was built using IBM Watson APIs, we developed the software for JW2 in our laboratory from scratch, using only open-source external libraries available in the public domain. Further, unlike JW1 that used only an episodic memory of question-answer pairs from previous semesters, JW2 used semantic processing based on conceptual representations. Given a student's introduction, JW2 first mapped the introduction into relevant concepts and used the concepts as an index to retrieve an appropriate precompiled response.

In August 2016, we deployed two separate virtual TAs to the discussion forums of the Fall 2016 offerings of the KBAI class that included both an online section and a residential section. We redeployed JW1 to answer routine, frequently answered questions as a TA named "Ian Braun" and we deployed JW2 to respond to student introductions as a TA named "Stacy Sisko."
Just like Ian Braun, every 15 minutes between 9am and 11pm, Stacy checked for newly posted student introductions. Just as with routine questions, if there was a student introduction that Stacy could reply to and that another TA hadn't already replied to, she would autonomously post a welcome message.

Once again while we listed both Ian Braun and Stacy Sisko among the teaching staff, we did not inform the students that were AI agents. To prevent students from identifying the human TAs among the teaching staff through internet searches, all human TAs operated on the discussion forum under pseudonyms.

5.2.2. Performance

Stacy Sisko autonomously replied to >40% of student introductions. Figures 6, 7 and 8 illustrate Stacy’s responses to student introductions.

Figure 6. In this introduction, the student expresses interest in learning more about artificial intelligence. Stacy responds that she also shares a similar interest in AI.

Figure 7. In this introduction, the student shares that he took another OMS course called Introduction to Operating Systems. Stacy responds that she took the course as well and asks the student whether he been able to apply what he had learned in the class, to which the student replies.
Figure 8. In this introduction, a student shares that he took another OMSCS course called Software Development Process. Stacy responds that she took the course as well, but now asks the student what he thought about the professor of the class.

Is SciPy available to use in projects?

I know the instructions said only standard libraries and numpy, but since numpy and scipy are usually installed as a package I though it was worth asking.

Figure 9. In this question about a class project with a coding component, the student asks whether they can use the Python library SciPy. Ian correctly replies with the course policies on using external libraries.

Is there any specific format for naming Assignment1.pdf file?

H0: Do we need to follow any specific naming convention for naming our assignment1.pdf file? For instance naming it getetshuename_KBAI_Assignment1.pdf will be ok?

Thanks ;)

Figure 10. In this question about a class assignment, the student asks whether there is a preferred way to name their submission. Ian correctly replies that there isn’t a specific naming convention, and the same student thanks Ian for the answer.
Figure 11. In this question about a class project with a coding component, the student asks whether they can upload additional files that their program needs to run. Ian correctly replies that additional files are allowed.

Figure 12. In this post about a class project with a coding component, the student shares their current progress and asks for feedback. Ian incorrectly answers the question as if the student was asking about how to get started with the provided code.

Figures 9, 10, 11 and 12 illustrate Ian Braun's interactions with students on the online discussion forum. We found that although Ian Braun was a redeployment of JW1, he performed better in the Fall 2016 KBAI class than JW1 did in the Spring 2016 class both in the coverage of routine, frequently asked questions and the proportion of correct answers. This improvement
likely was because by Fall 2016, we had a larger dataset of question-answer pairs because by then the class has been offered a few more times.

5.3. Jill Watson 3.0

5.3.1. Design

Given the success of Stacy Sisko in using semantic processing to reply to student introductions, we created a third generation of Jill Watson, Jill Watson 3.0 (or JW3 for short) that uses semantic processing for answering questions. Unlike JW1, JW3 does not use IBM Watson APIs. Instead JW3 relies solely on an episodic memory. Given a student’s question, JW3 first maps the question into relevant concepts and uses the concepts as an index to retrieve an associated answer from the episodic memory of questions organized into categories.

In January 2017, we deployed two separate virtual TAs to the Spring 2017 offering of the OMSCS KBAI class. We redeployed version JW2 (or Stacy Sisko) to respond to student introductions as a new virtual TA named "Liz Duncan" and we deployed version JW3 to answer routine questions as a virtual TA named "Cassidy Kimball." Once again while we listed both and Liz Duncan and Cassidy Kimball among the teaching staff, we did not inform the students that were AI agents. To prevent students from identifying the human TAs among the teaching staff through internet searches, all human TAs operated on the discussion forum under pseudonyms. We also increased the time interval during which Cassidy checked for newly asked questions to 6am and 1159pm based on our observations of the activity on the discussion forum.

5.3.2. Performance

Liz Duncan replied to 60% of all student introductions, a performance superior to that of Stacy Sisko in the earlier generation. Figures 13, 14, 15 and 16 illustrate Liz’s interactions with the online students.
Figure 13. In this introduction, a student shares that they took another OMS course called Computer Vision. Liz responds by recommending that the student share their insights throughout the course. After Liz’s initial response, other students respond to other parts of the student’s introduction.

Figure 14. In this introduction, the student shares that they just started the OMS program. Liz Duncan responds by commenting that KBAI is a good first class to enter the OMS program.

Figure 15. In this introduction, the student shares that they live in Atlanta. Liz responds by inviting the student to visit Georgia Tech in person if they are in the area.

Figure 16. In this introduction, the student shares that they are currently taking another OMS course called Computer Architecture in addition to KBAI. Liz incorrectly processes that the student took Computer Architecture in a previous semester, and responds and asks what they thought of the class, prompting the student to reiterate that they are currently taking the class.
We found that Cassidy Kimball performed much better than JW1 and Ian Braun. For example, of the questions that students asked about KBAI’s three class assignments, Cassidy autonomously answered 34%, and of all the answers Cassidy gave, 91% were correct. Figures 17 through 25 illustrate Cassidy’s interactions on the online discussion forum.

Figure 17. In this question about a class assignment involving a written component, the student asks whether there is a preferred format for citations. Cassidy correctly responds to part of the student’s question that the APA format is recommended. A human TA responds to the other part of the student’s question.

Figure 18. In this question about a class assignment involving a written component, the student asks about the level of detail they should include in their paper. Cassidy correctly replies that assignments can be at a high level of detail and don’t need to get into low-level implementation.

Figure 19. In this question about a class project involving a coding component, the student asks whether they can use the Python library SciPy in their code. Cassidy correctly replies that external libraries are not allowed. Another student asks a follow up question about the reason why this decision was made, which another human TA answers.
Figure 20. In this question about a class project involving a coding component, the student asks for more feedback after submitting their assignment to the automated grading system. Cassidy incorrectly answers this question as if the student was asking about which problem sets are graded. The student asks someone else to help, to which a human TA responds.

Figure 21. In this question about a class assignment involving a writing component, the student asks about whether there is a preferred format to name files. The student also inserts a sentence asking human TAs not to respond, possibly in an attempt to discover the identity of the virtual TA. Cassidy correctly responds to this question.

Figure 22. In this question about the class midterm involving a written component, the student asks about the level of detail they should include in their responses. Cassidy correctly replies to the question, but the student second-guesses her answer and asks another human TA for confirmation.
Figure 23. In this question about a class assignment, the student asks whether they can reuse content from a previously submitted assignment. Cassidy could have answered this question, but did not because the question was asked outside the time interval in which she checks the class forum for new questions. Since a human TA answered the question by the time Cassidy checked the class forum again, Cassidy did not answer this question.

Figure 24. In this question about a class project involving a coding component, the student asks whether they can discuss ideas with other students. Cassidy could have answered this question, but did not because another human TA Quentin Washington answered the question within 15 min. As Cassidy checks the discussion forum every 15 minutes, she did not have a chance to respond. Therefore, the next time she checked the class forum, since another TA had already answered the question, she did not answer.

Figure 25. In this question about the class midterm, the student asks about whether they can submit the midterm more than once. While Cassidy could have answered this question, we deliberately prevented her from answering questions about class submissions - those questions are among the most important that students ask, and for now we feel more comfortable that a human handles them.

8. Student Reaction

In the KBAI classes in Spring 2016, Fall 2016, and Spring 2017, we shared the true identities of the virtual as AI agents towards the end of the term. Student reactions to our use of virtual teaching assistants in online discussion forums have been uniformly and overwhelmingly positive. Figure 26 illustrates a small sample of student reactions from the KBAI class in Spring 2016 after the students learned about the true identity of Jill Watson towards the end of April 2016.
Figure 26. Students react to our class post in at the end of KBAI Spring 2016 class announcing the true identity of Jill Watson.

9. Discussion

There are several questions about the virtual teaching assistants that we have not fully answered in this article. The first question is how does Jill Watson work? As we briefly indicated above, Jill Watson 1.0 uses an episodic memory of questions and their answers from previous episodes. We developed JW1 using the IBM Bluemix toolsuite. In the second generation of Jill Watson, Ian Braun was a redeployment of JW1 for answering questions. However, Stacy Sisko used semantic information processing technology developed in our laboratory to reply to student introductions. In the third generation of Jill Watson, Cassidy Kimball too uses semantic information processing technology developed in our laboratory for answering questions as does Liz Duncan for replying to student answers.

Second, is the Jill Watson technology transferrable to other classes with different student demographics and using different educational infrastructures? To answer this question, we are presently building a new version of Jill Watson for a new Georgia Tech CS 1301 Introduction to Computing MOOC that presently has forty thousand students but no TA support whatsoever.

Third, is the Jill Watson technology effective in lowering the demands on the teaching staff? While it is too early to determine the answer to this question for the task of question answering, anecdotally there is some evidence to suggest that Jill Watson did reduce the load on the teaching staff for responding to student introductions and for posting messages to the class.

Fourth, is the Jill Watson technology effective in enhancing student performance and improving student retention. We are presently conducting studies and collecting data to answer this question about student engagement, learning and performance; it is too early to have insights into the issue of student retention.

Fifth, what ethical issues arise in using Jill Watson as an educational technology in an online classroom? As we mentioned above, we obtained IRB approval in advance of the Jill Watson experiments. Nevertheless, these experiments have raised several additional ethical issues. For
example, when it is appropriate to use AI agents without telling human subjects about them? Does the use of a feminine name for an AI agent implicitly promote gender stereotypes? Might the use of AI agents as virtual teaching assistants eventually result in reduced employment opportunities for human teachers? These are serious questions that require investigation.

10. Conclusions

We may view the Jill Watson experiments from several perspectives. First, we may view Jill Watson as an educational technology for supporting learning at scale. In fact, this was our primary initial motivation for developing Jill Watson and this is also how we motivated the discussion in this chapter. As indicated above, Jill Watson uses AI technology for supporting learning at scale by automatically answering a variety of routine, frequently asked questions, and automatically replying to student introductions.

Second, we may view Jill Watson as an experiment in developing AI agents so that for highly focused technical domains, highly selected subject demographics, and highly targeted context of human-computer interaction, it is difficult for humans to distinguish between the responses of AI and human experts. We found that in order to improve coverage, the design of Jill Watson gradually moved from using an episodic memory of previous question-answer pairs to using semantic processing based on conceptual representations.

Third, we may view Jill Watson as an experiment in human-AI collaboration. The KBAI class has become a microsociety in which humans and AI agents collaborate extensively and intensively, living and working together for long durations of time.

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