Virtual Agent Constructionism: Experiences from Health Professions Students Creating Virtual Conversational Agent Representations of Patients

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***Abstract*— This paper reports on applying constructionism with virtual agents in an educational setting. We introduce a methodology – Virtual Agent Constructionism, which involves health professions students creating virtual conversational agent representations of patients as part of coursework. The proposed methodology was implemented as an exercise in an educational course for three consecutive academic years. The aim of this paper is threefold – (i) to demonstrate feasibility of health professions students creating virtual agents in an educational setting as part of coursework, (ii) to report feedback from the students about the experience of creating virtual agents, and (iii) to report on initial trends that suggest that creating virtual agents helps health professions students improve their interviewing and interpersonal skills. In addition to these three innovations, we also present the virtual agents created as educational artifacts that can be used to train future students with their interpersonal skills.**

Keywords- embodied conversational agents; constructionism; virtual agents; medical education.

I. INTRODUCTION

Constructionism is the process of learning by creating. Seymour Papert defined constructionism as the theory that learning is most effective when as part of an activity the learner experiences constructing a meaningful product [1][2]. Research experiments have demonstrated that important skills can be taught in an educational setting by having learners create meaningful products as part of educational coursework [3]. For example, the NICE project [4] has children build and maintain a virtual garden to learn about the ecosystem. In spite of the success of constructionism based experiments in the classroom, little research has been conducted to explore the possibility of having learners create conversational virtual agent representations of people as the product in the constructionism process.

The primary goal of the research reported is to enable constructionism with virtual agents as a learning paradigm. We propose a methodology called Virtual Agent Constructionism. We define Virtual Agent Constructionism as the process of constructing a virtual agent representation of a conversational partner in an educational setting. The virtual agents created in this methodology are *embodied conversational agents* – computer-generated virtual characters that have a human embodiment and with whom users can conduct a conversation. Figure 1 illustrates a typed interview with an embodied conversational agent.

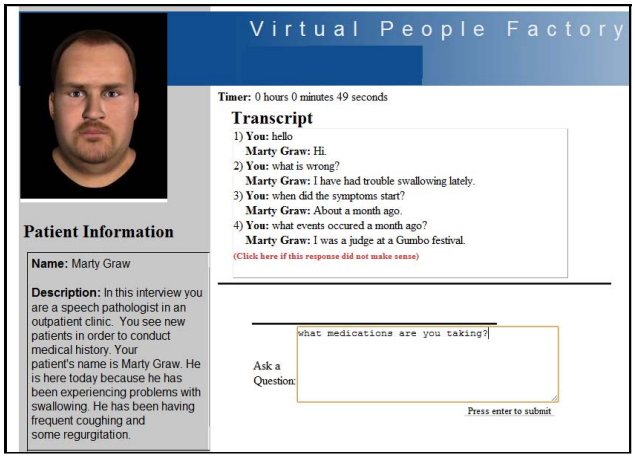

Figure 1. A sample interaction with an embodied conversational agent representation of a patient

We propose Virtual Agent Constructionism as a tool for interpersonal skills training. Although interpersonal skills are important in a variety of fields, our research focuses on interpersonal communication between health professionals and patients. Health professions students studying to become doctors, therapists, nurses, pharmacists and hospital staff require good interpersonal skills to establish rapport with their patients, build trust, and elicit required information quickly [5]. The presence (or absence) of these interpersonal skills directly impacts the quality of healthcare provided to patients. An important interpersonal skill valuable to healthcare professionals is the ability to understand the perspective of the patient [5][6]. In Virtual Agent Constructionism, by having healthcare students create embodied conversational agent representations of imaginary patients, we provide them an opportunity to think from the perspective of the patient. As they design and create a *virtual patient* – a conversational agent that plays the role of a patient, they are forced to think from a patient's perspective.

We integrated the proposed methodology in a health professions course over three academic years. Based on our experiences of having students creating virtual patients over three years, we present three main innovations:

i. **Feasibility**: Through our studies covering three separate years, we have demonstrated that health professions students are able to create a virtual patient in under five hours in an educational setting and as part of coursework.

978-1-4799-4038-7/14 $31.00 © 2014 IEEE
DOI 10.1109/ICALT.2014.79

ii. **Student Feedback:** Students gave overall positive feedback about the experience and reported high scores on perceived usability of virtual patient creation as an educational tool.

iii. **Improving Interpersonal Skills**: Initial trends suggest that creating virtual patients helps health professions students improve their interviewing and interpersonal skills.

II. Related Work

A. Constructionism – Learning by Creating

An example of constructionism using computer-generated tools is the N.I.C.E. project [4][7]. The Narrative, Immersive, Constructionist Environments for Learning (N.I.C.E.) is a virtual reality-based educational tool which has school children construct and maintain virtual gardens to learn about the ecosystem. An example of constructionism combined with virtual agents is the Authorable Virtual Peers project [8]. In this project, children with autism author and control a virtual peer to improve their reciprocal social interaction skills. Study results indicated that the students were able to improve their reciprocal social interaction skills by authoring these virtual peers.

B. Constructing Virtual Agents

In this paper, we are primarily interested in the verbal or conversational aspect of virtual agent creation. There are several ways of modeling the verbal capabilities of a conversational virtual agent. One such method is by creating a conversational corpus. The corpus-based approach is used predominantly to build question-answering virtual agents.

The corpus of a question-answering virtual agent consists of question-response pairs of what the users will say to the agent (questions) and what the agent will say back (response). When a user asks a question, the system searches the corpus for the most similar question and provides the paired answer. For example, if a user asked the virtual patient "How are you feeling?", "What's wrong?", or "How can I help you?" the virtual patient would respond with "I have problems swallowing my food". Gathering the various questions that can trigger a response comprises majority of corpus development time.

One method of reducing the time taken for corpus development is by using a crowd-sourcing approach for corpus development called the Human-Centered Distributed Conversational Modeling (HDCM) technique [9]. The HDCM method was observed to reduce the time required by domain experts for conversational modeling by 90% [9]. By reducing the time taken for creating virtual agents, the HDCM technique has made Virtual Agent Constructionism a possibility.

III. Course Integration

The course integration was implemented during three years – 2011, 2012 and 2013. The 2011 study was a pilot study were students created virtual patients in groups. The 2012 and 2013 studies had students creating virtual patients individually.

A. Population

Participants in the pilot and user studies were health professions students taking a course titled "Dysphagia Management" at the University of Florida during the Spring semesters of 2011, 2012 and 2013. Dysphagia is a medical condition where the patient has difficulty swallowing food or liquids. The diversity in dysphagia conditions facilitates creation of several virtual patients suffering from dysphagia but different from each other based on diagnosis. The Dysphagia Management course was taught for four months between January and April of each year. The studies ran throughout the duration of the course.

TABLE I. Participant Demographic Information

Year	Students registered for course	Students who created virtual patients	No. of patients created	Avg Age	% of Females
2011	31	31	7	24.7	87.5%
2012	28	18	18	25.0	93.0%
2013	29	15	15	23.2	93.1%
Total	88	64	40	24.3	91.2%

B. Virtual Patient Creation Procedure

Participants in the user studies created virtual patients using an online application called the Virtual Patient Pipeline developed at the University of Florida by the authors. The Virtual Patient Pipeline is in the form of a step-by-step process for creating computer-generated virtual patient characters. Creating a virtual patient using the Virtual Patient Pipeline involved the following steps and was spread over the entire course of the semester:

Tutorial (***1 hour***): The students attended a 60-minute tutorial session during the second week of classes to get familiarized with the Virtual Patient Pipeline.

Step 1 – **Patient Template** (***14 days***): The participants filled out a dysphagia patient template to create an initial version of their virtual patient. The template is a form/wizard with 124 unique questions that all dysphagia patients are expected to answer. For each entry in the template, the questions were pre-populated and the response was left blank for the creator to fill in. The patient template was created by mining data from student's interactions with previous virtual patients.

Step 2 – **Interview the virtual patient** (***12 days***): The participant was instructed to conduct at least two 10-minute interviews with their own patient in this step to improve their virtual patient and add any missing information.

Step 3 – **Interview each other's patients and provide feedback** (***28 days***): The participants interviewed each other's patients and provided feedback. This step comprised of two rounds. In each round, each participant interviewed two virtual patients created by two other participants from the class for at least ten minutes. The participant filled out a feedback survey about each virtual patient he or she interviewed. At the end of each round, the participant reviewed feedback provided about his or her patient by two

of their classmates who had interviewed their patient and made changes to their virtual patient based on the feedback.

C. Pilot Study (Spring-2011)

The pilot was a feasibility study, we wanted to explore if it was possible for students to create virtual patients. All the 31 students in the class participated and were randomly assigned into seven groups of four or five. Each group created one virtual patient from a profile for a patient (created by the course instructor). Participants answered a pre-survey and post-survey at the beginning and end of the semester respectively. On the final day of the course, each group presented their patients to the entire class and the instructor who tried identifying the diagnosis for the patient as an in-class activity.

D. User Study I (Spring 2012) – Study Design

All 28 students enrolled in the course for Spring-2012 were part of our study and were offered the opportunity to create their own dysphagia virtual patient for extra credit. The extra credit for the virtual patient creation exercise was a 5% increase on their final exam score. Eighteen out of the 28 students in the class (64.3%) volunteered to create their own virtual patient for extra credit. These eighteen students formed the treatment group (n = 18) for this study. The participants came up with all the information required for the patient themselves, including the diagnosis.

All the students in the class, including the eighteen students who created a virtual patient, participated in interviews with three virtual dysphagia patients over the course of the semester. These virtual patients were ones that were created as part of the pilot study. The three patient interviews were spaced evenly over the course of the semester and were part of a mandatory class assignment. Students were instructed to interview each virtual patient for at least 10 minutes. The ten students who only interviewed these three patients and did not create a patient formed the control group (n = 10) for this study.

E. User Study II (Spring 2013) – Study Design

There were two main limitations to the study design for User Study I. First, all the participants in the treatment group had volunteered to create a virtual patient. This might have resulted in a selection bias where only the most motivated students in the class were part of the treatment group. Secondly, the time spent with virtual patients by the treatment and control groups was not equivalent. The control group participants only interviewed three virtual patients while the treatment group participants interviewed three virtual patients and also created a virtual patient. In order to address these limitations we repeated the user study in Spring-2013 with a more rigorous study design. The only two differences between the 2012 and 2013 studies were:

(i) Participants in both the treatment and control groups volunteered to be part of the study for extra credit. The 29 students in the course were split randomly into a treatment group (n = 15) and a control group (n = 14) to avoid any selection bias.

(ii) Participants in the control group interviewed at least five other virtual patients in addition to the three mandatory virtual patients to ensure equal time commitment for both groups.

IV. Feasibility

A. Results

Forty virtual patients were successfully created by the students over three years.

Pilot Study: Seven virtual patients were created. On average, each participant spent 3.8 hours (SD = 2.6) and each group spent 16.8 hours (SD = 3.9). The average number of speeches was 370.0 (SD = 127.6) and the average number of questions was 1193.2 (SD = 280.7) for the virtual patients created.

User Study I: All eighteen participants from the treatment group successfully created virtual patients. Each participant spent an average of 4.9 hours (SD = 2.2) to create a virtual patient. The average number of speeches was 214.9 (SD = 52.8) and the average number of questions was 1044.6 (SD = 84.7) for the virtual patients created.

User Study II: All fifteen participants from the treatment group successfully created virtual patients. Each participant spent an average of 3.2 hours (SD = 1.3) to create a virtual patient. The average number of speeches for the virtual patients created was 203.7 (SD = 34.4) and the average number of questions was 933.8 (SD = 80.0).

B. Discussion

We present the successful creation of forty virtual patients by students as part of a classroom exercise over three separate semesters as a major innovation achieved in this paper. The virtual patients created were observed to be as complete as virtual patients that have been created in the past by healthcare education instructors [9]. Students were able to create virtual patients with an average time less than five hours with the help of the Virtual Patient Pipeline.

We would also like to highlight that the participants in the studies were able to create virtual patients with minimum intervention from the investigators. The only time the investigators physically met with the participants in all three studies was during the initial tutorial session. All other communication was done online via emails including clarifying any questions the students might have had. These results illustrate that virtual agent creation exercises do not require a huge time commitment from both the students and the instructor.

V. Student Feedback

A. Metrics

Participants from the studies were asked to rate the applicability of the virtual patient exercise based on the following aspects:

- Learning dysphagia information
- Improving clinical interviewing skills
- Valuable learning experience
- Enjoyable

Participants from the control group rated interviewing the virtual patients while participants from the treatment group rated creating a virtual patient. The ratings were on a 7-point Likert score with 7 being the virtual patient exercise being highly applicable.

B. Results

The results of the participant's ratings on the feedback survey from both User Study I and II are plotted in Figure 2.

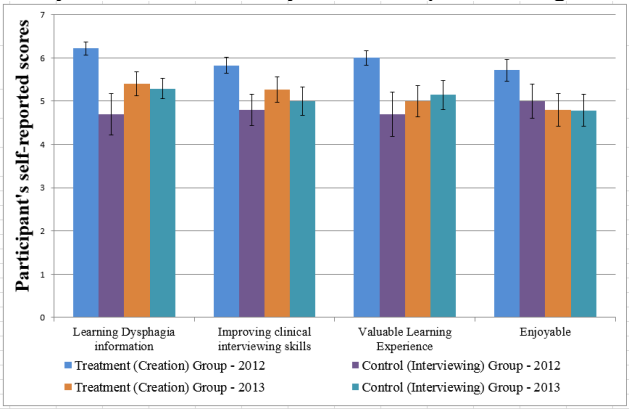

Figure 2. Participants self-reported scores of applicability of the virtual patient exercise.

User Study I: ***Participants who created a virtual patient found the exercise to be both useful and enjoyable.***

The treatment group participants gave significantly higher ratings for creating virtual patients than the control group participants on all five aspects mentioned above.

User Study II: ***Participants from the control and treatment groups found the exercise useful and enjoyable***

The participants from both the control and treatment groups rated the virtual patient exercise to be useful and enjoyable. None of the differences in rating were significant for this user study, although creating virtual patients was rated slightly higher than interviewing on three out of the four metrics.

Listed below are comments by the treatment group participants about the virtual patient creation exercise:

"Creating the virtual patient allowed me ***the opportunity to apply what I was learning in class. I cannot overstate how valuable this experience was, since I learn material much more easily when I am manipulating the information or applying it than when I am passively being exposed to it. "***
This project ***helped me to put myself in the shoes of the client,*** *and to* ***think about how I ask patients for clinical information.***
"This was such a creative way to apply what we are learning. ***I learn best by using information, so this exercise was ideal for my learning style.***

C. Discussion

It has been observed that the response from students to new virtual agent based exercises introduced in their curriculum has been negative [10]. The negative feedback from students about new technology based exercises has been observed to be directly proportional to the time commitment required to learn and use the new technology [10]. The participants from the three user studies were able to create virtual patients in less than five hours using the Virtual Patient Pipeline. This led to the students rating the virtual patient creation exercises to be more enjoyable and useful. The takeaway from this experience is that the technology that students use to create virtual agents needs to be simple and facilitate creation of agents without too much of a learning curve. This finding illustrates that the students perceived the virtual agent constructionism exercise as a valuable learning tool with good applicability for teaching dysphagia information and interviewing skills.

VI. INTERVIEWING SKILLS

A. Metrics

During both user studies I and II, participants in the control and treatment groups interviewed three virtual patients. First virtual patient interview was during the first week of classes, second during mid-semester and final interview at the end of the semester. Performance in these three virtual patient interviews were the metrics for evaluating improvement in interviewing skills. For every virtual patient interviewed, there were critical pieces of information that the interviewer had to discover. These critical pieces of information were called ***discoveries***. Each virtual patient had different discoveries based on the diagnosis. An example of a discovery is "*Swallowing problem started three months ago*". The percentage of discoveries made by the participant during an interview was the metric for measuring interviewing skills.

B. Results

Percentage of discoveries made: The percentage of discoveries made by the participants from both User Study I and II are plotted in Figure 3.

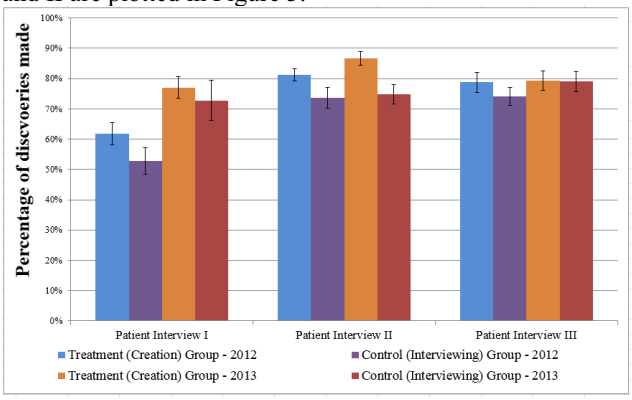

Figure 3. Percentage of discoveries made by participants in both user studies

We performed a mixed-design ANOVA with the percentage of discoveries made by the participants as the within subjects factor and the experimental groups as the between-subjects factors.

User Study I: ***Participants from both the control and treatment groups significantly improved their discoveries made between patients one and two.***

There were no significant differences between the two groups during any of the three interviews. There was a significant difference within group ($F_{1, 24} = 62.2$, $p < 0.05$) in the percentage of discoveries made by the treatment group participants between the first patient interview (Mean = 61.7%; SD = 15.6) and the second patient interview (Mean = 81.3%; SD = 8.5). There was also a significant difference in the percentage of discoveries made by the control group participants between the first patient interview (Mean = 52.8%; SD = 13.7) and the second patient interview (Mean = 73.6%; SD = 10.9).

User Study II: ***Participants from the treatment group performed significantly better than the control group participants during the second virtual patient interview.***

There were a significant difference ($F_{1, 27} = 9.3$, $p = 0.005$) between the two groups during the second virtual patient interview. There was no significant difference between the two groups during the other two interviews. There were no significant within group differences over the three virtual patient interviews.

C. Discussion

Participants who created a virtual patient improved the percentage of discoveries made between the first and second patients during both user studies. However this improvement did not persist with the third virtual patient interview. This might be attributed to study fatigue and the fact that students get busy closer to the end of the semester. Also filling out the patient template, which happened between interviews one and two, might have had the most positive effect on interviewing skills improvement when compared to other tasks in the virtual patient creation process. Since only the treatment group participants consistently improved the percentage of discoveries made between patients one and two during both user studies, we claim that there is a trend that suggests virtual patient creation helps improve interviewing skills. This trend needs to be further investigated with a more robust study design and appropriate metrics.

VII. EDUCATIONAL ARTIFACTS

Virtual agents created as part of the constructionism process can be used for training other students with their interpersonal skills.

As a result of these studies over the past three years we now have 40 different virtual dysphagia patients created by students that are diverse in their backgrounds and medical history information. Each of these 40 virtual patients are capable of 10-minute conversations at their current level of development. Out of these 40 patients, ten patients are currently being used in classroom interviewing exercises to train health professions students with their interpersonal skills. These ten virtual patients have enabled more than 200 interactions to date with students to help improve their interpersonal skills.

VIII. CONCLUSION

In this paper, we have introduced the methodology of Virtual Agent Constructionism and through integrating the methodology as an exercise in a health professions course demonstrated feasibility. Student feedback to the implemented exercise was also reported. Initial results indicate that participating health professions students could improve their clinical interviewing skills by creating virtual patients. As future work, we plan to investigate if the positive effects of creating virtual patients are reproduced while interviewing real patients. We would also like to deploy Virtual Agent Constructionism-based exercises in several other healthcare courses and build a library of virtual patient scenarios that can then be used to educate healthcare students around the world.

ACKNOWLEDGEMENT

The authors would like to thank Dr. Brent Rossen and Dr. Andrea Kleinsmith for their advice and assistance in conducting the studies reported. This work was made possible by a Veterans Administration Rehabilitation Research and Development Grant (Grant ID: B0339-R).

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