# TSI-enhanced Engaging Pedagogical Agents

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***Abstract* – This paper presents an ongoing project that builds engaging, affectionate and effective pedagogical agents in 3D virtual worlds for learning. Employing the theory of Transformed Social Interaction (TSI), we design pedagogical agents with abilities of self-representation, emotional states reasoning and situational awareness. A prototype of a virtual quiz show, QuizMASter, has been implemented to realize these abilities, and will be used to test for the effectiveness of the approach.**

***Keywords- virtual quiz games, pedagogical agent, transformed social interaction(TSI) theory, BDI agent, multiagent systems.***

## I. INTRODUCTION

Embodied as visually pleasing creatures or agents that *live* in 3D virtual environments, intelligent and autonomous software agents are able to react to their environment and use multi-modal interaction capabilities to engage users. Together, these technologies have given rise to a convergent concept called *intelligent virtual environments* [2]. This advancement has revolutionized the virtual world genre of the Internet online community that provides computer-simulated intelligent virtual 3D environments whereby users can interact with one another and use 3D objects embedded in that environment. The intelligent virtual environment allows for a new and exciting research area of developing animated pedagogical agents.

This paper presents an approach to developing engaging pedagogical agents to enhance the engagement of students. Base on the Transformed Social Interaction (TSI) theory, the looks and behaviors of the agents are subtly transformed depending on the individual student's emotional engagement in the attempt to achieve for pedagogical goals.

The goal of our project is to come up with a solution to creating engaging pedagogical agents using TSI theory. MAS is ideally positioned to offer a solution to this problem. The agents in a MAS are ideal for modeling the NPCs in a game as well as keeping track of individual interests, motivations, and goals. A MAS is particularly well-suited to application domains where virtual entities are self-directed and can actively pursue their goals within an environment that they can interact with, including interactions with other entities that are also in pursuit of their own goals. In a MAS, these entities are called agents, and it is easy to see how they are ideally suited for modeling people—they are active and social in a way similar to people. To take things one step further, some MAS architectures use a Belief-Desire-Intention (BDI) model where agents are given beliefs, desires, and intentions as a means for defining and pursuing goals through the development of plans [11]. Of course, BDI agents are artificial entities mimicking people, but the BDI model gives them qualities that make it easier for humans to work with them, taking a programming exercise that is potentially quite abstract and grounding them in terms that are easily relatable.

Research has been done into combining MAS with gaming engines. However, in order to fully realize the benefits of using a multi-agent system, a gaming framework would need to be built from the ground up, incorporating multi-agent concepts. The level of effort to do this would be large, so it is worth exploring other options.

There is an interest in the gaming industry for AI middleware, so it seems reasonable to consider a more modular approach, integrating with existing technologies, rather than building something from scratch. With this in mind we have decided to combine a 3D Virtual World (3DVW) engine with a MAS system. This has already been done to some extent with Gamebots [1], but there were issues that could not be addressed because the system being used was not open source. With this in mind, we are using Open Wonderland (http://openwonderland.org/) as the 3DVW technology and Jason as the MAS platform. All of these technologies are open source, affording us full control of both the server and client code to make any changes that are required to develop a fully working integrated system.

The rest of the paper is organized as follows: Section II describes the background of this research. Section III presents literature on related studies that motivate our work. Sections IV and V describe our method and implementation. Section VI describes a design to test the system's effect. Section VII briefly summarizes the paper and presents our ongoing work.

## II. BACKGROUND

### A. *Motivation in educational computer games*

Past research on motivation in educational computer games was dominated by Malone and Lepper's (1987) "taxonomy of intrinsic motivations for learning" [16]. Their taxonomy asserted that challenge, curiosity, control and fantasy were the motivational elements for the players of educational computer games. However, this assertion was limited to isolated individuals. In contrast, recent learning theories emphasize the importance of social and contextual factors in the learning process [17].

### B. *Transformed Social Interaction*

Bailenson et al. (2008) suggest the theory of Transformed Social Interaction to describe the transformation of interaction in virtual environments. According to the theory, real-time transformations can be classified into three categories or dimensions: self-representation, sensory-abilities and situational context [3].

*Self-representation:* Self-representation is the dramatic and subtle changes to the appearances or behaviors of the avatars chosen by the users, such that emotional bonding can be established. In other words, the avatars *do* represent the users in virtual worlds. There is evidence in support of the advantage of self-representation. For example, Bailenson et al. found that the morphing of faces of political candidates with potential voters increases the affective bonding in a low information context [4].

*Sensory-Abilities:* These transformations empower avatars to complement human perceptual abilities. For example, in face-to-face communication, it is estimated that 60% of the time involves gazing (Argyle, as cited in [12]). People looks twice as much while listening (75%) as while speaking (41%). Vertegall and Ding concluded that people are more likely to speak when they are being gazed at more [12]. For the autonomous agent and the avatar it represents, the ability to process eye gaze or motion data is advantageous in any implementation of virtual world applications.

*Situational context:* These transformations alter the spatial or temporal structure of a conversation. For example, the communication between agents and students can be optimally configured in terms of the geographical setup of a conference room. A class of 20 students can sit directly in front of a virtual instructor, and perceive the rest of the students as sitting farther away. Furthermore, by altering the flow of rendered time in the communication session, users can implement strategic uses of rewind and fast forward during a real-time interaction to increase comprehension and efficiency.

### C. *Agents' roles in Affective Game-based learning*

Conati (2002) and Kort et al. (2001) are looking at the use of intelligent agents to monitor student emotion when playing educational games, so that they can intervene when students become overly despondent [7, 9]. If the student becomes frustrated after making a mistake the agent intervenes and attempts to make the student feel better about their performance. By changing the affective state of the player, the agent not only makes the learning experience enjoyable, but also productive.

### D. *QuizMASter*

QuizMASter is a multi-agent system (MAS) based educational game developed by a group of researchers at Athabasca University. Ithelps students perform adaptive testing and collaborative learning through friendly competition [5, 8]. Conceptually, QuizMASter is designed to be similar to a TV game show, where a small group of contestants compete by answering questions presented by the game show host. A prototype of QuizMASter using a JADE MAS was successfully implemented on Open Wonderland (http://www.openwonderland.org). The implementation provides an opportunity to explore the capability of expressing emotions and how to apply those emotions to avatar behavior. Specifically, the QuizMASter agents can be enhanced to operate within the dimensions of TSI to maintain high levels of engagement.

## III. LITERATURE

There has been a significant amount of research in the area of pedagogical agents that can provide for learning environment that enhance the engagement level of students. Research shows that learning programs with well-designed animated virtual pedagogical agents engage and motivate students, produce greater reported satisfaction and enjoyment by students, and produce greater learning gains than programs without such agents.

Kosinowski developed several agents to illustrate the benefits and technical issues of pedagogical agents [10]. In a study with one of the agents, Kosinowski inspected the motivational aspect of an agent's presence in an environment. By including several modalities of human-human dialogue into the tutoring process, learning environments with an agent become more appealing to use. This study shows that the persona effect is present even in mute agents and thus, for motivational purposes an agent should be considered for any developed learning environment. Although a dynamic approach (non-verbal actions, body movement) is implemented in some of the agents, environmental awareness remains an issue. Kosinowski concludes that a representation of all relevant facts of the environment has to be created for the agent with the following features: 1) The agent must know about the current task's status, its own position and which utterances have been made in the dialogue. 2) Idle-time behavior elements (yawning, weight-shifting, foot-tapping) as well as a humanlike visual appearance are required to create a believable agent. She also envisioned that further research would require cooperative work between communication theorists (dialogues), linguists (speech), graphics specialists (agent appearance) and animators (agent movement).

Zakharov, Mitrovic, and Johnston employ a dimensional approach to track affective state along the valence dimension by identifying users' facial features [14]. They developed a facial-feature tracking application and a set of rules that control an agent's behavior. The agent will respond to a user's action dependant on his/her cognitive state (as determined from the session history) and affective state. To accommodate the preferences of a variety of users, two female and two male Haptek2 Characters which appear as young people approximately 20 to 30 years of age were created for an experiment. The results indicated a range of preferences associated with pedagogical agents and affective communication. Affective interaction is individually driven and in task-oriented environments affective communication carries less importance for manylearners.

Yan and Agada developed a procedure to produce head and face movements during speech by a virtual pedagogical agent by combining different voice recordings, facial expressions and head movement patterns [13]. Results of their experiments show that facial expressions and head movements have significant impact on students' impressions and engagement with a virtual pedagogical agent. Virtual pedagogical agents that produce natural head movements and appropriate facial expressions while narrating a story produce much more positive user experiences than virtual pedagogical agent that lack these behaviors.

## IV. METHOD

Results from the work of Yan and Agada (2010) provide a platform for creating believable pedagogical agents in an immersive and interactive virtual environment like Open Wonderland. Following the framework of TSI theory, we further enhance the approach to improve the interactivity and effectivenessof pedagogical agents in QuizMASter:

*Self-identification:* We implement the self-identification dimension of TSI using facial-identity capture with a tool called FAtiMA. Each of the users' face will be morphed with QuizMASter agent's face to capitalize on human beings' disposition to prefer faces similar to their own [2] and general preference of appearing younger [13].

*Sensory-abilities:* We implement the sensory-abilities dimension of TSI using a movement and visual tracking capability. The general challenge of sensory abilities implementation lies in two areas: the complexity of human senses and the processing of sensory data of different modality and historicity. For the reason of simplicity, we only keep track of visual tracking capability, and thus remove the need for modality. We use a unidimensional scoring system to measure the level of engagement when the user is visually looking at or away from the host agent or the contestants. When the user is gazing at the host agent, the score will be incremented, and when the user moves the viewing direction away from the host agent or the contestants, the score will be decremented.

*Situational-context:* We implement the situational-context dimension of TSI by using the best-view feature of Open Wonderland [8], whereby the temporal structure of a conversation can be altered. For example, each participant of QuizMASter either sees the actual behavior (e.g., facial expressions, direction of eye gaze, nodding and head shaking behavior) of other group members or sees transformed behaviors that are created to induce participants to conform to a certain behavioral model.

To test for the effectiveness of the approach, we propose the following general hypothesis: enhancing the pedagogical agent with the self-representation, sensory-abilities, and situational context dimensions of Transformed Social Interaction theory will result in higher levels of student emotional engagement and increase satisfaction. We will conduct an experiment with two scenarios: The first scenario will use agents with none of TSI dimension capabilities applied, while the second scenario will involve agents with TSI dimension capabilities. Satisfaction of students will be compared and measured using a self-reported questionnaire.

## V. IMPLEMENTATION

### ARCHITECTURE

QuizMASter and Open Wonderland are implemented on multiplayer online game middleware called Darkstar server, as shown in Figure 1. All actions in the served environment are divided up into sequences of short tasks that are executed within a transaction that immediately writes results to an internal database, guaranteeing that state is not lost even during server failures. It also provides an abstract communication mechanism, allowing simple messages to be sent to the server from a client, and from the server to any subset of other clients connected to the same server.

*JVoiceBridge*: This is a pure Java audio mixing application that was developed as part of Open Wonderland to provide server-side mixing of high-fidelity immersive audio. It runs a separate server that mixes SIP audio for multiple users, based on where the virtual space they are. It communicates directly with the Darkstar server over a private channel in order to keep all the audio in sync with the state of the world as users are added, removed, and move around.

*Shared Application Server*: The shared application server (SAS) is the final standard server component. The SAS allows server-hosted application sharing. Multiuser collaboration-aware applications are written specifically for Open Wonderland, and are implemented entirely in the client and Darkstar server. Moreover, the user model is stored in the SAS.

*Open Wonderland Client*: The Open Wonderland client is a single application that acts as a browser for connecting to a Open Wonderland server. As with the server, the client provides several core services based on existing open source components. The rendering layer of the client consists of two separate projects. JMonkeyEngine is a popular rendering framework for writing OpenGL-based applications in Java. JMonkeyEngine provides the basic scene graph and rendering framework, but is limited to working on a single thread at a time. The core services layer provides features used by Open Wonderland modules. These services include the position of objects in the 3D world, the ability to move objects, and collision detection. Extended core services, like the ability to load models, calculate real physics, and enforce security, are layered on top of the core as modules.

*MAS CArtAgO Artifacts*: CArtAgO (Common ARTifact infrastructure for AGents Open environments) is a general purpose framework/infrastructure that makes it possible to program and execute virtual environments for multi-agent systems. CArtAgO is based on the Agents & Artifacts (A&A) meta-model for modeling and designing multi-agent systems. Due to the fact that these artifacts can be modeled in Java, some of the core components of the Open Wonderland (OWL) such as non-playing characters (NPC) have been wrapped as artifacts, in order for the Jason agents to manipulate, manage, and communicate with them.

*MAS Jason-CArtAgO bridge*: The capability of Jason agents to create a workspace using the bridge provided by CArtAgO is leveraged to create a workspace and run the OWL client within a workspace. Once this workspace node is exposed on a network, it allows the Jason agent to join a workspace of other OWL clients and manage, manipulate and communicate with artifacts of the respective OWL clients, using RMI.

One of the main advantages of leveraging these capabilities of Jason-CArtAgO MAS is that it enables customization of the rendering of visible artifacts for different clients such as NPCs. The rendering messages sent to the clients within OWL simply need to be disabled in addition to setting up the above mechanism.

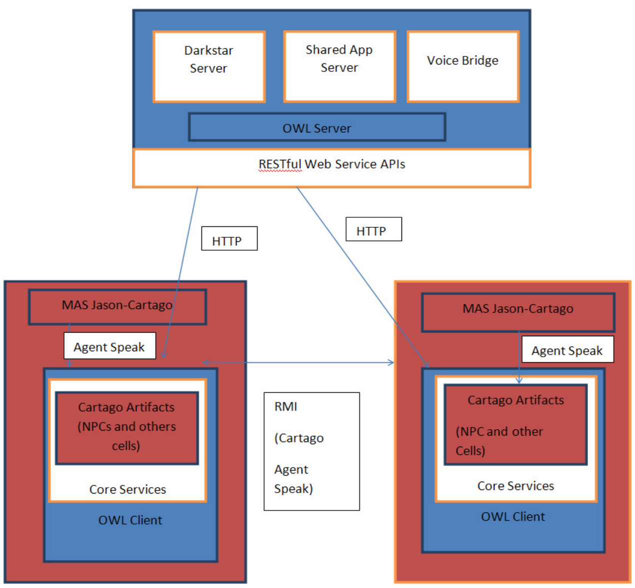


Figure 1: The proposed architecture.

## SCENARIOS

We applied simple and generic rules for every quizMASter game:

1) All students receive a question and have one minute to answer.

2) After one minute of issuing the question, the answers given by all the students are evaluated. A point is given for the correct answer.

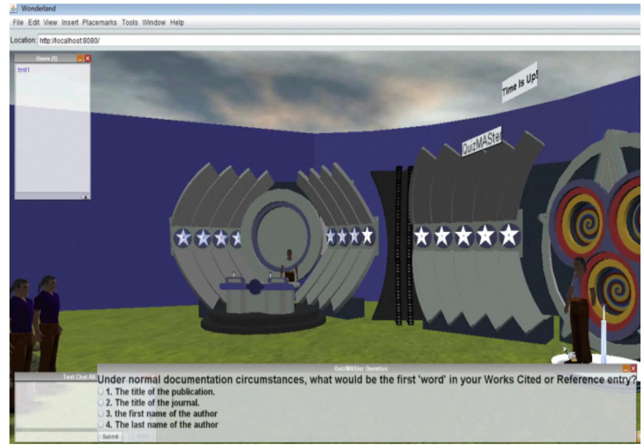


Figure 2: QuizMASter in Open Wonderland.

3) At the end of the questions, the student(s) with highest points win the game.

When a student registers to play QuizMASter, the system generates a student agent to collect data about the learner using pre-tests and questionnaires. The student agent builds the student model through continuous monitoring of the behavior and performance of the student. The information collected is used by a QuizMASter agent to generate a profile of the registering student. Based on this profile, a pedagogical agent uses an *adaptive testing* based algorithm to determine the student's knowledge/proficiency level and ascertain their starting level. Using an item bank, a student level can be estimated by using a linked-list data structure grouping questions of equal difficulty in the same bin. According to the correctness of the current response by the student, the agent will select the next test item adaptively, either from the more difficult items in the left bin or from the easier items in the right bin. If there are no other students at a comparable level, non-playing characters are used.

A game comprises a number of rounds. In each round, a pedagogical agent uses a root-mean-square averaging algorithm to determine the joint proficiency level of the group. Based on the result, the agent selects a number of candidate questions from the repository. Another agent acting as the game show host then presents the questions to the contestants.

Contestants score points by correctly answering questions before their opponents [2] or before the timer runs out. In the context of the multiagent environment, answering a question is accomplished using the Contract Net Protocol (CNP) [15]. The CNP has two stages: the propose stage and the contract stage. In the propose stage, the host agent as the initiator asks the contestants for the answer or "proposal" to a question by sending a CFP performative message. The contestants can either respond with an answer/proposal or refuse to answer the question. In the contract stage, the host then sorts the answers according to correctness and response time. The contestant that sends a sufficiently correct answer fastest is awarded a point.

By using CNP, answering a question may be viewed as a kind of contract negotiation. Here all contestants are given the chance to answer every question while only one contestant can recievethe point. This improves the pedagogical agent's ability to determine the knowledge base of the group. The answer given by each contestant, along with the time taken to respond and the amount of hints used is further analyzed by the pedagogical agents to determine and update information about the knowledge level of the individual and the group as well as provide feedback to the instructor. The data collected may also be used for machine learning. For example, the records of the student's performance can be used to improve the metadata of repository questions and expand QuizMASter's knowledge base.

Finally, the contestant with the highest score is declared the winner of the game.

*Contestant proficieny and quiz items*

The QuizMaster game does not discriminate between contestants initially. However, based on the contestant performance and the parameters of the questions, contestant proficiency is recorded and used for further selection of quiz items.

Each quiz item has several sets of parameters:

Content related:

- Ontology or topics
- Answers

Format related:

- Problem type (e.g., multiple choice, true/false, word problem)
- Available hints

Difficulty related:

- Bloom's Taxonomy [6]
- Difficulty level
- Discrimination of contestant level (how well the response to the question reflects the learner's real ability [8])

When a contestant answers a question correctly or incorrectly, the difficulty and content parameters of the question, as well as the time taken to answer the questions, are recorded to build the proficiency profile of the contestant.

## VI. SCENARIOS AND TESTING

Two scenarios are designed to distinguish the effect of applying TSI dimensions capability:

**Scenario A:** Scenario A employs the TSI approach. The preliminary image of the Host agent will be morphed with students' images and rendered differently to each student reflecting the self-representation dimension of TSI (see Figure 3). In Figure 3, Stephan is the face of the generic pedagogical agent (Host), while Wyatt is the uploaded face of a student.. Below the two pictures there is an adjustment bar that can be used to adjust the amount of morphing that we need to use. According to TSI theory, 40 : 60 is a good ratio and was used to generate the transformed face shown on the right hand side.. We used a tool called evolver (http://www.evolver.com) for this as the Agent NPC images can be easily used in OWL and OWL allows evolver avatars.

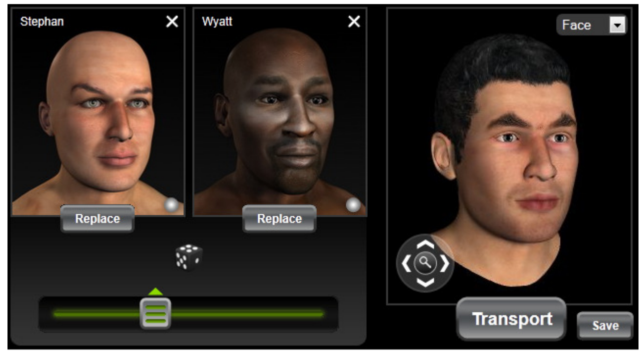


Figure 3: Image morphing.

Sensory abilities of TSI will be applied by recording and observing the student avatar behaviors, especially his/her gaze direction. There will be a crowd of agents that will primarily make sounds and gestures of applause and empathy. After all contestants enter the studio, the Host Agent will greet each and every student, addressing his/her name with eye-gaze directed to that student. Note that the rendering of the second greeting will be customized for each student applying the self-representation and situational context dimensions of TSI. Rules of the game are explained by the Host to all students. This is followed by the agent individually confirming with each student, addressing them by names, whether they understood the rules or not. If any student indicates that they did not understand the rules, the rules will be explained again to that particular student only, using the decoupling of rendering as noted by TSI dimension of situational context. This will be followed by the question and answer session. If the student gets the answer right, the crowd reaction would be to express delight (cheering and clapping with sound and animation) in that student. If the student gets the answer wrong, the crowd reaction would be to express sadness (squirming with sound and animations) for that particular student. In addition, if the student provides a correct answer, the Host Agent will congratulate the student, and for the student who gets it wrong, the Host agent will wish him luck for the next question and will give him/her correct answer. The renderings for each student will be different. This customized experience of crowd cheering for each student along with the Host seemingly paying more attention to him more than anyone else will make him or her feel more emotionally engaged.

All negative behaviors of the students will be hidden from other students. The displayed score of student agents will depend strictly on the performance of the real students. If

Student A is leading by a large margin compared to Student B, then the Agent for Student A will score greater or equal number of points ita real student. However, the Agent for Student B will lag (in terms of scored points) in comparison to the student. Furthermore, hints will be provided to Student B in this case. This will ensure that the Real Student B never scores 0 points or does not obtain last place, so that he/she does not get discouraged and stays motivated. All the renderings of hints provided to a weaker student will not be delivered to stronger students.

**Scenario B:** Scenario B does not engage TSI capabilities of agents. After all students enter the QuizMASter studios, they will be greeted by the Host agent without any personalized greeting. Rules of the game are explained By the Host Agent. If any of the students do not understand the rules, the rules will be reiterated to everyone. Every question and answer session will be followed by the Host Agent and Real Student chat (banter talk). Please note that this episode of inter-question chat between the Host agent and the Real student will be rendered to all students. Hints will not be given for this scenario.

## VII. CONCLUSIONS AND FUTURE WORK

This paper presents an approach to building a 3D virtual game show system for learning. The architecture is based on an integration of a multiagent system and a virtual world. Agents are developed using TSI theory which has been shown to be engaging and effective for learning purposes.

As an ongoing project, there are several directions that require further attention and efforts: (1) although the approach we took follows the TSI framework, the theoretical implication of TSI is richer than our current implementation. For example, the first dimension of TSI includes behavioral transformation, and we have yet to implement this aspect. Similarly, the implication of sensory abilities and situational transformation means more than simple movement tracking and avatar interaction. Based on the evaluation of the initial results, we will design more of the related abilities into the agents. (2) We will continue to work on a reasoning model for human users – a key capability of the agents is to formulate a model of the users and devise a strategy of reacting to them. Given the large amount of available context information, including performance, emotional state and the situation, a general and coherent model of the users in the game at any given point of time is significant to the effectiveness of the approach. (3) The proof of concept of the approach relies on a proper testing methodology and empirical data. While initial testing is designed to compare TSI and non-TSI scenarios, rigorous testing or experimentation will be instrumental to generalize any result.

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