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Scaffolding for Students Stuck in a Virtual World  
Villarica and Richards

## Educational Scaffolding for Students Stuck in a Virtual World

Ryan Villarica and Deborah Richards

Department of Computing  
Macquarie University  
NSW, Australia  
Email: [deborah.richards@mq.edu.au](mailto:deborah.richards@mq.edu.au)

### Abstract

*Virtual worlds provide students with educational opportunities to explore and have experiences that are difficult to provide in reality. However, ensuring that students stay motivated and on task is important if the learning goals are to be achieved. Building on the findings of previous studies involving agent-based virtual worlds, adaptive collaborative learning and intelligent agents, we have designed an empathic intelligent virtual agent that provides educational scaffolding to encourage and support the students to understand what they are learning with less frustration. We have identified models of 'stuck' behaviour and corresponding empathic response patterns that we have incorporated into the behaviours of the intelligent virtual agents in the Omosa Virtual World for science inquiry.*

### Keywords

Virtual Worlds, Empathic, Educational Scaffolding, Motivation, Adaptive Collaborative Learning

### INTRODUCTION

Virtual reality is being used in many areas such as distance learning, training, therapy treatments and social interaction (Correia et al. 2014). Teachers around the world are looking at Three-Dimensional (3D) virtual worlds like Second Life for collaborative learning. However, a lack of learning activity design may hinder the support and collaboration potential of the software (Lee 2009). Intelligent learning agents have great potential for widening the use of virtual worlds for teaching and improve a learning environment's ability to support and guide students (Johnson et al. 2000). Specifically, detection of the learner's emotions and the use of emotion expression models by the agents can help tailor a student's activities within a learning environment (Rowe et al. 2009).

Intelligent virtual agents (IVA) are artificially intelligent embodied virtual characters designed to interact with humans. An intelligent learning agent is an IVA designed to assist learning. They are powered by a knowledge base, which includes an extensive list of possible different questions, responses and gestures, allowing the virtual agent to react and respond to human input in a human-like way (Janssen 2010). Through the use of intelligent agents, that only step in when needed, the hope is to encourage students to be immersed in the environment and give them enough challenge to learn. Conversely, agents can become more intelligent by learning what it means for a student to be stuck and be redesigned or repurposed to be even more intelligent and adapt to the students' needs. In this way the intelligent learning agent aids learning and is also a learner.

Kim et al. (2007) found that their pedagogical peer agent's empathic response had a positive impact on learner interest and increased their belief in themselves. A benefit of virtual worlds and intelligent learning agents is that they can simulate scenarios that are difficult or expensive to experience in the real world. Virtual worlds have a great learning potential in the educational world (Eschenbrenner et al. 2009).

A difficulty in implementing intelligent learning agents that adapt to the learner and his/her needs is to know how to use the data that is collected by the system. These can be in the form of actions performed by the user, events or interactions. Extracting and simulating emotional information is proving to be a challenging aspect to capture, yet the benefits are quite rewarding in the improvements that students can gain (Leony et al. 2013). For example, agents can demonstrate complex tasks, guide the student to the most important details they should look at, and reflect emotional responses to the learning environment (Motola et al. 2009). Some projects (e.g. (Kim and Baylor 2006)) have utilized the bayesian networks to analyse the user and environmental data to determine the most appropriate agent interaction.

Recently, the Omosa 3D Virtual World (VW) for teaching scientific inquiry skills has been trialled in Australian High Schools. In Omosa VW, interactive humanlike characters are used to guide the students through their virtual world activities in a reactive way. Observation of the students using the application have found that some

students lose motivation, get bored, get stuck and waste time. The learning experience and outcomes could be improved if the system were able to detect when a student was in one of these states and provide tailored educational scaffolding, in line with the theory of zone of proximal development (ZPD) (Verenikina 2003), to help the student move to a state conducive to learning. Based on the benefits that virtual learning agents potentially offer, this project aims to answer the research question:

*How can intelligent agents provide educational scaffolding to the demotivated student to maximise their time and enhance their 3D virtual learning experiences?*

The next section describes the approach taken to address this question, followed by the results of our literature review to understand the phenomena of being stuck. Based on the literature, we present one of the agents in the Omosa VW and show how she has been redesigned to show empathy and support the student. Finally, we offer our conclusions and suggested future work.

## **APPROACH**

The Omosa Virtual World project uses a learning sciences methodology known as design-based research (DBR) (Collins et al. 2004). DBR uses real world contexts like classroom environments that tests educational designs based on theoretical principles. This means that the research questions are explored through applying them to Omosa VW and measuring their effect in the classroom. Therefore, to answer the above research question we must redesign the existing VW and try it in the classroom. An example of our redesign can be found in the design section.

As a precursor to our redesign we needed to understand the both the problem (i.e. being stuck) and what features might be useful to help to motivate and enhance the learning experience. To determine how we could add educational scaffolding we identified the following three specific subquestions:

1. What does it mean for a student to be ‘stuck’
2. How to determine and model being ‘stuck’, and
3. How can an intelligent agent react with emotional empathy and task-based empathy.

To answer each of these questions, a systematic and intensive literature search has been conducted. The search and selection process followed the method used by (Dale and Mollá 2006). The following search terms were used: 3D virtual worlds; Active Worlds; Second Life; virtual education; virtual worlds; Affect-based Feedback Behavior in Pedagogical Agents; Affective computing, basic-emotions, non-basic Emotions; Agent-based systems; Animated pedagogical agent, Computer-aided learning, Encourage, Persuade, Empathy; Architecture. The first search included 60 papers including 2318 references. Based on title, 20 were excluded, a further 9 were excluded based on abstract and a further one paper excluded based on content, leaving 30 papers with a total of 1165 references.

The databases searched and the number of papers retained are as follows: ACM DL Digital Library 4; Analytic Teaching1; ascilite 1; Cambridge Journals 1; citeseerx.ist.psu.edu 1;Coventry University 1; dehub 1; dspace MIT 1; EBSCO Industries, Inc 1; journals.tdl.org/jvwvr 1; prezi 1; IEEE Computer Society ; 1; IEEE Xplore Digital Library 2; IGI global PUBLISHING 5; International Journal of Artificial Intelligence in Education 1; IOS Press 1; Journal of e-Learning and Knowledge Society 1; Journal of Medical Internet Research 1; MIT Media Lab 1; North Carolina State University 1; Researchgate 5; Sage Journals 1; Sciencedirect 31 Springer Link 13; Synergy 1; tacticalanguage 1; Taylor & Francis Online 4; University of Tasmania 1; usc.edu 1; Utah State University 1; Wiley Online Library 1. These databases were selected because they contained papers that are related to the topics covered in this literature review. The results of the literature search have been categorised based on the three subquestions specified above and presented below.

## **RESULTS OF THE SYSTEMATIC LITERATURE REVIEW**

### **Defining what it means for a student to be ‘stuck’**

Students that are in an emotionally negative state, for example, frustration or anxiety can stifle a students’ learning goals. Intelligent agents may have the ability to detect negative emotions before they give up. Once any negative emotion is detected the intelligent agent can respond in a way that can be beneficial to the student. The first step is to develop a predictive model for a student who is ‘stuck’ (McQuiggan et al. 2007). Bursleson and Picard (2006) describe the concept of ‘Flow’ (Optimal experience) and ‘Stuck’ (Non-optimal experience).

Stuck is when the student is overwhelmed by an activity and thinks that they don’t have what it takes to be successful. It includes feeling out of control, losing concentration, losing focus, mental tiredness, distress caused by the learning activity, and feeling like time is very slow (McQuiggan et al. 2007). This is when agents’ support

should come into play to provide educational scaffolding. Educational scaffolding is an instructional technique whereby the teacher models the desired learning strategy or task, then gradually shifts responsibility to the students. This is a chance for the student to realize that this is an opportunity to overcome a difficult task that will make them learn more effectively.

Expressing that someone is stuck is usually a mental activity rather than a physical activity. Failing at that same thing again and again is necessary to a certain extent. Handling “the way the failure is responded to” is more important than focusing on the failure. Those who push through failure and overcome the frustration tend to be more effective learners (Picard and Winslow 2006).

Most intelligent agents have some kind of non-verbal behavior like facial expressions or body gestures. These behaviors make the agents more socially plausible. The study by Robison, McQuiggan et al. (2009) uses an agent called Laura that responds with empathy to a user. As part of the “frustration-handling” procedures, they respond with verbal behaviour and statements like “sorry to hear that you are frustrated”. Agents should be able to exhibit both verbal and non-verbal communication and work together in a complementary way.

User emotion may be demonstrated through how the learner types and clicks, the words used in their interaction and frequency of verbal interaction; also through how the learner fidgets in their chair. Picard and Winslow (2006) talk about using the Affective Agent Research Platform to sense a learner’s emotions and let the learning agents respond with educational scaffolding activities. This platform uses a set of sensors, mouse pressure detection, intensity of the users’ grip, skin conductance sensor, sitting posture, facial expression, head movement, mouth fidgets, blinks and pupil dilations. However, the use of these physical devices are not feasible in the context of a VW to be used in Australian classroom.

### How to determine and model being ‘stuck’

Intelligent virtual agents need to be believable and need to express empathy automatically. The agent’s reasoning and behaviour is impacted by its affective state and personality. The study found that characters that exhibited empathic behaviour were met with positive results (Dias and Paiva 2005). Robison et al. (2010) describe profiling student personalities with goals. Emotional state changes were recorded to find patterns. They found that personality profiling can help with providing affective feedback models. Barry (2001) points out the four most common emotions are fear, anger, sadness, and joy, along with eight basic emotions: fear, anger, sorrow, joy, disgust, acceptance, anticipation, and surprise. However, none of the existing frameworks seem to address emotions commonly seen in SMET (Science, Math, Engineering, Technology) learning experiences, some of which we have noted in Figure 1. These sets of emotions are then arranged into a model that links the connection between constructive learning, un-learning, positive affect and negative affect, known as valence, as shown in Figure 2. McQuiggan and Lester (2007) define the meaning of valence as the degree of attraction, ranging from negative to positive. Also relevant in the measurement of emotion is the notion of arousal, which is defined as the level of stimulation, ranging from low to high (Lang 1995).

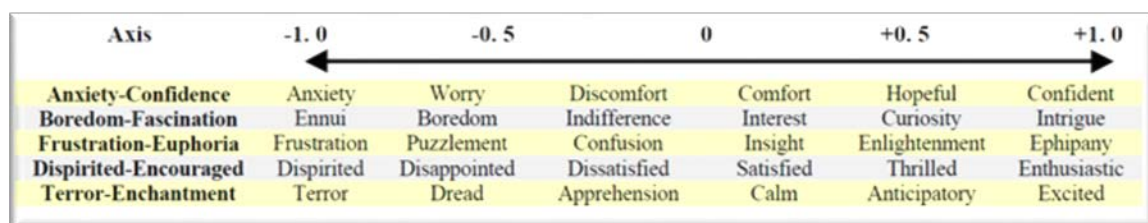


Figure 1. Emotion sets possibly relevant to learning (Barry 2001)

Picard and Winslow (2006) describe a model that promotes constructive learning through linking learning and emotion in an evolving loop of learning emotional states. Their loop starts with: 1) Anticipation, expectation and exploration (no intervention required); 2) Disappointment or discouragement (if they stay here too long then intervention may be productive); and 3) Intervention, which should then lead back to step 1. This loop is said to be natural in the learning process. Sabourin et al. (2011) use the Crystal Island VW to explore the way empathic virtual agents are able to copy the affective state of users. Their agents were also able to interact with other agents. Their framework uses appraisal theory by observing the student tasks or goal orientation. Bayesian networks are used to predict student emotion.

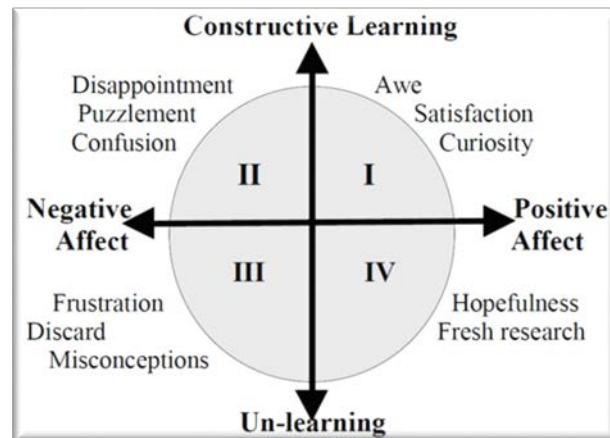


Figure 2. Proposed model relating phases of learning to emotions in figure 1 (Barry 2001).

Also in the context of Crystal Island, Robison et al. (2009) describe an agent that asks the user about their current emotional state through a dialog box with the question: “Hi Alex, how are you feeling?” The possible responses relate to emotions such as: anger, anxiety, boredom, confusion, curiosity, delight, excitement, flow and frustration. The agent then offers suggestions according to the user’s response. McQuiggan and Lester (2007) present a system called CARE (Companion-Assisted Reactive Empathiser) that creates a model of empathy for intelligent virtual agents in a virtual Treasure Hunt application. This work seeks to understand how the user is feeling so that the agent can provide verbal and nonverbal behaviour that matches the user.

### How to react with emotional empathy and task-based empathy

Virtual agents should know when to react with parallel empathy (same emotions) or reactive empathy (different emotions, that is, to counter negative emotions). The system described by McQuiggan et al. (2008) tracks situational data like actions, visited locations and character interactions. This data is used to create empathy models which are used to drive runtime empathic behaviors by responding in parallel or reactive empathy (McQuiggan et al. 2008). Picard and Winslow (2006) refer to “affective support” and “task support” responses that can be made by the intelligent agent. These responses can be verbal or through body language. This reaction is used to provide educational scaffolding. Verenikina (2003) describes this term as a way that teachers or peers can give students the skills they require so they can learn the material.

Prendinger et al. (2004) describe actions and their corresponding responses that can be used for empathic interaction. Schertz (2005) points out that mimicry of others happens unconsciously from childhood into adulthood. This attribute contributes to making a virtual agent more believable, relatable and likeable. Kim (2005) describes six emotional states in a form of emoticons that the user can click on to indicate what emotional state they are in. The system then responds appropriately according to what emotional state was indicated.

Chen et al. (2012) describes virtual agent interaction, behavior and response models that can be applied to general learning situations. They include interaction with virtual agents, for example, greetings, self-introductions, and farewells. Hall et al. (2005) looks at FearNot which focuses on the issue of bullying in schools. The results showed that emotional interactions resulted in the higher belief and interest in the character because they believed their interactions were real. Paiva et al. (2005) also study the application FearNot school bullying program where eight to twelve year olds experience virtual situations of bullying. They also point out that characters must be believable. Their system needs a way to trigger emotional states that would lead to empathy. The emotional module appraises the situations and activates emotional states. Picard and Winslow (2006) study the links between emotion and learning using the Towers of Hanoi activity. They found that feelings of frustration can be used to signal back to the student that they should try something else. The learning agent COSMO supports positive emotions with words like “Fabulous!”, encouraging the student to be positively affected. A limitation of COSMO is that it could only respond verbally to the users’ gestures, for example, it could not perform smiles or frowns. Non-verbal interaction can include facial movements or gestures for believability and likability. In Crystal Island (Robison, Mcquiggan et al. 2009), a progress summary is provided for emotionally happy students as there is no need to interrupt their session. Summaries are provided throughout. Intervention is used when the student is sad with the aim to find out the problem. Instead of guessing if they are sad, they try to direct the students to where help can be found, for example, reading a virtual book or talking to another character.

Other methods for detecting if the student is 'stuck' that weren't included in this research include the use of empathy between virtual agents, detecting students without direct student questioning, and intervening when the student is blatantly wasting time. Rodrigues et al. (2009) describe empathy between virtual agents that could explore the learning portion of the appraisal system devised by the Ortony, Clore and Collins Theory of Emotions. This appraisal system could take into account how to detect students stuck without asking 'how are you?' This could be by detecting their paths that were taken repeatedly, jumping up and down randomly on objects that usually don't allow for jumping, that is, other people, and wasting time through being stagnant or wandering around in non-vital areas. However, a student that was exploring the world could be misinterpreted by the system as wandering around aimlessly or wasting time. This could be counterproductive and trigger negative emotions from the student. This will require more research in order to explore the possibilities more thoroughly.

## DESIGN

This section describes the design of the new functionality. This includes usability design principles, empathy design, the data models used and how they are used. Many of the data models are built on the existing models used for evaluating 3D virtual worlds (Hanna et al. 2012).

Stasko et al. (2007) describes usability principles that include learnability, flexibility and robustness. Learnability involves support for learning for users of all levels. This depends on the scope of user diversity. Flexibility of a system involves support for multiple ways of doing the same tasks. This requires consistency of controls, a standard way of navigating through the virtual world and interacting with virtual agents. Robustness involves support for recovery so that mistakes can be undone and environmental elements can be reset.

Emotion can be demonstrated through verbal and non-verbal interaction by both students and by virtual human agents. Here we focus on verbal empathy by the student and by the virtual agents. We have also identified two main types of empathy, task based and emotional (Kim 2005). Task based empathy responses can be straight forward text based information. A task-based empathy sequence can be responses to questions such as "Where should I go next?" with a current sample response being, "If you have not been there already, why not look at our village hall". These responses can be included with emotional empathic responses. An emotion-based empathy sequence can begin with an agent asking "How are you?" These empathic responses can be further reinforced using facial emotions and body language along with examples of the avatar's facial emotions. These responses and dialog trees need to be decided upon based on appropriateness and believability. The next subsection describes what dialog and empathic responses are currently used in the Omosa virtual world application and how they can be enhanced to provide empathic feedback.

### Introducing Omosa Virtual World

We have developed a scenario-based virtual world called Omosa where school students learn about scientific enquiry, ecology and biology through virtual hands on experiences. Students are able to observe, collect data and interact with intelligent virtual human and animal agents. To introduce the scenario, the students take the role of junior scientists invited by the Chief Scientist at the IEIA (Interplanetary Environmental Investigation Agency), to help find out why planet Omosa has been experiencing ecosystem change. There are indigenous people and animals that are affected by the environment, in particular they are losing an important food source. The native Omosans have allowed scientists to study the planet to investigate the reasons why the environment is being negatively impacted.

There are several characters the students are able to interact with: Lyina and the hunter, Omeweye the village wiseman; weather systems expert Zafirah, Charlie the ecologist and Simon the biologist. Each character has a list of seven to nine questions and a "goodbye" statement to indicate the end of conversation. Here we analyse the dialog interactions possible by the student with Lyina the hunter. Table 1 categorises each question/answer tuple to determine if it is informational, directional, supportive responses or salutational. Informational responses are facts or opinions given by the agent. They help with the students' task of researching and discovery. Directional responses are suggestions as to where the student can go next, what they can do next or who they can talk to next. They are instructions that provide task-based or goal based empathy. Supportive responses are emotionally empathic responses that help agents relate to students' emotions. Salutational responses are greetings or farewells. These can be in conjunction with non-verbal actions such as waving. Each character begins interaction with the student by a greeting or a wave, followed by a set of questions that the student can ask.

Table 1: Comprehensive list of questions that can be asked to Lyina and categorised.

Question	Answer	Category
Who are you?	My name is Lyina. It means "shining one" in Omosan. I am a hunter, one of the best among the Omosans. I hunt Yernt especially, which are prized for their meat.	Informational
How long have you been here?	I have lived in the village on Omosa my whole life, and started hunting as soon as I was old enough to shoot an arrow.	Informational
Where am I?	You have met me on the way to the hunting grounds as I was getting ready to leave the village.	Informational
Where should I go next?	If you have not been there already, why not look at our village hall where we keep our history records and where storytellers sometimes meet? I believe the hall is full of evidence of the Omosan way of life. If you have already been to the hall, you could go to the hunting grounds next.	Directional
What do you eat?	We Omosans eat meat, fish, and also gather nuts, seeds, and berries. Sometimes we grow Taro if we are not getting enough meat.	Informational
What do you hunt?	We hunt Yernt mainly. We don't hunt Tooru much for meat but we do use them occasionally for fur.	Informational
Where do you hunt?	We hunt in lots of different places. Obviously we don't hunt in any of the burnt off areas, where we practice our fire-stick farming. But we hunt on the fields near the woodlands where the Yernt tend to appear.	Informational
Are there stories in your village about life in the old days?	Yes, we have a tribal storyteller, Omeweve, who can share with you stories about olden days on Omosa. You can find him near the village hall. He is the old man with the white beard.	Informational
Why do you think the Yernt are dying out?	Honestly, I do not know. Maybe it is too dry and the grass is not good for them to eat.	Informational
(Initial greeting)	Hello there!	Salutation
Goodbye.	N/A	Salutation
(Return greeting)	Welcome back!	Salutation

### Applied agent support

This sub-section outlines a verbal emotional empathic dialog design that can be applied to any virtual agent with some tweaks and changes to suit the personality of the virtual agent. An emotion-based empathy sequence begins with an agent asking "How are you?" We use the six emotional states of Kim (2005): interested, bored, confident, anxious, satisfied and frustrated. A user can respond to the virtual agents' question by selecting a response that represents each one of the six emotional states. The system then responds appropriately as shown in Table 2. We use the set of empathic responses by Chen et al. (2012) to provide links between the different states of emotion with empathic voice/dialogue and empathic facial emotion. These models can be combined to provide a set of virtual agents' verbal emotional empathic responses. We have added another emotional status of "inquisitive" that would prompt the original set of questions that was asked.

Table 2. Verbal empathic agent responses based on Kim (2005) and Chen et al. (2012).

Emotional Status	Users' response to "How are you?"	Sample virtual agents' emotional empathic response
Frustration	I'm really getting frustrated right now.	I'm sorry that you are frustrated. Cheer up, never give up.
Interested	Great, I'm finding this activity very interesting!	I'm glad to see you so interested. I'm very happy.
Anxious	I'm really stressed out at the moment. I don't know what I'm doing!	I feel sad to see that you have feelings of anxiety. But don't worry too much. Remember to keep learning.
Confident	I'm learning a lot, this stuff is easy!	You are great. I am glad to see you so confident.
Bored	I'm so bored, I've got everything and spoken to everyone. Just killing some time.	Do the learning activities make you feel bored? Sometimes we need to persist to the end to gain knowledge.
Satisfied	I think I've spoken to everyone and read everything I've collected. I've learnt a lot today.	That's great! I'm glad to see you satisfied.
Inquisitive*	Can I ask you a question?	Sure, go ahead! Anything to help (display initial set of questions to ask agent)



Randomised task-based activities can be suggested by agents in response to negatively valenced emotions in order to reduce repetition and potentially increase believability and reduce boredom. Table 3 contains a proposed set of verbal task-based empathic responses of the virtual agent from negative valence student responses.

Table 3. Proposed verbal task-based empathic agent responses from negative valence responses.

Emotional Status	Users' response to "How are you?"	Summary task	Sample virtual agents' tasked-based empathic response
Frustration	I'm really getting frustrated right now.	Read rainfall report	Maybe you can have a closer look at the rainfall report. You might find some interesting results.
Anxious	I'm really stressed out at the moment. I don't know what I'm doing!	Read Charlie's notes	Maybe you can have a closer look at Charlie's notes. There's a lot there, but it might be helpful.
Bored	I'm so bored, I've got everything and spoken to everyone. Just killing some time.	Observe wildlife	I find the hunting grounds a very interesting place to visit. There are a lot of wildlife to observe and interact with. Just watch out for the hunters and any large Tooru!

The virtual agents in Omosa VW have been redesigned with these added verbal emotional and task-based empathy models. To demonstrate the new dialogue, we provide some examples using Lyina the hunter. In the current version, Lyina simply says "Welcome back" when a student meets her after the first time. In the modified version she says "Welcome back. How are you?" A range of responses are possible. If the student chooses "I'm really getting frustrated right now", Lyina responds "I'm sorry that you are frustrated. Cheer up, never give up". Figure 3 shows the options and Lyina's responses when a student is bored.

Empathic responses by the virtual intelligent agents can be further depicted using non-verbal empathic interaction. Using non-verbal empathic interaction can further reinforce emotional empathy by using facial emotions and body language. These further enhancements requires additional skills in 3D modelling in the areas of face and body animation and could follow Chen et al. (2012).



Figure 3: Student's set of responses to Lyina followed by Lyina's response (Bored).

## CONCLUSION AND FUTURE WORK

As potential future work, alternative solutions to the Affective Agent Research Platform by Picard and Winslow (2006) that are suitable for classroom contexts and use with minors that detect the physical behaviours of students could be explored. Similarly, non-verbal empathic responses by the intelligent learning agents need to be designed and incorporated to support the agent's verbal behaviours and to show appropriate responses to the feelings expressed by the student.

Other methods for detecting if the student is 'stuck' that weren't included in this study include the use of empathy between virtual agents, detecting students without direct student questioning, and intervening when the student is blatantly wasting time. These topics could explore the learning portion of the appraisal system devised by the Ortony, Clore and Collins Theory of Emotions. This appraisal system could take into account how to detect students stuck without asking the question 'how are you?' For example, the system could use input and action detection such as jumping up and down randomly on objects that usually don't allow for jumping, that is, other people, and wasting time through being stagnant or wandering around in non-vital areas. However, misinterpretation of false detection could be counterproductive and trigger negative emotions from the student. This requires more research in order to explore the possibilities more thoroughly.

Other topics that could be explored include reacting upon automated negative emotion detection. This could ideally be used in a just in time (JIT) way that can alert the teacher that a student is stuck and can hence monitor if the intelligent virtual agent is providing the right form of educational scaffolding.

This project aims to personalise the learning experience of science-related skills through intelligent agents to answer the research question: How Can intelligent agents apply educational scaffolding to the de-motivated student to maximise their time and enhance their 3D virtual learning experiences?

There is a vast array of models and empathy responses that can be utilised to provide help to an emotionally frustrated student as discovered in the systematic literature review. The discussions note the key trends that have been implemented in the past.

The proposed design incorporated verbal and non-verbal empathy feedback with the proto-type concentrating on verbal emotion-based and task-based empathy in response to situational appraisal and confusion detection. These ideas, designs and proto-types can be expanded upon to improve intelligent virtual agents and their role to provide just in time (JIT) support.

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