University of Technology Sydney

# Believable Conversational Agents for Teaching Ancient History and Culture in 3D Virtual Worlds

A thesis submitted for the degree of
Master of Science in Computing Science

by

**Kiran Ijaz**

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## CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as a part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

*With gratitude to my parents -*
*my guiding stars who introduced me to love, life and learning.*

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# Abstract

This thesis introduces believable conversational agents as an engaging and motivational learning tool for teaching ancient history and culture in virtual worlds.

Traditional approaches are lacking engagement, interactivity and socialisation, features that are of tremendous importance to modern students (digital natives). At the same time, modern 3D visualisations primarily focus on the design side of the given space and neglect the actual inhabitants of these ancient places. As a consequence, in such historical or cultural 3D visualisations it is difficult to engage the students in the learning process and to keep track of students' learning progress. Furthermore, this approach neglects the knowledge carriers (inhabitants of the ancient site) which are an important part of a particular culture and played an important role in significant historical events.

Embodied conversational agents envisaged by this thesis for teaching ancient history and culture must be believable as they act in highly dynamic and heterogeneous environments such as 3D Virtual Worlds with both human and autonomous agent participants. In these virtual environments participants behave autonomously and frequently interact with each other and with software agents. Therefore, embodied conversational agents must know their surroundings, be aware of their own state in the virtual environment and possess a detailed knowledge of their own interactions as well as the interactions of other participants. We label such agent abilities as "awareness believability" and develop the necessary theoretical background and the formalisation of this concept. We also discuss the $I^2B$ (Interactive, Intelligent and Believable) framework that implements awareness believability using the combination of the Virtual Institutions technology, the AIML engine and the visualisation layer of Virtual Worlds.

Through a detailed literature review on virtual agents' believability we identified the ability to continuously learn new conversational skills as another important aspect of being believable. Thus, this thesis also explains how AIML specific rules and virtual agents' interactions with subject matter experts help to dynamically improve the conversational corpus of virtual agents via imitation learning.

To validate the impact of supplying agents with awareness believability we conducted a number of case studies specific to the domain of ancient history and culture. The studies confirmed that the identified awareness features are indeed making the agents perceived as more believable. Furthermore, the studies provide important evidence in favour of using virtual agents for improving the knowledge of students in the domain of ancient history and culture.

# CHAPTER 1

# Introduction

The aim of this chapter is to introduce the reader to the problem of using Virtual Worlds for teaching history and culture to modern students. Those students(often labeled as digital natives) are born into the age of the internet, have very different capabilities to older generations and require a different approach to learning. Video games and Virtual Worlds in particular are believed to be one of the most successful technologies for teaching digital natives. Further, we present additional details supporting the usefulness of the Virtual Worlds technology.

Unlike other existing virtual reality solutions, we propose to engage students not only by providing 3D recreations of significant ancient cites but suggest that students should also interact with virtual humans representing ancient population in Virtual Worlds. Development of these virtual humans not only provides learning through interactions but also raises the question of the believability of such interactions in virtual environments. Henceforth, in this chapter we debate the role of virtual agents as an important educational component of such Virtual Worlds, highlight the important characteristics of enhancing their believability and explain how these features should be integrated to produce virtual humans.

This chapter also outlines the key motivation behind this research and the methodology we opted to solve the related issues. This chapter also demonstrates how to evaluate learning and believability for better students engagement and motivation in such learning environments.

## 1.1 Motivation

We live in a period where staging interesting experiences is vital and almost every industry (including education) must focus on providing entertainment. Advancement of video games and internet technology shows a huge drift towards entertainment in modern societies. This growth in the entertainment industry has certainly affected education as well as many other aspects of our lives and it is best understood through its impact on the economy. Our economy can be said to have undergone the following three stages of evolution. We started with the product economy, then successfully moved through the service economy to the current experience economy [PG98]. To illustrate this concept, the classical work of [PG98] uses a very intuitive birthday cake example. In the era of the product economy, mothers preferred to bake a cake from scratch with minimal cost of a few dimes. With the advancement of a goods-based industrial economy, mothers started buying pre-mixed ingredients and paid a bit more. As the service economy took hold, busy parents started ordering cakes from bakeries or grocery stores. From the 1990s to now, in the experience economy era, parents neither bake the cakes nor arrange a party. Instead, they often choose to outsource the entire event to some business like "McDonalds". In the latter case, the cost of providing an engaging experience significantly outweighs the cost of services and products. The basic product "cake" is often thrown in for free [PG98].

Similar to the economy, the concept of engaging experiences is widely applicable to other domains including education. Students demand engaging learning experiences in traditional learning environments. The existing literature suggests video games as one of the best mediums to provide these experiences to students. Video games have emerged as the largest entertainment providing industry in the last few decades. They have changed the way our young generations live and play, and have widely impacted the entertainment industry. [BBG09] explains the features of video games: they have provided interactive and complex experiences for players by rendering characters, landscapes, compelling narratives and realistic animations. The unique advantage of these games is the player's engagement: [Pre03] demonstrate it as the ability to keep people in their seats for hours and hours, actively trying to achieve new goals, determined to overcome their failures and immersed as part of this interactive entertainment.

Modern kids and young adults prefer playing video games to reading a book and the best way to teach "digital natives" - kids who are born after the internet - is through a video game [Pre01a]. The author of [Pre03] says that reading text books is not motivating them and students often regard the traditional learning setup as boring and ineffective. In contrast to traditional learning activities, young students spend large amounts of their time playing video games. Studies claim [Pap09, Pre01b] that children who have grown up with these new technologies seem more engaged with video games and have short attention spans in traditional learning methods. It is vital to bring video games technology to traditional learning to make it more motivating and effective.

The key reason for this drift in learners' attitudes towards traditional learning methods is the way the young generation thinks and processes information. Growing up with all these new technological advancements, the young generation's minds have gone through a major alteration [Her97]. Technology has offered a new potential for learning and these interactive media have led towards new preferences for a games playing generation, particularly in the area of learning. This new technology has shaped learning abilities completely different by from the pre-video games generation. The major difference is that digital natives are active participants, they do parallel processing, prefer graphical illustrations and a connected experience to get information and solve problems [Pre01b].

Virtual Worlds is a technology which resembles video games and has similar potential to provide learning with entertaining experiences. Virtual Worlds inherit qualities from games like interactivity, immersion, rich graphics to engage and motivate students in learning tasks. they also offer opportunities to collaborate irrespective of the physical location, to support gestures, emotions and non-verbal communication. Virtual Worlds are not designed for one specific purpose and can be applied to any context as opposed to video games. General purpose Virtual Worlds give more flexibility to design the learning environment while providing the same entertaining and immersive experiences to students.

Virtual Worlds can be differentiated from video games as they do not often provide a clear script or narrative. In Virtual Worlds, learners themselves build knowledge through investigating, analyzing, interpreting, problem solving and evaluating in an immersive environment, rather than through pre-scripted instructions [AM08]. Unlike computer games, Virtual Worlds allow users to create their personal world, interact with this virtual space and other users in it, rather than just interacting with a preprogrammed environment. Virtual Worlds, without any preset narrative and even with no preset objective are, able to support learning as explained by [Ste04]. Having no preset narrative also enables students to individually develop interaction concepts as well as collaborate with other students in all aspects of the situation.

There exists substantial evidence that Virtual Worlds can improve education and provide contextual learning:

- US-Canadian border training in Virtual World for customs students showed improvement in students' performance over traditional learning. This project provided customs and immigration training scenarios in SecondLife[1] to simulate real life interactions among visitors and customs staff at US-Canadian

[1] Second Life (SL) is an online virtual world developed by Linden Lab which was launched on June 23, 2003.

border. This study showed an improved success rate in results of failing students which increased from 56% to 95% in year 2008. It also provided an opportunity to students to experience more realistic daily life customs procedure than classroom learning [HD09].

- Another example is the River City project, which confirmed that science students who studied in Virtual Worlds demonstrated increased motivation and improved their results. The River City project was initiated by Harvard University for teaching scientific inquiry in middle school science classes. River City was designed as a multi-user Virtual World, where students visited a city and worked together in teams to investigate health problems. Students developed a hypothesis, collected data and conducted experiments to provide recommendations to other members of the research community. This study reports a high level of engagement for students particularly those who were low performers and had given up as learners in traditional classrooms. Through the River City project, these failing students performed equally well as high performing students in traditional classroom [CD05, DB05].

However, despite these enormous potential for this technology as educational tool, there is a downside. In traditional classrooms, teachers set the agenda and structure of the learning task towards attainment of learning outcomes. But in Virtual Worlds students are often left to themselves without a teacher and a structured learning approach. Virtual Worlds as a successful learning medium has been discussed by many researchers [CD05, HD09] but to provide a structured learning approach is an area which needs further exploration [De 10]. Currently in Virtual Worlds, students are often guided through visual cues, message boards and similar pointers but this aid still requires students to explore environments by themselves [BM08].

This free exploration with unlimited choice and endless information makes learning sometimes difficult. Students in Virtual Worlds are more likely to get distracted from the learning goal due to the possibility of engagement in various other activities. For instance, a student may have been busy exploring a new shopping mall meanwhile his peers have learnt the given task and moved on. Other students may need assistance to choose between several options to complete a task.

Consequently to take full advantage of the virtual learning environment, we require a structured learning approach similar to a traditional classroom to guide students. In such learning environments, the role of the teacher certainly becomes important. One of the several roles of the teacher is to guide students through the learning activities to attain desired outcomes. A well structured learning approach enables can ensure learning task completion and focus learning activities while maintaining students' motivation in Virtual Worlds. Having fixed objective in such learning environments also leads to difficulties of assessing whether certain goals have been met [BHO10].

One possible way of providing structured learning in Virtual Worlds is through implementing a classroom setting similar to traditional learning. But traditional classroom setups in virtual Worlds do not fully utilize the features provided by these immersive environments. Virtual Worlds encourages "learning by doing", parallel processing for various tasks at hand and independent investigation which are rarely fully supported in traditional classroom settings [BHO10]. Nevertheless, implementing classroom settings in virtual learning environments will have the advantage of better communication and coordination among students over the traditional classroom environment.

Another cost effective approach to provide a personalized, engaging and focussed learning setup in virtual worlds is to use virtual agents[1]. Virtual agents can inhabit and provide support all the time in a virtual learning environment irrespective of any differences due to time zones. According to [JRL00], virtual agents in learning environments use non-verbal behaviours to improve communication between different participants which ultimately helps to motivate and engage students for better learning outcomes. It is also a cost effective option to provide multiple virtual agents so that every student can be accompanied by a personalized virtual agent to support him/her in learning. We do not suggest fully replacing a human teacher, but we suggest an additional learning resource to engage students.

Having a teacher in a learning setup also requires him/her to be able to fluently communicate with students. Communication could be defined as a process of sending and receiving messages which enables us to express, share knowledge and skills. In learning, communication helps to establish collaboration and promote teacher-student relationships to enrich the learning environment. A teacher must be a good communicator to effectively deliver knowledge and to motivate students [B99].

However it is difficult to supply virtual agents with similar communication capability to human teachers. Successful communication is a complex concept as outlined in [Lit01] and a life long learning process. Virtual agents in learning environments must be able to communicate with students to share knowledge and build a bridge of understanding. Many agent-based systems designed in the past have ad-hoc and developer specific communication mechanisms. Although these agents can achieve impressive tasks, participating agents are often based on context specific assumptions and can not accommodate tasks outside their capabilities [DG00]. Human communication can be defined in terms of two categories:

[1]Embodied graphical characters controlled by a computer program

verbal and non-verbal communication. Both types of communication categories play vital roles to exchange knowledge. Currently, there is no technology available for an agent that fully supports fluent communication with humans.

It is true that a few attempts have been made to provide closer to human communication to virtual agents [JR97, Sol01, Wal04, Cor88], but these communication procedures are still far from perfect and lack the features we aim to attain in this thesis. Verbal communication for virtual agents is mostly pre-scripted and based on Natural Language Processing [Wal04, JR97]. These verbal communication systems also depend on the virtual agent's designer to continuously extending their knowledge base either manually or automatically. Recently, many authors [Mat97, IH07] have researched non-verbal behaviours for virtual agents but these have been developed for underlying specific environments. Current literature suggests a need to combine both verbal and non-verbal communication mechanisms for virtual agents.

An even harder task is to make these virtual agents believable in virtual learning environments. A believable agent should be lifelike in its behaviour, its actions must appear to be real and it must have the capability of engaging an audience [Mat97]. Believability itself is an open issue to investigate. Believability is subjective in nature as it raises this question: does a viewer find the agent's behaviour believable? In the learning process, believability for virtual agents is important to keep students motivated and engaged. A virtual agent should have an engaging personality and depict believable behaviour in each current situation. Through such life-like behaviours, believable agents may motivate students to frequently interact and learn in virtual environments.

Studies in virtual agent's believability have approached this concept in terms of independent features like personality [Nea97], emotions [RB95], facial expressions and gestures etc. Existing studies suggest that a virtual agent with unique personality, who has emotions and can express its feelings though facial expressions and gestures during interactions is perceived as more believable. But these believability features in the current literature have been studied independently and their role collectively is yet to be investigated. A virtual agent's personality includes its behaviour, beliefs, style, emotions and the way it performs different actions. An interesting personality enables an agent to engage and motivate students in the same way as animated characters in movies. Similar to humans, for an agent to carry out successful interactions, it must be capable of using these non-verbal communication features [CKW05, HMP05].

Currently, existing agents are not perfectly believable due to believability not being well studied and features like awareness not integrated. As stated above the literature in believability focusses mainly on providing agents with engaging personality, emotions and how to make interactions more believable through gestures and facial expressions etc. But a virtual agent in 3D Virtual Worlds for assisting learning must also be well aware of its surroundings especially regarding objects and agent/human avatars present. To behave believably, virtual agents should also be able to recognize and be aware of their interactions with other agents/students. When asked about a virtual agent's own plans by students, it should be aware of its own goals, beliefs and any immediate plans to appear as believable to students. The current literature has introduced the concept of environment awareness in terms of obstacle avoidance during navigation [HA04] or pointing at objects in static environments [LVT99a]. This thesis investigates these awareness features and any impact they may have on virtual agents' believability.

To sum up, we conclude that virtual agents are important for structuring the learning process of a student in 3D Virtual Worlds, but these agents must be believable, as believability of virtual agents is critical to motivate, engage and ensure knowledge is gained by students in the learning process. To make them believable, we must investigate believability as a concept and integrate new features, e.g environment-, self- and interaction-awareness into agent's conversations.

## 1.2 Research Problem

The initial research questions we wanted to investigate were: how to make learning history and culture studies an interactive experience? How to advance visualization of historical places and people, provide an engaging learning experience to students include active participation of students while learning, offer students a personalized learning experience based on their background knowledge of the subject? As an answer to these challenges, we decided to develop an innovative and engaging educational technology.

We commenced addressing the above given questions can be addressed by investigating currently available interactive technologies. Among various technologies, we opted for 3D Virtual Worlds as a new medium to teach history and culture; due to its close resemblance to video/computer games. In the previous section, the need for new interactive technologies in this age of information overload has been discussed. There is enough evidence to confirm that Virtual Worlds is an appropriate technology to facilitate the above mentioned features. However, how to utilize Virtual Worlds for education requires further investigation. Currently, there are two popular methods used to introduce learning in Virtual Worlds:

1. No human involvement: this is the most widely used approach for knowledge sharing and learning in virtual worlds and similar technologies. This method is suitable for teaching about architecture especially destroyed cities and cultures. It usually provides visual representation of significant artifacts

and buildings with information notes. The key drawback of this method is that it does not provide teaching instructions and material in an interactive way; learners are expected to learn by themselves.

2. Human teachers: each student visiting the virtual space gets an avatar representation of himself to interact with others and to navigate in the virtual space. The human teacher then interacts in Virtual Worlds to transfer knowledge but this involvement incurs cost and requires 24/7 availability which is hardly possible in such environments.

The first approach with no human involvement is not suitable as we are aiming at well structured and engaging knowledge transfer. The second approach with human teachers in a virtual environment is also not desirable due to the teacher's full time availability requirement and high associated costs. The challenge therefore is: how to provide an interactive experience to students and make it an active learning environment. The literature suggests that utilizing autonomous agents is an effective solution to provide engaging learning environment. Such an approach helps to save the associated cost of using human resources and provides full time support to students. As these agents are inexpensive to employ in the learning environment, we can also use multiple agents to support personalized learning. Another important challenge in Virtual Worlds is the use of non-verbal behaviours to improve communication. Existing studies report that human users in Virtual Worlds prefer verbal or textual communication [IH07]. Implementation of these autonomous agents will also enhance the interactive experience through non-verbal behaviours.

The next question to address was: how do we develop these agents which are suitable for the educational domain with the characteristics mentioned above? As part of our group project the Virtual World of SecondLife was chosen as the interactive learning environment and the city of Uruk[1] was recreated as proof of the concept in SecondLife. Autonomous virtual agents in this project were required to adhere to roles and regulations given for the ancient society. To develop these virtual humans, we have used the Virtual Institutions(VI) [Bog07] technology which helped to implement rules and regulations of the society. A detailed technical discussion will be given in the following chapters.

In order to ensure active knowledge transfer to students who visit the Virtual World, it was important to make agents capable of active participation in conversations. Therefore, virtual humans as residents of the virtual learning environment were made conversational in nature to stage an active and engaging learning experience. These conversational facilities made agents capable of communicating with other participants/visitors, and sharing the knowledge of their daily routine and surroundings. Relying on natural language processing alone for these conversations may limit the overall believability of these agents in Virtual Worlds. Conversational agents in the learning environment must be able to relate to students'queries and provide them with believable responses in the current situation. Thus, it requires an agent to be believable in the current context.

This aspect of conversational agents could be put in the form of a question as: what characteristics must a conversational agent have to act believably and have believable conversations with students? Through the literature review, we investigated the existing research to make virtual agents believable and engaging. Currently, a few characteristics emphasized in the literature are to provide conversational agents with emotions, personality, facial expressions and gestures etc. In our case, we focus on having believable conversations with virtual agents

[1]Uruk, situated 250 km south of Baghdad, on an ancient branch of the Euphrates River in Iraq, also known as Warka, is the first major city in Sumer built in the 5th century BC, and is considered one of the largest Sumerian settlements and most important religious centers in Mesopotamia.

and how these agents should use sophisticated reasoning to give more believable replies to human visitors in the learning environment.

Therefore, our aim was to create reasoning mechanisms to make agents believably communicate with students while being aware of their surroundings, using extensive references to objects, avatars and their own relative location. Agents must also be able to converse and inform about their own goals, plans, beliefs and states. Agents' reasoning was also directed at being aware of the agents' interaction with other human and agent participants in virtual environment. We label such believability features as "awareness believability" of embodied conversational agents collectively.

Direct inclusion of human visitors in 3D virtual learning environments and their interactions with embodied conversational agents for learning raised the question of believability. A comparison of agents with and without the above given believability features was necessary to measure the impact of these features on agents' conversational behaviour. We also wanted to investigate how aware-agents(we use the term for embodied conversational agents with given awareness believability features) are perceived in comparison to non-aware agents by students during their conversations. Similar to the concept of believability, this evaluation is not well defined in the literature. Evaluating the believability of these conversational agents and any impact these aware-agents may have on students' learning was the next vital step we wanted to investigate. Evaluating engaging experiences and believability in virtual learning environments is subjective in nature. To support this concept, we were required to conduct quantitative and qualitative studies to evaluate believability and the success of learning in these virtual environments.

Summarizing all of the above challenges, we formulate the research problem as:

**Research Problem**: *How to develop believable and (environment, interaction and self)aware embodied conversational agents for teaching history and culture in Virtual Worlds? How to the evaluate believability and the success of introducing these agents for active learning?*

## 1.3 Objectives

This research aims to develop believable conversational agents and to explore the possibility of applying them to education in Virtual Worlds; particularly for teaching history and culture. We also want to evaluate the believability aspect of these conversational agents and their success in the virtual learning environment. To accomplish this, we have set the following objectives:

- To study the believability characteristics of interactive conversational agents.
- To develop believable conversational agents for Virtual Worlds.
- To evaluate the believability of conversational agents to teach history and culture in Virtual Worlds.
- To evaluate the impact of introducing believable conversational agents to teach in Virtual Worlds in comparison to traditional education methods.

## 1.4 Research Method

In this section, we present the list of objectives together with the corresponding research hypothesis and together with the research methods adopted to achieve each of these objectives. Figure 1.1 demonstrates the research methods adopted to carry out this research.

- *To study the believability characteristics of interactive conversational agents*:
  The research hypothesis associated with this objective is that interactive conversational agents would be more appealing to students if they were more believable. The detailed literature review highlighted the existing features of believability and helped to identify the need for considering others namely, environment/object awareness, considering the agent's interactions with other humans and agents and awareness of self goals, states and behaviours in conversations. To be believable, agents should also have good locomotion and gesture mechanisms and be able to relate to the current conversation. By means of exploratory research, the characteristics of believability were described, the mapping between concepts in 3D Virtual Worlds, interactive conversational agents and believability was established.

- *To develop believable conversational agents for Virtual Worlds*:
  The research hypothesis associated with this objective is that believable and engaging conversational agents to teach history and culture in 3D virtual Worlds based on the above mentioned features could be developed. The hypothesis was investigated by means of a prototype to develop believable conversational agents in Virtual Worlds. The prototype further provided a proof of the concept that using believable conversational agents to teach history and culture.

- *To evaluate the believability of conversational agents to teach history and culture in Virtual Worlds*:
  The research hypothesis affiliated with this research objective is that environment -, self - and interaction-awareness features, use of gestures in conversations and locomotion could the improve believability of conversational agents in Virtual Worlds. Due to the subjective nature of the believability concept, we selected a conventional quantitative research process to vali-

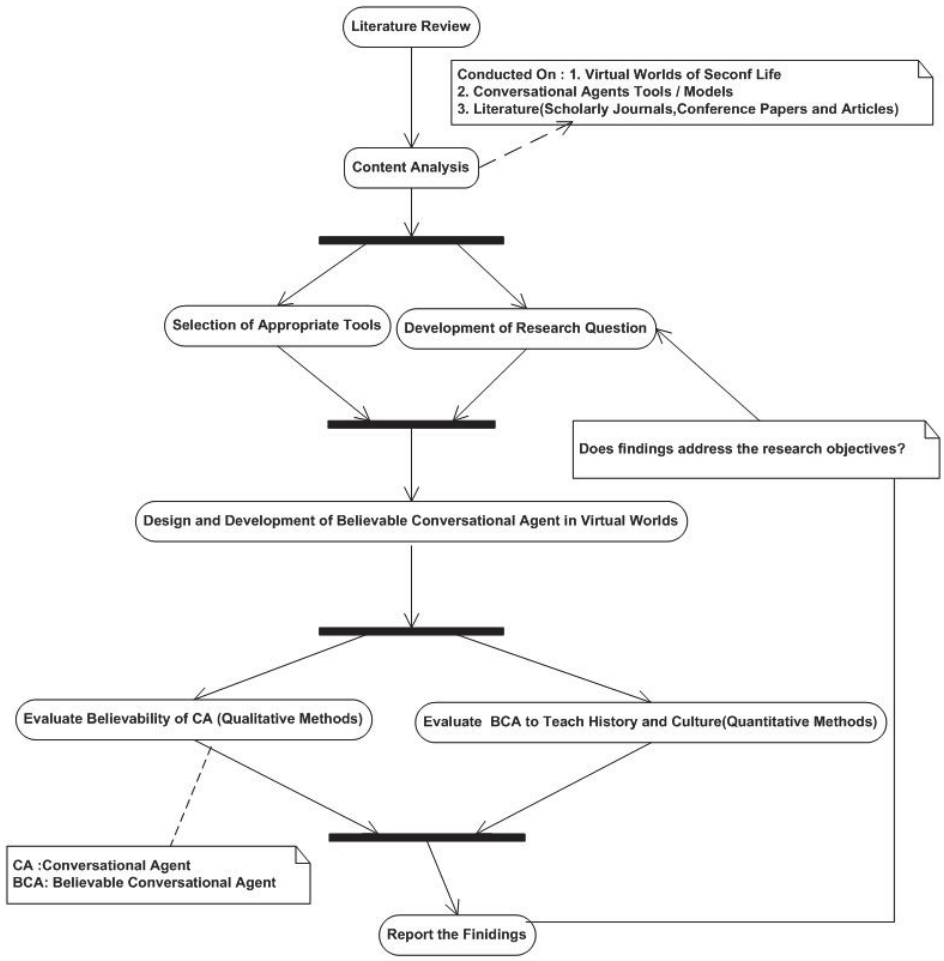



Figure 1.1: Research Approach Used

date this hypothesis. As a result, a set of data to compare our aware agents with un-aware agents was collected using a qualitative data gathering process. Based on these data collected, we further devised a believability index for each awareness feature as well as for the believability of conversational agents to provide a quantitative comparison of believability.

- *To evaluate the impact of introducing believable conversational agents to teach in Virtual Worlds in comparison to traditional education methods*: The research hypothesis affiliated with this objective is that believable conversational agents to teach history and culture in Virtual Worlds will provide an engaging learning method compared to traditional education setups. The qualitative approach has been adopted to validate the success of employing believable conversational agents to teach history and culture in Virtual Worlds. Data collected for this study were based on examining two participating student groups. One of the student groups had to learn historical facts based on traditional text reading. In contrast, the second group was made to visit the Virtual World and have conversations with believable embodied agents. These data were further compared to evaluate the learning in Virtual Worlds with the assistance of embodied conversational agents in contrast to reading the text as in traditional education settings.

## 1.5 Significance

In this section we present the contributions of this thesis and highlight the significance of these contributions to computer science and to establishing a better education environment in Australia.

### 1.5.1 Contributions

This research study aims to make the following contributions.

- Developing conversational agents in 3D Virtual Worlds to teach history and culture.
- Enhancing the believability of conversational agents by providing awareness features(environment-, self- and interaction awareness). With given awareness features, incorporating a relevant set of gestures and proper locomotion to support the believable conversations.

- Providing embodied conversational agents with learning capability to extend their knowledge base through interactions with a subject matter expert.
- Evaluating the believability of conversational agents through a quantitative approach.
- Examining the success of applying believable conversational agents to teach history and culture in 3D Virtual Worlds by conducting a qualitative study.

With the help of literature analysis and our group expertise, we selected history and culture as learning subject in Virtual Worlds. Introducing believable conversational agents to teach history and culture in Virtual Worlds is expected to significantly contribute to research in the following areas: Believable Conversational Agents, Multiagent Systems, Virtual Worlds and Education. We will discuss the significant contributions for each of these domains below:

- Believable Conversational Agents: Believability enhancement of embodied conversational agents requires us to investigate the role of awareness features like environment-, self- and interaction awareness, use of gestures and visually correct locomotion. To the best of our knowledge, awareness characteristics of believability for conversational agents are not well studied in the literature. We envisage that incorporating all these attributes in virtual agents' conversations will cater for a more consistent notion of believability in agents' interactions with humans.

- Multiagent Systems: Creating embodied conversational agents as virtual inhabitants of an ancient society in 3D Virtual Worlds offers enough ground to study beliefs, desires and intentions of these agents. Incorporating awareness believability features like environment, self and interaction helps to study complex reasoning in such multiagent systems.These systems with direct human inclusion also provide an opportunity to observe interesting interactive behaviours of conversational agents with other human and agent participants. Having multiple embodied agents in a dynamic environment such as 3D Virtual Worlds enables us to study an in depth concept of believability.

- Virtual Worlds: In this research, we highlighted the significance of utilizing Virtual Worlds as a medium for learning history and culture. Investigating awareness believability for embodied conversational agents not only improves the conversational behaviour of such agents but also promotes use of Virtual Worlds for various applications. This thesis suggests that having AI conversational agents in Virtual Worlds makes it more engaging and may increase the immersion of its users. Investigating believable conversational agents also helps to improve the communication mechanism between agent/human participants in Virtual Worlds.

- Education: Study of present conditions and literature review revealed a need for new engaging learning methods in this age of massive information and advanced technology. The concept of learning in Virtual Worlds proposed in this thesis can provide an engaging believable learning experience to students. Interacting with believable conversational agents in Virtual Worlds also presents much more engagement than learning about ancient history in a traditional way. This method of learning can also be used to encourage students to use textbooks for completing the given tasks in Virtual Worlds. In summary, having students interact with AI conversational agents in Virtual Worlds brings important benefits to the education process and encourages active learning among students.

Apart from the above mentioned computer science areas and education, this project also brings significant contributions to the Australian education system and augments the traditional teaching methodology with current technology. The Australian government has taken a major initiative to identify a set of national research priorities to provide greater focus, direction and importance to the nation's research and innovation system. We indicate the national research priorities relevant to this project in the following section.

### 1.5.2 National Research Priorities

This research addresses the following national research priorities announced by the Australian government: Frontier technologies for building and transforming Australian Industries. In particular, it tackles the following priority goals [DES03]:

- Frontier Technologies:
  Frontier technologies and their applications are one of the highest priority areas of Australian Government. This project focuses on utilizing emerging technologies to provide a better and engaged learning environment. Our aim is to introduce Virtual Worlds technology to motivate and engage students for learning ancient history and culture. This research will help us to bring the emerging technology of Virtual Worlds to schools to engage students in the learning process.

- Smart Information Use:
  This research aims to present historical information in an engaging way,

where students are active participants and not just passively absorbing the knowledge. Education among other key industries in the Australia also requires smart information use. An innovative use of technology for education would make the learning process more engaging and further help to enhance the education methods. Our goal is to present information in an engaging way; where students can actively participate rather than passively absorb the knowledge. Students' interactions with conversational agents (who are inhabitants of the historical city) in 3D Virtual Worlds would make it possible to smartly transfer the knowledge.

## 1.6 Summary

This research suggests the use of embodied believable conversational agents to teach history and culture in 3D Virtual Worlds. Interactive Virtual Worlds combined with believable conversational agents can offer an exciting new tool for education and knowledge exchange. To accomplish the the transition of conversational agents from simple text based dialog systems to embodied life-like characters these conversational agents require several capabilities to be believable. Existing studies consider believability features like facial expressions, gestures, and gazes to name a few. We have noticed through the literature that existing embodied agents lack several things namely providing comprehensive environment knowledge, Interaction and self awareness during their conversation. In an effort to enhance the believability of conversational agents to teach history and culture; we plan to integrate environment information, interaction with other agents/humans and self awareness, believable gestures and locomotion during the conversations in Virtual Worlds. To Emboding conversational agents with the given role of knowledge sharing requires these agents to learn with time as part of an immersive and dynamic Virtual World. Therefore, we also propose a learning mechanism for embodied conversational agents to expand their knowledge of the current domain to have more believable interactions. To evaluate the proposed believability features and learning effectiveness of students in such interactions, we have conducted user studies to analyze our approach.

## 1.7 Structure

The remainder of this thesis is structured as follows:

**Chapter 2** highlights the major concepts of the problem domain: Virtual Worlds, Current Methodologies for Virtual Worlds and their applications in education. This chapter also presents the need and major motivation to use Virtual Institutions technology to provide formal methodology in Virtual Worlds. Virtual and conversational agents in Virtual Worlds will be described specifically in the context of their applications for the education domain. This chapter also demonstrates the concept of believability and its existing characteristics in the literature.

**Chapter 3** outlines the proposed believability characteristics developed in this thesis: Environment-, Self- and Interactions Awareness to improve believability of embodied conversational agents in Virtual Worlds. The concept as well as the detailed formalization of believability for embodied virtual agents is discussed. This chapter also explains the relationship between human subject matter experts and virtual agents. It also discusses the need for explicit learning of historical facts by virtual agents and our proposed approach to achieve it.

**Chapter 4** presents our specific approach to implement these believability features for embodied conversational agents. It also presents the role of virtual institutions technology to develop these believability features in Virtual Worlds. All the relevant technical details to integrate environment awareness, agent's own information such as personal goals, plans and interaction with embodied conversational agents' behaviours are also included. The role of agents' learning and how it impacts on overall believability of current virtual agents is described. This chapter also illustrates the technical implementation of agents' learning capability through a communication layer implemented with AIML engine and SecondLife technology.

**Chapter 5** illustrates our case study to implement these believability features for embodied conversational agents who participate in the teaching process of ancient history and culture. This chapter starts with introducing the historical significance of the city of Uruk and lists its vital inventions for human history like writing, astronomy, mathematics, wheel etc. We also discuss our approach to teaching ancient history and culture to digital natives who spend most of their time playing video games and surfing the internet. It also includes the technical details of re-creating an ancient city in Virtual Worlds of SecondLife and populating it with virtual agents to represent ancient populations.

**Chapter 6** is concerned with applying the proposed believability features to virtual agents to enhance students'learning and interaction behaviour. It is also concerned with applying the proposed believability features to achieve students interactions improvement to virtual agents specifically to enhance their learning behaviours. To test these believability features, we have developed a believability index which also helped us to apply a quantitative approach to measure the believability. Secondly, the chapter also evaluates the learning effectiveness of Virtual Worlds for ancient history and culture. A qualitative approach has been adopted to explain the learning outcome of visiting the virtual city and conversing with virtual humans(agents).

**Chapter 7** presents a few concluding remarks of this research and suggests directions for future work, in particular to introduce group based learning activities and to observe group based agents' behaviours, to investigate the combined effect of all the given believability behaviours, studying text to speech conversion for embodied conversational agents in Virtual Worlds. In the current work, we have a limited set of gaze behaviours implemented for our agents, in particular regard to this direction we want to integrate more complex facial expressions, emotions and gazes for conversational agents. Another direction for our future work can be a more enhanced learning method for embodied conversational agents in the context of teaching history and culture.

# CHAPTER 2

# Background

This chapter provides the background information that helps to gain a detailed insight into the Virtual Worlds concept and explains why we need to emphasize believability for participants' interactions inside them. The concept of Virtual Institutions which helps us to implement Virtual Worlds as multi-agent systems is included in this chapter. How Virtual Institutions' technology helps us to implement norms and regulations for all human/virtual agent participants is also discussed in the next sections. Having a learning setup in Virtual Worlds and the inclusion of embodied conversational agents as a teaching source leads to investigating the concept of believability.

Therefore, the next sections will introduce the concept of believability and its related features which are necessary to have believable conversational agents in Virtual Worlds. We will also present the current Virtual Worlds' applications for learning and education. The role of conversational agents as an important educational entity and their existing applications for learning in Virtual Worlds are also explained in the next sections. We begin this explanation by introducing the concept of Virtual Worlds.

## 2.1 Virtual Worlds

The concept of Virtual Worlds is quite broad and it includes all kinds of imaginary spaces. A theater play could be taken as an example, where reading a written script and enacting the same script are two different ways of expressing these Virtual Worlds to the attendees [Bog07]. The high level concept given in Figure 2.1 depicts Virtual Environments which are defined in literature as:

<u>**Definition**</u>**:** ***Virtual Environments*** *are imaginary spaces which are often represented through a medium. These spaces may only exist in the mind of their creator and are broadcast to share with others [SC02].*

For the purpose of explaining Virtual Worlds, we focus on Immersive Virtual Environments in this taxonomy presented by [Bog07]. We are concerned with the type of Virtual Environments which offer immersive experiences to their participants and support high immersion that takes all of participants' attention. These environments are also interactive and participants act actively rather than passively observing the environment as explained by [Bog07]. To give a comprehensive idea of this specific Virtual World, here we outline some of the characteristics of this environment.

### 2.1.1 Interactivity

Virtual Worlds which support interactivity are different from theaters or movies, in which audiences are just passive viewers. Providing opportunity to actively participate and have influence over this experience makes these Virtual worlds more authentic. As mentioned by [SC02], interactivity comes more promptly by adding computers to the equation. The computer supported virtual worlds

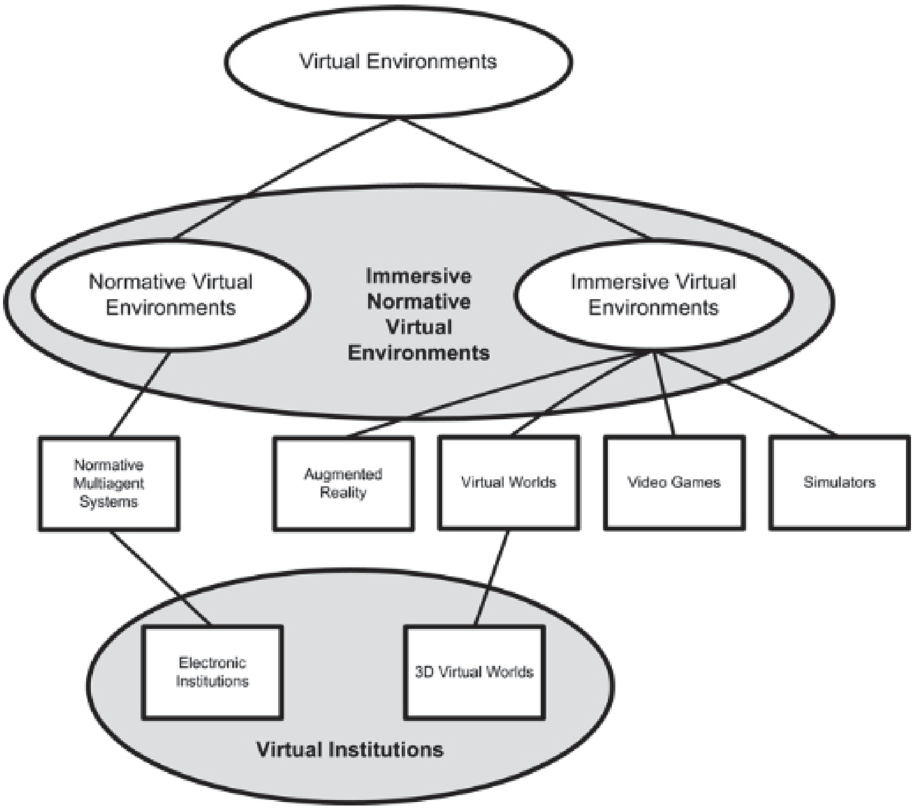



Figure 2.1: Concept Taxonomy of Virtual Environments [Bog07]

include computer games, simulations for various purposes and flight simulations.

Computers could assist the design of interactive environments which give response to user commands, leaving participants with a feeling of being an active part of the environment. Participants in such environments could interact with various objects, places and other participants. A simple example of interactivity is to allow participants to have different views of these environments from different positions and angles [Bog07].

In Virtual Worlds, interactivity is usually achieved through different input/output channels and rich graphics. Participants in such environments are able to move around, can view surroundings with different camera angles, change directions, pick/edit objects and can also interact with other participants.

### 2.1.2 Embodiment

Embodiment is another important feature supported by some Virtual Worlds. Every participant in Virtual Worlds has a bodied representation or avatar of himself to inhabit the world. These avatars help users to make realistic interactions within Virtual Worlds. Such avatars are 3-dimensional representations of various creatures which have functional body parts. In fact, avatars help to provide identity and personality to individual participants in these virtual environments.

Participants in Virtual Worlds can manipulate these avatars and they also help participants to navigate in virtual space. Besides providing a representation in a virtual environment, embodiment also fosters the following advantages as discussed by [Tay02]:

- Presence - is one of the most important advantages of embodiment as it gives the signal of being 'there'. Users not only roam through the virtual environment with their mind but also find themselves physically present there in body.

- Communication - The user behaviours that make up presence in the worlds are also related to the interpersonal and some form of social communication. Embodiment has provided both presence in the space and communication.

- Affiliation - Embodiment allows users to have affiliations and presents them with other participating groups in the Virtual World. More specifically, participants can signal affiliation through their bodies, accessories, etc.

- Socialization - In addition to signals of group affiliations, participants use their avatars for social interactions. Participants gather for various events like weddings, meetings, games etc in these embodied spaces.

### 2.1.3 Collaboration

Some of the Virtual Worlds also provide an important feature known as collaboration. Collaboration has been defined by [Tay02] as an act of working together on a common task or process. In Virtual Worlds, collaboration is related to community building and interactivity. Nonetheless, collaboration is particularly concerned with interactions between participants.

Virtual collaborations enable people to work together across boundaries of space, time and organization. Virtual Worlds provide various kinds of facilities to collaborate and jointly work with to accomplish the tasks. These collaborations in Virtual Worlds happen in different forms like text, audio, video, interactive 3D objets etc.

### 2.1.4 Persistence

Another significant feature of these Virtual Worlds is persistence. A virtual world continues to exist and function regardless of individual participants leaving the environment. This persistent behaviour of Virtual Worlds separates them from computer games where the user shuts down the whole game world when he/she leaves the environment as describe by [Bog07].

Persistence also impacts the way people interact with each other in these imaginary spaces and with other artifacts in the environment as pointed out by [Bel08]. For instance, when a participant working on a team based task leaves the virtual environment; he/she may not find the task/objects in the same state when he joins back into the virtual space, because during his absence other group members may still work on the task and modify the environment which is always alive. Persistence therefore changes the participants' perception about the environment that the world exists with or without their presence. Persistence also gives independence to geographically distributed participants to work collaboratively and use the environment synchronously.

### 2.1.5 Immersion

Immersion plays an important role in a participant's whole experience of the Virtual World. Immersion enables Virtual Worlds to lift all the barriers between the participant and the world. The effect of immersion is achieved by various factors including the representations of environmental artifacts and body representations, an enhanced degree of body tracking, and a decrease in delays between body movements and subsequent changes in sensory input as described by [ZXH07].

According to [NP09] immersion also improves the degree of engagement and sense of presence in activities being undertaken by the participants.

### 2.1.6 Definitions and Terminology

All the aforementioned features should be present in the virtual world we are focussing on in this thesis. Thus, our definition of "Virtual Worlds" in terms of these characteristics is as follows:

**Definition:** ***Virtual Worlds*** *are persistent and immersive imaginary spaces supporting sensory feedback, visualized through computer simulations and designed for their embodied users to inhabit, collaborate and interact [Bog07].*

There are several definitions of Virtual Worlds given in the literature but the term 'Virtual Worlds' in this thesis represents an environment with the above mentioned features. Where we mention 'virtual worlds' (no capital letters) we refer to the general concept similar to Virtual Environments. However, when we use 'Virtual Worlds', we refer to a particular type of Virtual World as covered by the previous definition [Bog07]. A boundary line between Virtual Worlds and similar Virtual environments has been drawn in [SZ99]. The following features have been suggested by the authors:

- Multiple Users: The support for multiple users in Virtual Worlds differentiates them from standard virtual reality and game engines.
- Artifacts Manipulation: The ability to manipulate shared Virtual Worlds' artifacts differentiates them from traditional chat rooms.
- Real-Time Interactions: The real-time interaction with other participants and artifacts differentiates Virtual Worlds from traditional email services and web.

To be able to perform these interactions and to collaborate, all the Virtual Worlds' inhabitants are represented by avatars. A formal definition of this term is as follows:

**Definition:** ***Avatars*** *are one,two or three-dimensional graphical representations of humanoids and other creatures* [She03].

The immense growth of widely available graphics technology in recent years has also led to the advancements in Virtual Worlds. Initially, avatars were represented with simple geometrical objects. But now avatars can have a similar appearance as the physical appearance to a person in the physical world. One type of Virtual World and avatars available today belongs to the 3D Virtual Worlds. The key feature which distinguishes this class from other virtual worlds is the ability to be visualized using 3-D computer graphics. We present a formal definition below:

__Definition:__ ***3D Virtual Worlds*** *are multiuser Virtual Worlds designed using the metaphor of architecture and visualized using 3-dimensional computer graphics* [Bog07].

3D Virtual Worlds as simulated by computer graphics that closely resemble the physical world, and also provide physical world rules like gravity, navigation, real-time actions in the space, communication among participants and topography. Designers in Virtual Worlds have also created spaces like in fantasy movies and books. Some of the features available in these environments are not present in the physical world, like teleportation[1] and flying in the environment.

Collaboration among users in Virtual Worlds could be conducted through methods like text and real-time voice communication. The user interface of most Virtual Worlds is supplied with a chat window to communicate with other participants. Through these chat windows, some Virtual Worlds allow you to select participants where others provide restricted access only to the participants in close proximity to the sender. Many recent Virtual Worlds now provide the opportunity of voice over IP(VOIP) communication. [WGB07] has outlined the Virtual Worlds which have been using real-time voice communication and their affect on participants' behaviours.

Human participants in form-based computer applications are referred to as 'users', whereas 3D Virtual Worlds(as originated from computer games) bring new terminologies and here humans are called "players". This thesis borrows

[1] Teleportation is instantaneous displacement of objects/avatars happening in virtual worlds, distance does not matter and without passing the intervening spaces.

the term ”participants” from [Bog07], to emphasize that this work in 3D Virtual Worlds extends beyond computer games. Along with the human participants, we also focus on the fact that software-driven avatars are also an active part of these environments.

Distributed Artificial Intelligence has studied the autonomous software-driven components in computer generated environments as mentioned in [Sie05]. In these systems, such components are called ”agents”. We also use the same standard terminology ”agent” for the software driven participants in 3D Virtual Worlds. Both types of participants in 3D Virtual Worlds(humans and agents) are represented with avatars.

## 2.2 Case Studies: Virtual Worlds in Education

The section is intended to give an insight into educational projects in Virtual Worlds and it will help to illustrate the use of 3D Virtual Worlds technology in the context of specific learning practices.

Virtual Worlds and games are becoming more a way of life for young generations. Recently, educators and researchers have started realizing the need to capture the attention of these upcoming students. Virtual Worlds can deliver dynamic content, interactivity, creativity and a feel of social bond. Virtual Worlds like SecondLife, Active Worlds, OLIVE etc offer enough opportunities to their participants to creatively learn and share information. In next the section, we will discuss a few key projects and their major features to support learning.

### 2.2.1 Active Worlds Educational Universe

Active Worlds(AW) is one of the oldest Virtual Worlds available which provides social connectivity. It was first launched in 1994 and has changed several times since then. Active Worlds is an environment with a highly active user community and about six million downloads of Active Worlds browsers. Active Worlds is currently operated by the Activeworlds incorporation and has a dedicated educational world, known as the Active Worlds Educational Universe (AWEDU)[2].

AWEDU has a diverse community of educational institutes contributing research and learning in 3D Virtual Worlds. The availability of Active Worlds technology to the educational community made it possible to explore concepts/theories and design creative curricula. Active Worlds has a quite diverse community with hundreds of educational institutes in-world. All the participants have avatars which are allowed to chat(instant messaging and voice chats) with each other and can also build complex structures from primitive objects. There is a market place for textures, avatars and models and these items can also be exchanged among participants.

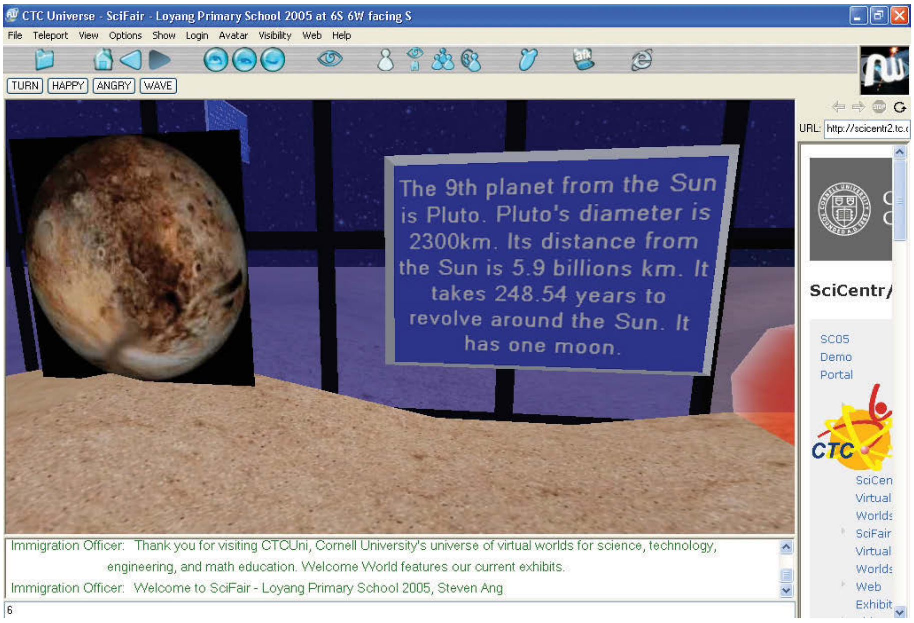



Figure 2.2: Active Worlds: student's Work From Loyang School [Kim06]

[2]Active worlds educational universe URL: www.activeworlds.com/edu/awedu.asp

Active Worlds browser allowes its users to participate in two ways: as a free visitor or as a paid citizen. Visitors have limited capabilities like restricted access to some worlds, content can be deleted etc. However, a paid citizen has permission to create its own private space inside the world, use communication facilities, create permanent content, personalized avatars, make it a safer learning and teaching place.

Some existing studies have found Active Worlds is as a supportive educational environment for providing constructive informal science and technology education [Pra05] and [PSS06]. Another example of Active Worlds use in education has been discussed by [KQ06], this study was conducted with primary school students studying science subjects. This study compared student groups learning science subjects in Virtual Worlds versus reading the same information from text.

| Specification for Active Worlds | |
|---|---|
| Version | Active Browser 5.1 |
| Licence Cost | Initial subscription fees and licensing cost for Worlds |
| Engine | RenderWare |
| Platform | Windows, Worlds Server SDK: Window, Linux |
| System Requirements | Pentium 3 CPU 650mhz or equivalent 128MB RAM Microsoft Windows 2000, XP or Vista DirectX 7 or later Windows Media Player 6.4 or later D3D video card with at least 16MB and the latest drivers |
| Objects | Developed using RenderWare Script RWX and trueSpace Objects COB and .X format |

Table 2.1: Active Worlds System Requirements

The outcome of this study was encouraging and indicates how for some students virtual and interactive environments can be more motivating, improve attendance and student's performance. Additionally, the authors claimed that Virtual Worlds could be used to support practical teaching methods, where visualization in such environments may provide a more memorable learning experience. A list of specifications for using Active Worlds platform is given in Table 2.1.

### 2.2.2 SciLands in Second Life

SecondLife[3] is one of the most popular non-game based 3D Virtual Worlds these days. Lately, in 2010 it had about 18 million registered accounts with over 50,000 registered users online at any time. SecondLife is different from Active Worlds and other similar Virtual Worlds as it is owned and maintained by Linden Lab, instead of multiple private parties.

SecondLife has a client application which enables its participants, known as "residents", to interact with each other. These residents embodied as avatars can explore the environment, participate in individual and social activities, trade items, virtual properties and services [Wik10c]. SecondLife, similar to Active Worlds, also offers two types of access to residents: basic and premium SecondLife accounts. Basic account holders pay no fee, but also have no rights to own private land in SecondLife. However, premium account holders need to pay for their land ownership.

Communication among residents can be done by two methods: local chat, and instant messaging (known as IM) globally. IM is a private mode of communication and does not require participants to be in close proximity to communicate. But local chat can only be done between two or more avatars within a certain distance i.e. 25m [Wik10c]. A recent version of voice chat (v1.18.1.2) is also available both as local and IM conversations. Table 2.2 shows the system specification required to use Virtual Worlds of SecondLife.

[3] SecondLife can be accessed at: www.secondlife.com

| Specification for SecondLife | |
|---|---|
| Version | SecondLife Client 2.1.1.208043 |
| Licence Cost | Initial subscription fees and licensing cost for Worlds |
| Engine | SecondLife platform |
| Platform | XP, Vista, Windows 7, Mac OS X, and most distributions of Linux. A third party version for Solaris and OpenSolaris. |
| System Requirements | Operating System: Windows(Service Pack 2,256MB or higher), Mac(1 GHz G4,512MB or higher) Video Cards: nVidia or higher. |

Table 2.2: SecondLife System Requirements

SecondLife has a dedicated area for science and technology where various organizations share their virtual boundaries to create a virtual continent. The SciLands in Europe is supported by Imperial College London to provide a common place for real projects in science and technology, where a wide range of scientists participate from across the world. There are about 23 science and technology organizations in SciLands[4] and these lands have their own membership and ownership regulations. Most of the projects in SciLands are educational and these aim to provide: research, learning, teaching, collaborative work and public awareness [Wik10b].

A few interesting projects include a 3D real-time weather map, a 3D submarine ride and tsunami demonstration in Virtual Worlds of SecondLife by US National Oceanic and Atmospheric Administration (NOAA), where Imperial College London and the London Strategic Health Authority (SHA) jointly work on a public health project and own a future hospital on SciLands. This project aims to promote public awareness about future health reforms in London and also arranges training for clinical staff. SciLands also hosts the space projects from National Aeronautics and Space Administration (NASA), a couple of vir-

[4]SciLands can be accessed at: http://www.scilands.org

tual demonstrations the like Apollo 11 Landing Site on the Moon and Rocket Ride to Space promote learning and awareness about these real life projects.

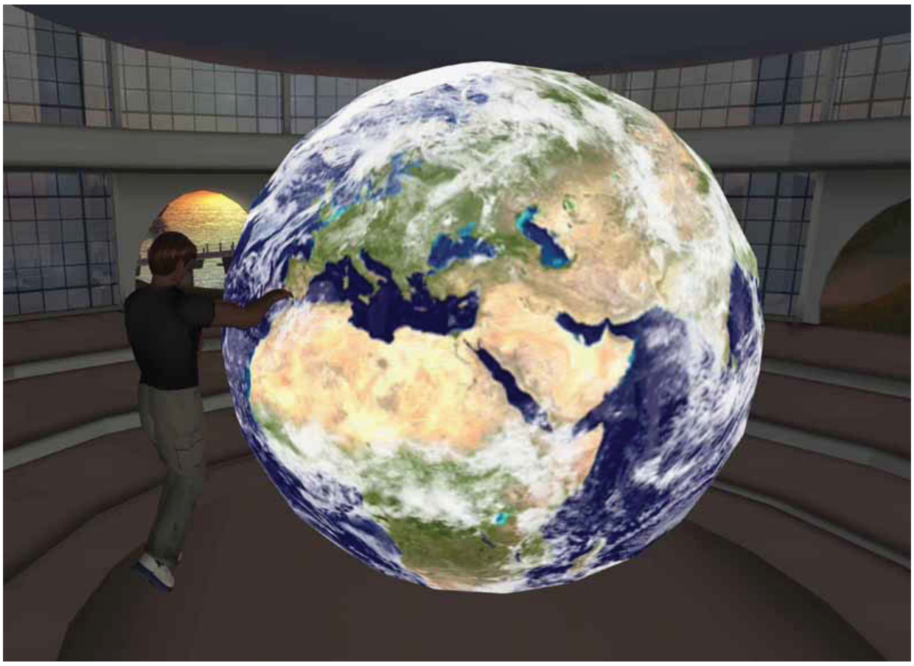


Figure 2.3: A virtual spherical projection screen located in SciLands [Wik10b]

Moreover, SciLands not only provides teaching and research opportunities in these science and technology projects, but has also been used for international collaborations on various projects. One such example is the international Virtual Association of Surgeons (iVAS) where speakers from different countries meet and discuss surgical robotics, education and simulation. A study conducted by Imperial College for surgical students in a traditional classroom, compared a simulated operating suite with a SecondLife based operation theater. The study showed 'no significant difference' between the two approaches, but students recorded less anxiety when going to the actual operation theater after participating in SecondLife than the operating suite or lecture approach [De 08].

SciLands and similar projects suggest various uses of Virtual Worlds: teaching and learning, organizing events globally, collaborative research projects, distributed research communities, providing simulations and modelings.

### 2.2.3 Project OpenWonderland: Collaborative Learning in Mixed Reality Spaces

Project Wonderland is an open source initiative, free of cost and publicly available. It has been developed on top of Darkstar game engine technology[5] and serves as a toolkit for creating 3D Virtual Worlds. This Sun Microsystems supported project allows users to communicate through audio and graphically interactive environment. This project has recently been evolved and named as OpenWonderland which is fully maintained by its community. It also promotes collaborative work by sharing applications in real time which include: web browsers, word documents and games. University of Essex and Sun Microsystems with other partners have been developing it as a training and educational tool. Although, it is in the early stages of development, but open source access and its functionality provide educational potential.

A distinguishing feature of this project is its support for a mixed reality environment. It brings together the advantages of combining real and virtual interactions. This project is hoped to be used for lecture-based learning in the future and it would provide collaborations among geographically distributed learners. This would help to offer economical courses for a wide range of learners either in Virtual Worlds or in mixed reality settings. This platform could also assist institutions with various campuses. In this scenario, courses offered in the main campus could also be attended virtually by learners in offshore locations. This system could also support tutorial based activities to engage students in simula-

[5]Project Wonderland is based on Darkstar technology, resources for further development could be found at : http://projectdarkstar.com

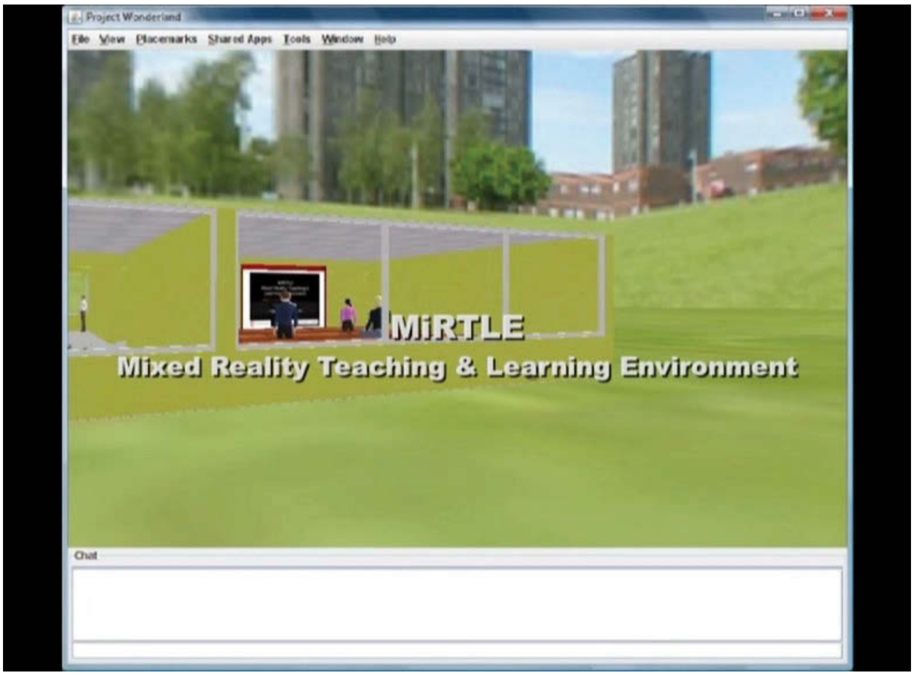


Figure 2.4: OpenWonderland: MiRTLE Project using Virtual Worlds in classroom [Hor08]

tions of course material or to collaborate for course assignments.

Use of OpenWonderland for education has attracted many of the education community as listed in [Wik10a]. This education community has initiated various projects such as teaching courses of computer science and physics, providing communication and team working skills within health care students, organizing collaborative events etc. Mixed Reality Teaching and Learning Environment (MiRTLE) is a joint initiative of Sun Microsystems with the International Academy at Essex university(UK) and the Shanghai Jiao Tong university in China. This project proposed to bring together local and remote learners in a traditional university lecture-based environment [Hor08].

The MiRTLE project promotes the integration of face-to-face teaching environments in Virtual Worlds. This was achieved by a traditional class room setting with a large screen in front, use of microphone and camera at the back of the class. The students participating from a remote location were presented as avatars in the virtual world on the front screen. This enabled the remote students to be part of the class, who can communicate via text and audio link exchange with physically present students. These remote students were able to see the virtual world, physical class room and map of these two environments together.

Project Wonderland is only in the early stages of development and has its basic functionality implemented. Its ability to bring the virtual world, real spaces and individuals together make it more interesting both for educational and business contexts, but it has been shut down for quite some time due to lack of funding available. Major specifications to use project Wonderland are presented in Table 2.3:

| Specification for Wonderland | |
|---|---|
| Version | MPK20 |
| Licence Cost | Open Source and freely available but needs high level technical skills for use |
| Engine | Project Darkstar |
| Platform | Windows XP, Mac OS X, Linux and Solaris x86. |
| System Requirements | Operating System: PC: 1.5GHz+ and 1GB RAM, OpenGL drivers Solaris and Linux( nVidia cards and drivers required), Java SE6(JDK 6). |

Table 2.3: Project Wonderland System Requirements

### 2.2.4 OLIVE Platform: Surgical Education and Incident Training

Forterra systems provide an OLIVE(Online Interactive Virtual Environments) platform to build secure and scalable 3D Virtual Worlds. These virtual worlds provide opportunities for training, learning, collaboration and analysis to users. The main features provided by the system are use of avatars, text chat, Voice Over Internet Protocol(VOIP) and non-verbal communication through various body movements. In various training environments, expressive movement with body gestures plays an important role in communication. Until recently, this platform was used for US military training but now it has been considered for medical training, emergency planning, transportation and businesses as pointed out by [For10].

OLIVE has been based on a client server architecture which could support thousands of geographically distributed users at one time. External parties can build and manage their own personal Virtual Worlds through OLIVE SDK. A worth mentioning application of the OLIVE platform is the Stanford Medical School project [LYH08], which was based on a replica of Stanford emergency facilities such as entrance and waiting area, hospital bed, medical equipment. The learning scenarios defined by the project were mass casualty, assessment in acute care medicine and cardiopulmonary resuscitation (CPR) training. Avatars in Virtual Worlds were coded to exhibit the symptoms of a population affected with various physiological and biochemical diseases. These avatars were later treated for physical injuries and psychological trauma after a bomb explosion incident as explained in [LYH08].


Figure 2.5: OLIVE: Explosive Incident Victims in Live Disaster Drill and in the Virtual Worlds simulation [LYH08]

The OLIVE platform has been recently explored for the possibility of its applications in education and distance learning. The OLIVE official website outlined the following main supportive features of this environment for educational projects:

- Formal classroom and institutional instruction
- Lecture, briefing, and panel based discussion 3D environments
- Sales, customer service, call center, and leadership training
- Integration with SCORM, flash, or other learning digital media content
- Display MS Office documents, desktop applications, and browser based content

This platform has revealed the potential for engaging learners, support for scientfic simulation, collaborative research communities. [De 08] claimed that Virtual Worlds will not replace face-to face learning activities, rather this environment will supplement traditional teaching and learning methods due to its support for role plays, scenarios based learning activities and experiences. Table 2.4 lists the specifications for the OLIVE platform.

| Specification for OLIVE platform | |
|---|---|
| Version | 1.0 |
| Licence Cost | OLIVE Provides licence for users |
| Engine | OLIVE Platform |
| Platform | Windows and Linux |

Table 2.4: OLIVE Platform System Requirements

In the next section, we explain the Virtual Worlds area and the relevant technologies to develop a believable learning environment.

## 2.3 Virtual Worlds as Open Systems

The use of Virtual Worlds for diverse applications requires a systematic support for participants' interactions. [Bog07] explained that inhabitants in these artificial societies in Virtual Worlds constantly grow, and with the help of immersion, participants become more and more engaged with the experience. Thus, it demands an explicit structuring of their interactions. In order to apply Virtual Worlds to a wide range of participants' problems, there is a need to explore the benefits of Virtual Worlds, deal with its growing complexity, investigate methodologies to regulate the interactions of participants and provide reliable and secure virtual spaces. The author in [Bog07] suggested considering open systems for a methodological design of Virtual Worlds. [Hew86] defines open systems as follows:

**Definition:** ***Open Systems*** *are software environments whose components are unknown in advance, can change over time and can be either humans or software entities developed by different parties.*

Such systems have been widely investigated by the researchers in Distributed Artificial Intelligence(DAI). Distributed Artificial Intelligence(DAI) is a subset of the Artificial Intelligence. The main aim of Artificial Intelligence(AI) research field is to create intelligent agents [RN03]. Definition of an agent is as follows:

**Definition:** ***An Agent*** *is anything that can be viewed as perceiving its environment through sensors and acting upon this environment through actuators* [RN02].

This concept of a agent in AI provides the context for further research. A major focus of this research discipline is to make the agent *intelligent*. In Distributed Artificial Intelligence, the agents are normally considered as software entities and their vital feature in this subfield of AI is autonomy rather than intelligence. In a DAI context, the definition below provides the concept of agents.

**Definition:** ***Autonomous Agents*** *are computational entities such as software programs or robots that can be viewed as perceiving and acting upon their environment and that are autonomous in that their behaviour at least partially depends on their experience within the environment* [Wei00].

In Artificial Intelligence and its other subfields, an agent is mostly mentioned in singular form. As the name shows, DAI is not concerned with studying the singular form of the agent. In contrast, DAI does not aim to achieve human-like intelligent agents and is rather focussed on investigating various interactions among these autonomous agents [Bog07]. In summary, Distributed Artificial Intelligence researchers are concerned with Multiagent Systems. The definition of Multiagent Systems is as follows:

**Definition:** ***Multiagent Systems****(MAS) are systems in which several interacting, autonomous agents pursue a set of goals or a set of tasks* [Wei00].

Having clarified the concept of Multiagent Systems we can now define Distributed Artificial Intelligence.

**Definition:** ***Distributed Artificial Intelligence*** *(DAI) is the study, construction and application of Multiagent Systems* [Wei00].

The most important challenge for the DAI community is to investigate how agents should interact to achieve their objectives successfully. Virtual Worlds, based on an open system metaphor, provides the opportunity to study these interactions where participants are both agents and humans. [Bog07] investigated the appropriate technology to enforce interaction regulations for such Virtual Worlds - Virtual Institutions. We deem this technology suitable for our purposes and later present the necessary background on Virtual Institutions.

In the next section, we look into appropriate techniques and conceptualizations for building Virtual Worlds suitable for educational purposes. In particular, we will focus on the view of designing Virtual Worlds as an open mulitagent system.

## 2.4 Virtual Institutions Technology

Virtual Institutions technology [Bog07] provides tools for the following purposes: formal specification of institutional rules, verification of their correctness, mapping those to a given virtual world and enforcing the institutional rules on all participants (both humans and autonomous agents) at deployment, thus creating a *regulated virtual world*. These regulations are specified in such a way that permits the participants to behave autonomously and decide independently within the limits imposed by the system.

Virtual Institutions technology(VI) has been implemented by taking a system-oriented view rather then considering the details of single participants. An important assumption was that participants can be heterogenous and self interested. Therefore, VI technology enables a system design where all the participants have to comply with institutional regulations. The specification is expressed through three types of conventions and their corresponding dimensions [Est03b]:

**Conventions on language – Dialogical Framework:** This helps to determine the language, ontology and illocutions particle an agent should use and also helps to define the roles they are supposed to play within the virtual institution. This prior definition of participants' roles helps to deal with the uncertain environment. As Virtual Institutions is based on an open system, cannot be predicted beforehand that who is going to participate and what kind of roles these participants perform. These roles help to define the organizational structure for the society of agents, and decide which relationships will exist between the agents and which roles agents can perform in the world.

There could be two types of agents in the society: internal agents and external agents. Internal agents(permanent residents of the institution) can play internal roles that represent the institution. These roles can only be played by internal agents; external agents(visitors of the institution) are supposed to play external roles only.

**Conventions on activities – Performative Structure:** This establishes the different interaction protocols (scenes) the agents can engage in, and the role flow policy among them. A scene is a logically independent activity that can be enacted by a group of agents. In Virtual Institutions each scene often corresponds to a particular space in the virtual world. For any specific scene, agents can only join and leave at certain points of the activity, for example, a fisherman agent can only join fishing after the owner of the boat for fishing activity as shown in Figure 2.6(b). These entry and exit points for scenes are specified with the help of a finite-state machine. The scenes of the institution help to define valid interactions among the participants.

Evolving from one point to another is based on the activity agents are supposed to perform which is shown as labels on arcs in a finite-state machine.

All of these separate scenes are then interconnected to form a network which represents the sequence of activities and inter dependencies and connects the various spaces in Virtual Worlds. Transit of agents from one scene to another is supported through a transition state depicted in Figure 2.6(a). This intermediate state also authenticates and re-routes the agents to/from the various scenes. Authentication protocols for participants are implemented through synchronization mechanisms inside transitions.

**Conventions on behaviour – Norms:** The institution provides a mechanism to restrict the agents' actions within scenes. These norms in the agent society help to restrict agent actions for scene movement and communications. The mechanism captures the consequences of agents' actions within the institution (modelled as commitments and obligations) and restricts the future actions of the agent.

Thus, Virtual Institutions technology helps us define the interaction protocol for all the specified scenes, relationships and role flows among the participants and norms of the society. An example of specifying the aforementioned dimensions is shown in Figure 2.6.

At deployment, the specification is connected to the virtual world (or respective area, i.e. an island in Second Life) and the state of the virtual world is mapped onto the state of the institution. Having the institutional formalization aligned with the virtual world drives the decision making of virtual agents controlling the avatars. Each agent has access to the institutional formalization and can sense the change of the institutional state and reason about the actions (both its own actions and actions performed by other participants) that resulted in the state change [Bog07]. So, for an agent there is no difference if it interacts with an agent or a human, as the result of the other party's actions can be sensed through the normative platform and interpreted on a high level via the specification.

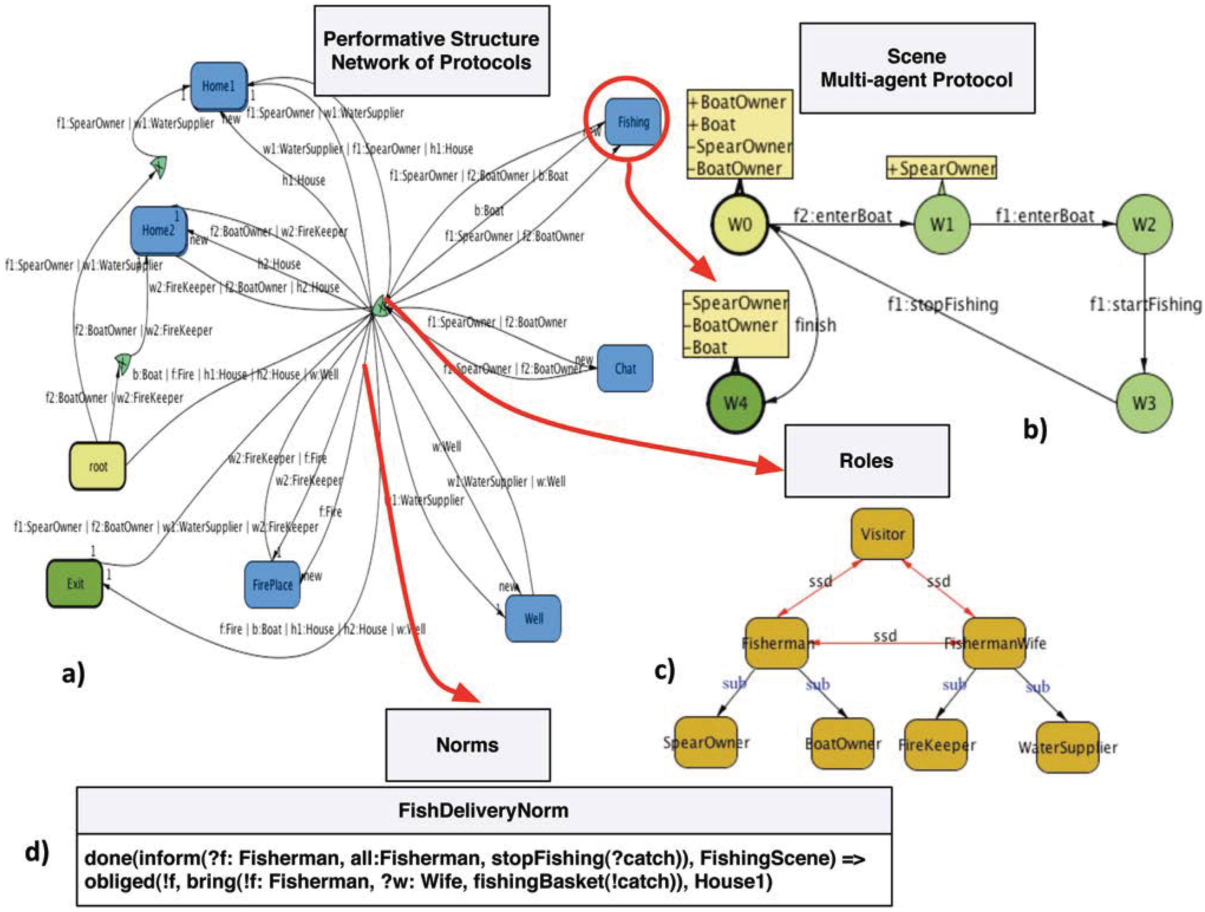



Figure 2.6: The Key Components of Virtual Institutions Specifications

### 2.4.1 Virtual Agents

As mentioned earlier, Virtual Institutions are not only capable of providing virtual designs of physical world spaces but also focus on interactions among the participants. Virtual representation of participants(avatars) plays an important role to stage these interactions. These avatars in Virtual Worlds not only represent human participants but can also provide the embodied representation to autonomous agents. Virtual agents are represented as graphical characters (avatars) that may or may not resemble the human body. It is not always the goal of these agents to act in a human-like manner, but to act "believably" given the representation they have. Thus, while evaluating the success of such agents many researchers nowadays evaluate their believability rather than their intelligence or human-likeness. Formally virtual agents are defined as [BBB00]:

**Definition:** ***Virtual Agents*** *are "Computer interfaces that come in a variety of guises and that present and process information according to a set of predefined algorithms. Agents may be designed to appear more anthropomorphic by fitting them with distinctly human-like (virtual) features such as voice recognition, synthesized voices, and computer animation that simulates human facial expression and gestures* [BBB00].

In Virtual Worlds, these virtual agents have the ability to interact and converse with other participants. The type of agents which can engage with other participants in textual conversations and can communicate are known as *conversational agents*. Designing educational Virtual Worlds following the Virtual Institutions metaphor facilitates the integration of believable virtual agents. Next we introduce the concept of virtual agents and show how to supply them with conversational ability.

## 2.5 Aspects of Believability in Conversations

Designing virtual agents which are able to converse and interact with humans in virtual environments require to have believable conversations. Considering a scenario where human visitors are enquiring about the environment/agents in which they are present themselves demands highly authentic and believable responses from embodied conversational agents. In next few sections, we will explore this conversational aspect of virtual agents to have more believable interactions.

### 2.5.1 Conversational Agents

The term conversational agent describes a software entity with computational linguistic ability to interact with the users in ordinary natural language or through some speech recognition system. Conversational agents have been used to simulate human conversation to interact with users. The architecture of conversational agents has two main parts: the natural language module and a computational algorithm to generate the informative dialogue between the conversational agent and the user as explained by [SA07].

The history of conversational systems dates back to the late sixties when these systems were first built to engage users in conversations for various purposes, one such example is ELIZA [Wei66]. ELIZA was simulated as a client-centered psychotherapist to converse with patients. The whole idea was simply to engage users and was based on keyword matching. With the growth in computer graphics and natural language interfaces, conversational systems entered new directions with many new architectures like MegaHAL [Hut97], CONVERSE [CBL97], ELIZABETH [SE02] AND ALICE [Wal03].

ALICE(Artificial Intelligence Foundation 2007) is the most widely used conversational system and this project uses it to provide conversational ability for the participants. ALICE is an acronym for Artificial Linguistic Internet Computer Entity, initially developed in 1995 by Wallace. Now it belongs to the open-source Alicebot community to further improve and provide people with a pattern matching based conversational system. Conversational knowledge in the English Language of Alice is encoded in AIML (Artificial Intelligence Markup Language) files extended from XML(eXtensible Markup Language). AIML poses data objects which act as basic units of knowledge, these AIML objects have two main parts known as *Topic* and *Category*. Topic is an optional element to keep track of the conversation's main topic, whereas, category parallels to a rule ad that rule contain both user input and output. Categories are further divided into *Pattern*, to match the user's current input, and *Template*, which is responsible for generating an ALICE chatbot answer as given below:

```
<category>
<pattern>ARE YOU CHATTING WITH ME?</pattern>
<template>Yes, you have my full attention!</template>
</category>
```

In contrast to simple chatbots, conversational agents not only engage in conversations but they also have a rich personalty through body movements and actions. [Mat97] and [Doy02] have explained that conversational agents, unlike chatbots have the goal of interaction but do not try to fool humans. Another important variation is that chatbots have no goals, behaviours or states whereas conversational agents act according to their motivational goals, behaviours and states.

By exploiting natural language technologies, these conversational agents are now used to engage users in various task oriented and information searching applications. Conversational agents are capable of supporting a broad range of applications in business enterprises, education, government, healthcare, and entertainment [LBM04]. These conversational agents were initially used to assist in customer focussed online enterprise applications which include:

- Customer Service: To respond to customers with general queries about products and services offered by the company
- Help Desk: As a first point of contact to resolve technical issues of employees

- Website Navigation: Guiding customers to navigate web sites

- Guided Selling: Assisting customers for different products in sales processes

Moreover, in recent years conversational agents have also been used for education, health-care applications as well as to entertain the user. In the following section, we discuss recent developments in conversational agents research in 3D Virtual Worlds.

### 2.5.2 Conversational Agents in Virtual Worlds

In a variety of 2D web based applications, conversational agents play many roles including guides, sales representatives, teammates and companions. Advanced graphics technology available now has shifted the focus of conversational agents research and now these agents perform many roles in 3D Virtual Worlds, video games and various other stand alone applications.

Effective deployment of these embodied agents in dynamic environments such as Virtual Worlds still has many challenges. [VHO] has discussed several challenges faced by conversational agents research to deploy them in Virtual Worlds. As conversational agents is a multi disciplinary research area, Authors in [VHO] have addressed challenges from different perspectives, including:

- Cognitive Research: the challenge is to provide coordination and management of various information channels with conversations inside virtual space in a believable manner.

- Computing Science: the challenge lies in providing the appropriate conversational ability, use of nonverbal communication, effective animation to represent agents' states, believability.

- Learning Technologies: the major challenge is to utilize the maximum capabilities of conversational agents in Virtual Worlds to achieve the desired learning goals.
- Engineering Research: this has focussed on providing effective and functional agents and controlled associated costs to provide student access.

Despite the challenges, conversational agents can provide several benefits in 3D virtual spaces including dynamic interactions, user engagement and motivation, enhanced flow of communication and can assist in different tasks at hand. We will further investigate the usability and challenges of conversational agents specifically in the education domain.

### 2.5.3 Conversational Agents in Education

Conversational agents in education can be categorized based upon their role in the learning process. [Lan09] discussed two types of educational agents which could act either as pedagogical/teaching agents or personal assistants. Assistant agents have been used to help with completion of specific tasks in some training environments. On the other hand, pedagogical agents are more complex and require natural language communication to deliver the knowledge. These agents can be authoritative in nature like a teacher or friendly as a peer in the learning environment [Lan09].

AutoTutor (automated tutor) was designed to be an animated pedagogical agent to help college students as a simulation of human tutors. It incorporates several tutoring strategies [AK99]. Autotutor presents challenging questions to computer literacy and physics students and engages them in interactive dialogues. During conversations with students, this animated agent uses facial expressions and gestures to create a natural and engaging learning environment. These con-

versational agents were generally presented as simple text based or as animated characters. In the last few years, embodied conversational agents have been proposed for education and training which can use emotions, gestures and can use text to speech synthesis. A model was presented by [Dos04] to build such a pedagogical embodied conversational agent that acts as a virtual reality instructor to autonomously train a human in virtual environments.
Another example of a pedagogical agent is Steve, demonstrated by [JR97], which lives in a virtual environment with other agents and students. Steve has been deployed in a virtual environment to help students learn about the physical and procedural tasks in naval ships. Steve can both instruct and help students in completing the assigned tasks. Steve can also participate as a team member for team training. This virtual reality environment can widen the types of interaction among the students and tutoring systems as compared to simple text based tutoring simulations as shown in Figure 2.7. The use of nonverbal feedback like gaze, pointing and facial expressions have allowed Steve to carry more natural tutorial interactions [JR97].

A similar attempt to use chatbots for Distance Education in Secondlife was conducted by [HPM05]. Freudbot was programmed to chat as a first person about the theories, concepts and biographical events of a famous psychologist Sigmund Freud. A representation of Dr.Freud chatbot in SecondLife environment is presented in Figure 2.8.

This transition of conversational agents from text based to interactive characters brought a new concept of natural interaction and believability to the learning environments. The concept of believability and the characteristics of believable agents is presented in the next section.

The majority of research on embodied conversational agents is focused on self-contained agent reasoning and actions, whereas their external environment is

Figure 2.7: Steve Agent in Virtual Ship while demonstrating a task

mostly ignored. We argue that believability of embodied conversational agents is tightly connected with their ability to understand their environment. In this work we amplify the importance of understanding an agent's surroundings and present a technique for supplying virtual agents with the ability to reason about their environment, to understand the interaction capabilities of other participants, their own goals and the current state of the environment, as well as to participate in conversations while referring to these elements. We hypothesize that such abilities will improve the overall believability of virtual agents and present the results of the user study confirming this hypothesis. Mostly due to historical reasons, the field of Embodied Artificial Intelligence (Embodied AI) is currently being dominated by robotics. Researchers in the field of robotics are faced with a number of difficult problems related to agent perception. Apparently simple tasks, like identifying the type of an object or recognising an already known object under different lighting conditions represent a significant challenge for modern robots. Perception and cognition are so tightly connected that without

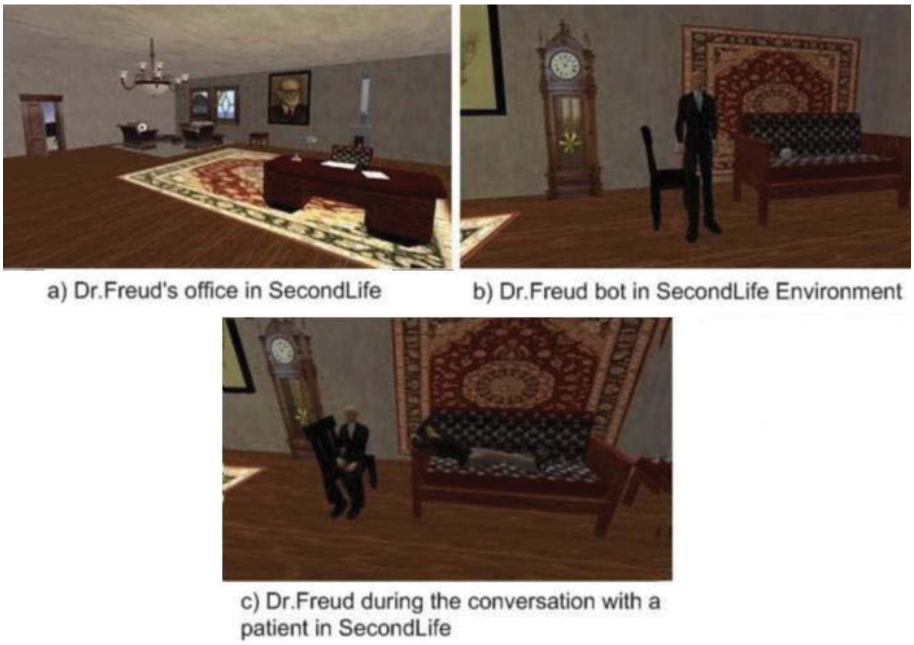



Figure 2.8: Freud Bot in SecondLife

solving the perception problem it is extremely difficult to advance in the area of cognition. This very fact, in our opinion, is responsible for the lack of success in embodied AI in its attempt to develop better techniques for agent cognition and reasoning about the environment.

On the other end of the embodied AI spectrum are virtual agents, for which the perception problem appears to be rather trivial. The contrast between robotic agents and virtual agents is best illustrated by the Robocup challenge [Fre08]. Enormous efforts and costs are put into accomplishing the goal of developing a robot soccer team that could beat a human team in 2050. In contrast to robotics, in virtual environments of many computer games we are long past this stage. It doesn't come as a surprise to a modern gamer that the team he controls can lose to a team controlled by a computer.

The key advantage of virtual agents over robots is that these agents are situated in a rather limited computer simulated environment that is much easier for an agent to understand and control [Mat97]. Therefore, it is believed that virtual agents have the potential to advance the state of embodied AI research [Liv06a] due to the fact that the perception problem in such environments is minimised. Each agent can operate with precise coordinates of other participants and objects in the environment, request their names, properties, distances to them and operate with a number of their own parameters (i.e. eye direction, body rotation etc.) to determine visibility of the objects, predict the movement of other actors and identify the target of their attention. Furthermore, in Virtual Worlds like Second Life it is even possible to supply agents with information about the elements constituting a particular object as each of the objects there is composed of a number of primitives. Having such information provides a very powerful toolkit for developing a sophisticated agent reasoning apparatus, an apparatus that is not anywhere in sight for modern robotic agents.

Having both humans and autonomous agents fully embodied into and constrained by the same computer-simulated environment provides fantastic opportunities for embodied AI researchers to study human behaviour, investigate cognition related aspects (while the robots are catching up on perception) and search for more practical application domains for the discipline. A literature review shows that the majority of virtual agents are not fully integrated with their environment. Most of the existing research in the area is focused on an agent's conversational abilities, use of gestures and emotions, while ignoring the objects in its environment, its own state in relation to the environment and the interactions of other participants with the environment. The lack of such abilities, in our view, defeats the key advantage of virtual agents over robotics and slows down overall advancement of the field. In Section 2.6 we explain what we mean about believability in virtual agents, define believability features, outline the state of the art in this area and identify the elements that haven't received appropriate research attention. Recent literature suggests the aforementioned characteristics are critical if we have to achieve believable agents. This concept of believability is discussed in the next sections.

## 2.6 Believability

The notion of believability has deep roots coming from the field of animation and theater [Mat97]. A believable character can be defined as lifelike in its behaviours, one whose actions appear to be real, who engages its audience and makes itself to be perceived as human like. Animation artists at Walt Disney Studio are among those who have tried to create their characters as believable. A classical work on these animated characters' "illusion of life" has been written by [TJ81] at Disney Studio, which elaborates the requirements for believability. Though, these characters are not real,they manage to impact the audiences' imagination to accept them as believable. Believability and realism have been differentiated by [Mat97] and [Doy02](p.342). According to these authors, a believable character by definition does not necessarily attempt to be a real character or one who tells the truth. Rather it is an art of representing a character as real in the context of its environment. However, it has been noted that believability as a generalized term is hard to define.

Artificial Intelligence (AI) researchers have borrowed the term "believability" from believable animated characters to create engaging life-like systems. Reactivity, interactivity and appropriate decision making while observing behaviours are a few characteristics which make autonomous agents suitable for achieving believability [RS06]. The active participation of the audience in the same 3D environment as the autonomous agents is another challenge to maintain the concept of believability, in contrast to which movies which only allow us to passively witness it. This interactivity requires the handling of different dynamic behaviours of human users; whereas in animations these behaviours are pre scripted. Believability is also a main requirement of modern computer games. As suggested by [Liv06a], "the need for modern computer games is not unbeatable AI, but believable AI".

Comparison of traditional believable characters in animations with believable interactive characters in AI shows that AI characters require something extra to create the illusion of life. As [Mat97] pointed out, AI interactive characters require various capabilities including achieving multiple goals and actions, realistic movements, perceiving the environment, memory, communication and reactiveness; which are all vital to make them believable. By contrast, animated characters have always been provided with such abilities. All the above mentioned requirements make it more complex to create believable interactive AI agents.

Earlier research in believability has been heavily influenced by the Carnegie-Mellon set of requirements for believable agents, which is based on research in drama and story telling [Loy97a]. These include personality, self-motivation, change, social relationships, and "illusion of life". Personality infuses everything that a character does - their behaviour, style, "thought", "emotion", e.g. their unique ways of doing things. Self-motivation assumes that agents have their own internal drives and desires which they pursue whether or not others are interacting with them, and they demonstrate their motivation. Change implies that characters change with time, in a manner consistent with their personality. Behaviour of agents and interactions between them should be in a manner consistent with their social relationships. "Illusion of life" is used as a label for a collection of features such as [Loy97a]: pursuing multiple, simultaneous goals and actions, having elements of broad capabilities (e.g. movement, perception, memory, language), and reacting quickly to stimuli in the environment. In this sense believable does not necessarily mean realistic.

The of characteristics emphasized by [Loy97b] were: responsiveness (reactive to new situations in environment), multiple independent actions (multiple actions and goals pursued at the same time), multiple connected actions (two inter-related actions), understanding incomplete information to the best of its knowledge and consistent behaviours. Two main forces to produce believability are visual qualities to represent it and dynamic behaviour generation as a result of its interaction with the user [JRL00]. Criteria for believability as [JRL00] pointed out are: Situated Liveness (awareness of the environment), Controlled Visual Impact (balancing movement behaviours), Complex Behaviour Patterns (simple behaviours reduces the believability) and Natural Unobtrusive Behaviour(e.g natural blink).

The existing literature suggests that believable facial expressions, believable gestures,believable conversations and believable gaze are also important characteristics to present the believable agent as life-like. A detailed description of these factors is given below:

### 2.6.1 Believable Conversations.

Believable conversation is a term often associated with "chatbots" or "chatterbots". These chatbots are software programs which try to make a textual or auditory intelligent conversation with a human user believable. Initially, they were used to simulate typed conversation but now they have roles as assistants to various commercial applications, games and web based applications. Chatbots like Eliza [Wei66] and ALICE [Wal03] are based on natural language processing.

Technically, they use pattern matching algorithms and parse the user input to provide the most suitable answer from their 'knowledge base'. Natural language processing and dynamic sentence generation make the human user believe in the chatbot's conversation and judge it as intelligent behaviour. According to [GT07], chatbots do not require a deep understanding of the conversation and are mainly based on: keyword pointing, pattern matching and corpus based text retrieval.

Now chatbots are in use to meet the challenge introduced by Alan Turing (1950). Turing's test originally involved three participants; where the interrogator has a role to differentiate between a machine (currently replaced by chatbots) and a man. Annual competitions such as the Leobner Prize and Chatterbox challenges are popular among researchers, though no program has managed to fool the interrogator as to perceive it human. Despite the technological advancements, no chatbot has yet pass the Turing test [Liv06a].
We can differentiate a chatbot from a believable conversational agent in several different ways. The basic purpose of chatbots is just to have some open ended conversation in natural language. They are not mainly concerned with body movements, behaviours and goals. Initially, these chatbots were designed to pass the Turing test to some extent. In contrast, believable conversational agents have personality, believable movements and they interact not only through natural language. [Mat97] pointed that most of the chatterbots do not have long term motivational structures or goals which drive their conversation. In the next few sections, we will have present a detailed review of such characteristics which help us to distinguish between both entities.

### 2.6.2 Believable Facial Expressions.

A believable conversation is conveyed through multiple channels, one of them is appropriate facial expressions. The meaning of the whole conversation is not properly communicated if someone is not able to relate the words with facial expressions of the other person. [CKW05] claimed that facial expressions alone can express very complex ideas like emotions related to happiness and sadness. These emotional expressions have cross cultural boundaries, but a fair amount of existing work deals with a list of 'universal emotion expressions': {happy, sad, fear, anger, disgust, contempt and surprise} presented by [Ekm72].

Facial expressions have been widely studied among computer vision and computer graphics communities which has led to the development of complex algorithms for automatic analysis of facial expressions. A comprehensive survey of these techniques has been presented by [PR00]. This study discussed the existing work in detection of facial expressions, identifying face in an image segment and making a classification of those expressions. It has been further noted that most of the existing work deals with specific cases of image and video analysis [PR00].

To achieve accurate and realistic conversation, lip and tongue movement during speech production is vital for the right expressions. Misunderstood facial expressions during conversation and correctly recognized but wrongly perceived expressions are a couple of critical issues pointed out by [CKW05]. He also observed that even duplication of facial expressions in a Virtual Human with perfect temporal and spatial aspects of the facial motion could not guarantee the believability of facial expression.

### 2.6.3 Believable Gestures/Upper Limb Movements.

In our daily interactions we not only communicate by words but we also use body language. Gestures are one of those factors in non-verbal communication which allow us to interact in a lively manner. Gesture selection and the right manner of its execution may increase the expressivity of the conversation [HMP05]. Believable gestures are related to good gesture selection aligned with current conversation; and believability also depends upon generation of realistic movements of an agent's upper limbs during the conversation. Most of the existing work in believable gestures falls into these two above mentioned categories [HMP05].

Existing work to generate believable gesture animations is usually based on inverse kinematics methods [GKP04]. In their study; [GKP04] analyzed motor control theories and showed that various features can generate movement trajectories in human gestures. Other gesture animation techniques allow a change in existing body position to have an expressive gesture.

A computational model to measure gesture quality was presented by [HMP05]. They focussed on six parameters to capture gesture quality and these include: Agent's Activation (Passive/static), Spatial Extent (Space taken during the agent's body movement), Temporal Extent (time duration of movements), Fluidity (Jerky versus stable movements), Power (e.g. strong movement) and Repetition (repeating specific movement). A combination of these parameters in such a way to as represent communicative intent in an agent can improve the believability of the agent claimed by [HMP05].

### 2.6.4 Believable Locomotion.

Believable locomotion is critical to make agents believable and life-like. To make locomotion believable; the agent needs to reach a target position from its current position by avoiding obstacles intelligently. It also needs to account for other factors like believable body posture, movement speed, interaction with other entities in the environment.

To produce believable motion in virtual characters; [Gra00] developed a model based on inverse kinematics which generates a set of believable stylistic and functional motions. Stylistic motions are specific to the personality of a character whereas functional motion deals with moving on a specific path way, stepping away from/over obstacles. He has also pointed towards interaction among characters and coordination of sub actions which comprise the final action.

Variation in movement is vital to believability of a character [Tha07]; as realistic individuals do not continue with the same movement cycle to reach a target position. Primary locomotion does not require these upper limbs movements but accessory movements (holding some object in hand) assist in improving overall believability of the character [Tha07].

### 2.6.5 Believable Gaze.

Gaze is one of the most important features which not only regulates interactions but is also used to express emotions, personality and moods to build agents that are believable, engaging and life-like. During interactions, gaze helps to synchronize the conversation and to convey the internal cognitive process of the participant. [LMT07] presented a gaze model which is based on cognitive operations to generate behaviours that reflect the inner thought process of the agent. To build believable virtual humans, it incorporates both task related behaviours (investigating the task on hand) and attention capturing behaviours (paying attention to unexpected change in the environment). This model produced a wide range of believable behaviours for various types of gaze avert (e.g hold the current turn), brief look, focus or weak-focus, at the target with specific speed, priority and reason.

The existing literature presents various gaze models and implementations of related behaviours for virtual agents. [HEN05] simulated gaze behaviours such as avert, examining the current task and gaze at visitors to build believable conversational agent. They measured the believability of the agent based on factors like satisfaction, engaging, natural eye, head movements and mental load among others; and this study showed significant improvements in communication between human and virtual agent.

To generate a believable gaze shift that can express user's desired emotional state [TLM09] investigated a hybrid approach that combines two of the previous techniques: Gaze Warping Transformation (GWT) and Expressive Gaze Model (EGM). This model claimed to provide believable and expressive gaze behaviours by combining head posture, torso posture and movement velocity of these body parts with gaze shift.

After studying these believability features; in the next section, we will discuss the research problem this project want to investigate and the related research questions which would set the bases for our research. Although, current literature outline these believability features for believable characters/agents, there exists no formal definition of believability and its features in existing work. In the next chapter, we made an attempt to formally define believability for believable virtual agents in Virtual Worlds and also formalize its existing features as well as incorporate missing features we have found through the literature review.

## 2.7 Summary

This chapter has introduced the concept of Virtual Worlds, embodied conversational agents as well as all the related terms and technologies. At present, mostly Virtual Worlds are implemented as unregulated environments which provide unstructured interactions for its participants. In our prototype, this guarantee has been provided via a formal methodology named Virtual Institutions [Bog07] as outlined in this chapter. This technology helped us to develop Virtual Worlds as multi-agent systems and to further regulate participants' interactions in Virtual Worlds.

One of the problems arising due to direct inclusion of human participants and their interactions with virtual agents is believability in such interactions.

This chapter has also presented the concept of believability and its associated features as discussed in the literature. Believability of embodied virtual agents and their interactions with other agent/human participants in virtual worlds is not well investigated in the literature. In the next chapter, we present the concept of believability for embodied conversational agents in Virtual Worlds, where our focus is the role of awareness believability and its implementation in our particular case study.

After reviewing believability and studying virtual agents, we found that believability is critical to provide engaging experiences in Virtual Worlds. All the aforementioned believability features play an important role to develop believable virtual agents but we also figured that virtual agents should have believable interactions with other participants. To have these believable interactions in addition to the given features in the literature, virtual agents should also be aware of their surroundings, interactions and their own self including beliefs, goals etc. In the next chapter, we will illustrate our case for these awareness features and their impact on virtual agents' believability.

# CHAPTER 3

# Believable Conversational Agents for Education

In the physical world for entertainment purposes, we see various characters in movies, animated films and other similar sources. These characters often continue to suspend viewers' disbelief in them. For instance, popular characters like Bugs Bunny and Mickey Mouse have impacted viewers' imagination for decades in such a way that the whole experience could be regarded as a real experience.

Believability is a that term first originated from animated characters like the one introduced by Disney Studio [TJ81]. As outlined in Chapter 2, these characters require a few features to be believable such as engaging personality, facial expressions, emotions and a believable gaze set. Similarly, embodied virtual agents in dynamic Virtual Worlds need these features, however those providing the reasoning and actions for these agents have mostly ignored the external environment. We label the ability of virtual agents to respond to the environment as *awareness believability* and a detailed discussion of its relevant features is given in the next few sections.

For an embodied agent to be considered believable in dynamic environments, learning plays an important role. It makes an agent adaptable to new changes in the environment and able to use newly acquired knowledge in its conversations with other agent/human participants. This chapter will introduce the need for learning new beliefs and roles for a virtual agent to provide believable interactions. In the next few sections, we begin with formalising the concept of believability and examining its existing features in the literature. We also outline the new features we identified and include them into the formalisation.

## 3.1 Exploring Believability Features

To identify the key elements that constitute the concept of believability we start with listing the key features of believable agents, specified in [Loy97b], as:

- Personality - A rich personality should infuse everything that a character does, from the way they talk and move to the way they think. What makes characters interesting are their unique ways of doing things. Personality is about the unique and specific, not the general.
- Emotion - Characters exhibit their own emotions and respond to emotions of others in personality-specific ways.
- Self-motivation - Characters don't just react to the activity of others. They have their own internal drives and desires which they pursue whether or not others are interacting with them.
- Change - Characters grow and change with time, in a manner consistent with their personality.
- Social relationships - Characters engage in detailed interactions with others in a manner consistent with their relationship. In turn, these relationships change as a result of the interaction.
- Consistency of expression - Every character or agent has many avenues of expression depending on the medium in which it is expressed, for example an actor has facial expressions and colour, body posture, movement, voice intonation, etc. To be believable at every moment, all of those avenues

must work together to convey the unified message that is appropriate for the personality, feelings, situation, thinking, and other behaviours of the character. Breaking this consistency causes the suspension of disbelief to be lost.

- Illusion of life - A collection of requirements such as: pursuing multiple, simultaneous goals and actions, having broad capabilities (i.e. movement, perception, memory, language), and reacting to environment stimuli.

The illusion of life feature is expanded by [Loy97b] in terms of: (i) Appearance of goals; (ii) Concurrent pursuit of goals and Parallel action; (iii) Reactive and Responsive; (iv) Situated; Resource bounded – Body and Mind; (v) Existing in a Social Context; (vi) Broadly Capable; (vii) Well integrated (Capabilities and Behaviours).

One of the problems that arises from the animation and theater origin of the majority of believability studies is that some features unique to autonomous agents operating in virtual environments are rarely considered. A further literature review helped us to identify some missing features. In the next section we will formally define believability based on a literature review as well as integrate the missing features we have identified for embodied conversational agents.

## 3.2 Formalising Believability

Summarising the existing features of believability and expanding the concept with our new findings we define a believable virtual agent as follows.

**Definition:** A *believable virtual agent* is an autonomous software agent situated in a *virtual environment* that is life-like in its behaviour, with a clearly defined personality and distinct emotional state, is driven by internal goals and beliefs, is consistent in its behaviour, is capable of interacting with its environment and other participants and can change its behaviour over time.

Consequently, believability is formalised as follows:

$$\beta =< P^T, E^S, L, SR, \Upsilon, \delta > \tag{3.1}$$

Here $\beta$ is the believability of a virtual agent, $P^T$ is the agent's personality, $E^S$ corresponds to the emotional state of the agent, $L$ corresponds to liveness, $SR$ - social relationship, $\Upsilon$ - the consistency constraints and $\delta$ - is the change function.

This believability formalisation ($\beta$) includes existing features to develop believable characters already discussed in the literature as well as missing features we want to investigate in this thesis. In the previous chapter, we outlined believability features such as virtual agent's personality, role of emotions, liveness and social relationships that a believable agent needs to be aware of in the current context. But believable conversational agents must be aware of themselves in relation to environmental objects, participants and also be aware of their own internal states to use this information intelligently in their conversations. Similarly a conversational agent needs to improve and change with time in a way consistent with its current personality. This thesis also emphasizes to having such features as $\Upsilon$ (consistency constraints) and $\delta$ (change function) to have believable conversational agents. Now, we will present the formalisation of existing as well as new believability features($\Upsilon$ and $\delta$) for embodied conversational agents.

### 3.2.1 Personality

While formalising the personality we consider the assumption of [EKM03] that a personality has $n$ dimensions, where each dimension is represented by a value in the interval $[0, 1]$. A value of 0 corresponds to an absence of the dimension in the personality; a value of 1 corresponds to a maximum presence of the dimension in the personality. The personality $p$ of an individual can be represented as:

$$P^T = [\alpha_1 \ldots \alpha_n], \forall i \in [1, n] : \alpha_i \in [0, 1] \tag{3.2}$$

### 3.2.2 Emotional State

Emotional state ($E^S$) is defined following [EKM03] as an m-dimensional vector, where all m emotion intensities are represented by a value in the interval [0,1]. A value of 0 corresponds to an absence of the emotion; 1 - is a maximum intensity of the emotion. This vector, given as

$$E^S = \begin{cases} [\beta_1 \ldots \beta_m], \forall i \in [1, m] : \beta_i \in [0, 1], \text{if t} > 0 \\ 0, \text{ if t} = 0 \end{cases} \tag{3.3}$$

is linked with the model of generating facial colour based on the theory of emotion-colour association adapted from [PK08].

### 3.2.3 Liveness

Liveness is an agent's ability to express the illusion of life. It incorporates the illusion of life features described in [Loy97b], plus verbal and non-verbal behaviour, as follows:

$$L =< V_b, NV_b, IL > \tag{3.4}$$

Here $V_b$ represents verbal behaviour and $NV_b$ stands for non-verbal behaviour, $IL$ is the illusion of life. Awareness is an essential part of human verbal behaviour.

In a conversation we are aware of where we are (environment awareness), who we are (self-awareness) and generally how the interaction is progressing (interaction awareness). Therefore, awareness is an essential component of the believability of embodied conversational behaviour, which we label as “awareness believability”. Further, we develop each of the subcomponents of awareness believability and will describe each of them in the next sections.

In contrast to emotional state and personality, the liveness aspect of believability has not been well studied. Some liveness aspects have been investigated by researchers, but we are not aware of any consistent study or an integrated solution that implements all aspects of liveness. Here we present our vision of how to develop agents that can exhibit liveness in a believable manner. Our implementation of Liveness ($L$) features is based on some basic functionalities of the Second Life technology and the adaptation of a number of contemporary AI techniques to distributed environments.

The most popular approach to verbal implementation is to utilise chatter bots like [Wal04] for mapping possible user questions to the replies of the agent. Text-to-speech engines are normally used for translating the resulting text response into voice. In our system we rely on a similar approach, however, what is normally missing in traditional approaches is the consistent integration of an agent’s environment into verbal communication with users. We rely on a model of environment-, self- and interaction-awareness, a detailed description of which is presented later in this chapter. The verbal behaviour of our virtual agents is currently limited to exchanging text messages with other agents and text chats with humans. For textual conversations with humans, agents employ the ALICE chat engine [Wal03] based on the AIML language.

For producing the formalisation of illusion of life we adapt Loyall’s [Loy97b] specification of “illusion of life”, uniting “situatedness” and “integration” into the concept of agents' immersion in virtual worlds:

$$IL =< Immersion, Goals, Reactivity, Proactiveness, Concurrency, \\ ResourceLimitation, SocialContext, BroadCapability > \tag{3.5}$$

### 3.2.4 Social Relationships

For social relationships we borrow the formalisation widely used in organisational theory [Est03a]. A social relationship between agents is considered to be the relationship between the social roles they play and is represented by function $f_{SR}$ assigning a numeric value to the social relationship between two social roles.

$$\forall Role_i, Role_k, \exists f_{SR} : Role_i \times Role_k \rightarrow \mathbb{N} \tag{3.6}$$

### 3.2.5 Consistency

Consistency across the personality of an agent and other believability characteristics is ensured in our formalisation by the set of consistency constraints ($\Upsilon$). We formalise those constraints as a penalty function that is 0, if the emotional state of the agent and liveness features are inconsistent with the agent's personality and 1 otherwise.

$$\Upsilon : P^T \times L \times E^S \rightarrow \begin{cases} 1 - \text{if consistent} \\ 0 - \text{if inconsistent} \end{cases} \tag{3.7}$$

These constraints must ensure the consistency of the agent behaviour over the entire range of its believability features:

$$\forall p_j \in P^T, \forall l_h \in L, \forall e_g \in E^S : \Upsilon(p_j, l_h, e_g) = 1 \tag{3.8}$$

To develop believable conversational agents for educational purposes, these agents must be aware of their environment of any interactions with other environmental objects and other participants; and also be aware of their own plans and motivations in the current role. But conversational agents should use these features in a way consistent with the agents' personality, liveness and their internal emotional state. We will discuss these features and their impact on conversational agents' believability in future sections.

$$\lambda : \{EA, IA, SA\} \tag{3.9}$$

### 3.2.6 Change

Change ($\delta$) is a learning function that updates a believability instance given another instance and the environment state:

$$\delta : EnvState \times \beta_i \rightarrow \beta_i' \tag{3.10}$$

Change is a characteristic that enables characters to grow and change with time, in a manner consistent with their personality. This work supports change ($\delta$) by creating a method for training the virtual agents to perform different verbal behaviours in various situations. Virtual agents are made capable of learning new facts over time from the subject matter experts. This method of learning was implemented by providing a communication layer based on AIML rules. In section 7.1.6, we will illustrate the method of modifying the AIML rules via learning.

## 3.3 Consistency and Change

In believability formalisation, we demonstrate the role of an agent's consistency across its personality and other believability features in the current context and also emphasize the importance of an agent's ability to update its internal beliefs(change) in a manner consistent with the current environment. Therefore, in the next section we will illustrate the role of learning and awareness believability for conversational agents to maintain their consistent behaviour in a learning domain.

### 3.3.1 Awareness Believability for Embodied Conversational Agents

A embodied conversational agent requires to be aware of its current environment, its interactions with other participants and its own internal states, beliefs and motivations. To illustrate the importance of integrating such features into agent conversations consider a scenario outlined in Figure 3.1. Here a human user learns in a Virtual World about the history and culture of the ancient city of Uruk [Bog11] through controlling an avatar of Fisherman Andel. There is a clear task he has to accomplish (catch some fish) and this task involves interacting with virtual agents representing ancient citizens of Uruk. As shown in the figure, the human is not clear about how to progress toward the assigned task and asks the agent (Fisherman Jigsaw) about his options. To be able to reply in a similar manner as shown in the picture, the agent must know its interaction state, its location in the environment in relation to other objects and avatars, its own goals and beliefs and the interaction capabilities of the user. We have formalised this awareness believability as a consistency constraint ($\lambda$), where a conversational agent must be able to use these awareness features in a totally consistent manner with the agent's personality, liveness and motivational state.

Figure 3.1: Scenario: A conversation between two Fishermen.

In 3D Virtual Worlds the integration of agents and environment in terms of agent reasoning is a feasible task due to the fact that the perception problem in such environments is minimized. Each agent can operate within the precise coordinates of other participants and objects in the environment, request their names, properties, distances to them and operate with a number of its own parameters (i.e. eye direction, body rotation etc.) to determine the visibility of the objects, predict the movement of other actors and identify the target of their attention. Furthermore, in virtual worlds like Second Life (http://www.secondlife.com) it is even possible to supply agents with information about the elements constituting a particular object, as each of these objects is composed of a number of primitives. We envision that developing such mechanisms to utilize this information provides a very powerful toolkit for a sophisticated agent reasoning apparatus that significantly increases the believability of agent behavior and its capacity to engage humans.

To make agents environment aware, we suggest that supplying virtual agents with an ability to reason about the objects in their environment, their own state, goals and beliefs as well as the interactions of other participants would result in more believable virtual agents, which can be used in a much wider range of problems than at present. The remainder of the chapter is structured as follows.

In the next sections 3.3.1.1, 3.3.1.2 and 3.3.1.3, we discuss and formalize the awareness believability features that have not received appropriate research attention. Finally, Section 7.1.6 illustrates the concept of learning for embodied conversational agents to enable them to grow and improve with time.

#### 3.3.1.1 Environment Awareness

The importance of environment awareness for agent reasoning is best illustrated in [Elp10], where it is suggested that our consciousness does not arise from the brain alone but from the brain's exchange with its environment. Humans are embodied in space and use various cues related to space, like pointing and referring to areas of interest and things in it, in everything they do (for more details see Chapters 1,2 in [ON78]). The existing literature presents a very limited picture of the use of environment awareness by animated agents. Agents like Cosmo [LVT99b] and Steve [JL00] are able to recognize and point to objects in a particular static environment but fail to use this interaction information with other participants, do not operate in a dynamic environment and can not orient themselves in a different environment. We suggest that awareness of environment objects alone would not be enough to achieve complete believability and virtual agents further require to be aware of other participants in the context of time.

We regulate the key features of environment awareness as including the position of objects and avatars in the environment, how these evolve with time and the direction vectors associated with avatars [GMH04]. We formalize environmental awareness as follows:

$$EA = \{Objects, Avatars, Time\} \tag{3.11}$$

Here $EA$ is the set of components of environment awareness and includes objects in the environment, other avatars representing agents and human participants with respect to the current time.

#### 3.3.1.2 Self Awareness

Knowing its own context and state within the environment, i.e. being self aware, is essential for a virtual agent to interact believably [Doy02]. To achieve that Doyle in [Doy02] proposed to annotate the environment and grant agents access to this annotation. One of the most studied features of self-awareness for virtual agents and animated characters is social role awareness [PI01]. However, self-awareness is a much richer concept and many of its characteristics remain understudied, in particular existing works mostly have ignored many vital characteristics that arise in dynamic environments.

Hallowell defines self-awareness [Hal55] as the recognition of one's self as an object in the world of objects and highlights the importance of perception as the key function in self-awareness. The list of elements we have identified to enable self-awareness is as follows:

$$SA = \{G, P, B, Sc, St, ObjectsUsed, Role, Gestures\} \tag{3.12}$$

Here $SA$ represents the set of components of self-awareness and which consists of the local goals of the agent ($G$), its current plans ($P$) and beliefs ($B$), current scene where the agent participates ($Sc$), its state within this scene ($St$), objects used by the agent ($ObjectsUsed$), the role it plays ($Role$) and the gestures being executed ($Gestures$).

#### 3.3.1.3 Interaction Awareness

The believability of interactions goes beyond the traditional focus on modeling the visual co-presence [GMH05], context awareness (perceiving other agents/objects in the static environment) [BMB07] and communication style (e.g. short vs long utterances, usage of specific vocabulary) of the agents. Human behaviour in interactions results from a mix of being rational, informed, impulsive, and the ability to influence others and cope with influences from others. All these nuances impact the richness of human interactions, hence, must be taken into account when considering the believability of interactions between virtual agents and humans.

Thus, having interaction-awareness involves an agent being "able to perceive important structural and/or dynamic aspects of an interaction that it observes or that it is itself engaged in" [DOQ03]. The components of the interaction-awareness model are outlined below.

$$IA = \{AV_{vis}, AV_{sc}, Actions, Objects, State, Pos, Or\} \tag{3.13}$$

Here IA represents the set of components included in our interaction awareness model. $AV_{vis}$ corresponds to the set of currently visible avatars. The $AV_{sc}$ is a set of all avatars within the scene where the agent participates in a given moment of time. $Actions$ represents the set of actions each of the agents in the current scene is able to perform given its state. $Objects$ refers to the list of objects the avatar can use. *State* is the state of the avatar in the world. *Pos* is the position of the agents in the virtual world and *Or* is agent's orientation vector in the virtual world space. In the next chapter we outline the implementation details of our approach.

### 3.3.2 Virtual Agents' Learning

Virtual Worlds based on Virtual Institutions technology presented in the previous chapter have two kinds of participants and support both human and agent involvement. The multi-agent approach provides a simple implementation of Virtual Worlds. This agent based methodology has additional benefits. Both agent and human participants in the Virtual Institutions based Virtual Worlds are given specified roles and they have to follow intuitional regulations. Ultimately, Virtual Institutions help us to provide a systematic approach to implement a society of human and agent participants in Virtual Worlds.

In addition to implementing awareness believability, virtual agents also require continuous learning of new facts to have believable interactions in dynamic Virtual Worlds. We have defined these agent's learning characteristics as a function "*Change (δ)*" that updates agents' knowledgebase with time, in a manner consistent with their personality. Virtual agents should be capable of learning new verbal behaviors over the time in a manner well integrated with their environment. All the aforementioned characteristics of believability are undoubtedly critical to develop believable virtual agents. On the other hand, these believability characteristics increase the complexity of developing believable virtual agents. Furthermore, the literature suggests that passing the *Turing test* is still not possible [Liv06b].

In this project, Virtual Institutions combined with Virtual Worlds give a common ground for agent and human participation. This technology further helps us to investigate new ways of collaboration and interaction between the two entities as explained in [Bog07]. A term coined for this collaboration by [Bog07] is known as *co-learning*. This concept of co-learning, on the one hand enables an agent to learn from human participants, on the other hand allows the agent to extend the knowledge of humans by presenting valuable information.

In Virtual Worlds, both agent and human participants are represented with *avatars*. Therefore, an avatar is either controlled by an human or an autonomous agent. An intermediate interface is used by both of these participants which translates the decision makers(human/agent) requests to/from institution's understandable language. This intermediate interface acts as a *communication layer* and it can support text based collaboration among the participants. Moreover, virtual agents use this layer to communicate believably with the help of the virtual Institutional layer and the underlying Virtual World.

Initially, we planned to provide implicit agent's learning, where an agent has to observe ongoing conversation between the subject matter experts and students(supposedly both human participants). During this silent interaction, the agent was expected to learn and correct its beliefs. Because of having students and experts in two different geographic locations with different time zones, it became practically impossible to organise both students and subject matter experts online at the same time. Thus, we opted for a more convenient option where subject matter experts could directly converse with agents and train them during interactions.

Let us consider a conversation between an *agent(King Imgursin)* and a subject matter expert*(Kiran Galaxy)* to get a clear picture of the learning protocol. During the conversation if *King Imgursin* does not understand or gives a wrong response, the subject matter expert is capable of correcting its beliefs as part of this conversation. When King Imgursin was asked: *"Do you know all the people*


Figure 3.2: A Training Session with Agent(King ImgurSin)

*in the city?"* as shown in Figure 3.2, the response given was completely irrelevant. Then the expert says *"I want to train you!"* to initiate the training mode. After verification, the human expert needs to refer back to the same question to update the AIML knowledge base for the given category. King Imgursin(Agent) confirms the update made to the current query in the end by saying *"Old Reply"* will be replaced with *"New Reply"*. Technically, with the help of the AIML engine the new response has been stored in AIML knowledge base as a new category. In future, if similar questions are asked then the agent *(King Imgursin)* should be able to respond with updated facts. A detailed implementation of agent's learning to maintain its believability is presented in the next chapter.

## 3.4 Summary

Multi-agent systems and Virtual Institutions based implementation for Virtual Worlds suggest that behind each avatar there are always two entities: an autonomous agent and a human. This presence of human and agent participants in such interactive environments raises the need for believable interactions. Our concerns of an agents' awareness of its own environment, interactions with other human and agent participants, its own beliefs, goals and actions are summed up as believability awareness. Formalision of a virtual agent's believability and its characteristics has been outlined in this chapter.

Another contribution of this chapter is to present the concept of virtual agents' learning. It is suggested that in dynamic environments such as Virtual Worlds, each agent participant should always have updated facts to be believable. Keeping in view our underlying domain of culture and history, virtual agents must always have updated facts to have believable interactions with human visitors. We opted for a learning method where a subject matter expert who used to teach relevant historical facts to virtual agents during their interactions.

In the next chapter, the concept of awareness believability and its corresponding implementation in Virtual Worlds will be presented. Furthermore, the next chapter will also illustrate the technical details of learning module implementation as part of the virtual agents'communication layer.

# CHAPTER 4

# Approach and Implementation

The previous chapter has introduced the concept of believability and formalisation of this concept. In this chapter we show how this formalisation can be used as a basis for implementation of believable virtual agents for teaching history and culture. We structure the existing work of our research group along the dimensions of the resulting believability formalism and show how the implementation techniques being used can be integrated into an $I^2B$(Interactive, Intelligent and Believable) framework. While we borrowed most of the techniques from previous works of our group, we have also identified some elements of believability that were not addressed in the past. In particular, this chapter investigates the conversational abilities and introduces the concept of awareness believability.

Thus, in Section 4.1, we outline the $I^2B$ framework that integrates the implementation techniques produced by our research group in the work on simulating the culture of Uruk [BRS10]. This framework unites those techniques following the dimensions of our believability formalism. Further, in Section 4.2 we identify awareness believability as a missing element of this framework. The remainder of the chapter focuses on the awareness believability for embodied conversational agents and extends over the $I^2B$ framework to integrate this feature while strictly following our believability formalism.

Another contribution of this chapter is addressing the "Change" element of the believability formalisation. We explain how this element relates to making agents capable of learning new behaviours. The particular focus of our work is on making them learn conversations by imitating human experts.

## 4.1 The $I^2B$ Framework

The formalisation discussed in the previous chapter can form the basis for a complete believability model of virtual agents operating in an interactive 3D environment. Further in this section, we show how each of the formalisation components has been developed by our research group using contemporary software engineering techniques [BRS10]. We outline those techniques by the example of the $I^2B$ (Interactive, Intelligent and Believable) technological solution, which supports the development of believable virtual agents for virtual worlds and game engines. The ambitious aim behind developing the $I^2B$ framework was to build a complete framework around our believability formalisation that features each and every single element of this formalisation. The target visualisation platform we chose for this framework is the virtual world of Second Life[1].

We outline the key features and implementation issues with an emphasis on those elements of believability developed by our research group that have not received appropriate attention in the past (e.g. illusion of life) [BRS10].

### 4.1.1 Personality and Emotional State

Creating agents capable of expressing rich personality and emotional state has been widely investigated in the past. The most common approach is to implement both personality ($P^T$) and emotional state ($E^S$) as arrays of variables, where each variable represents a personality feature or an emotional state feature correspondingly. The actual models are based on the extensive body of psy-

[1] http://secondlife.com

chology research on various personality features and emotional dimensions. For modeling an agent's personality in our framework we rely on the model proposed in [Nea97]. For modeling the emotional state we rely on the emotional model proposed in [Loy97b], where possible emotions are limited to 5 possible types: happiness, sadness, fear, gratitude, and anger [BRS10].

### 4.1.2 Liveness

In contrast to emotional state and personality, the liveness aspect of believability has not been well studied. Some liveness aspects have been investigated by researchers, but we are not aware of any consistent study or an integrated solution that implements all aspects of liveness. Here we present our vision of how to develop agents that can exhibit liveness in a believable manner.

Our implementation of Liveness ($L$) features is based on some functionalities of the Second Life technology and the adaptation of a number of contemporary AI techniques to distributed environments as detailed in [BRS10].

#### 4.1.2.1 Non-verbal Behaviour

Supplying agents with convincing non-verbal behaviour is another well-studied aspect of liveness. Depending on the context and personality of the agent and the supporting verbal behaviour, non-verbal behaviours ranging from sweating and tears to gestures and gaze can be produced on the fly. In our case we limit the implementation to gaze and gestures. Each agent is supplied with a list of possible gestures as mentioned by [BRS10]. Depending on the current emotional state an agent can select a certain gesture and play the corresponding animation. $I^2B$ agents are also supplied with a programming solution dealing with idle gaze behaviour. When the agents are moving around their gaze is not fixed, but changes using our attention based model. The agent can shift its gaze between objects and avatars depending on the level of its interest in those. It will predominantly follow the movements of avatars approaching the agent at close proximity. Our method for implementing gaze is based on the work of [LMT07].

### 4.1.3 Illusion of Life

To enable all of the elements from the illusion of life ($IL$) formalisation our research group came up with a programming solution based on the Virtual Institutions infrastructure [Bog07]. Further we describe how each of the elements was implemented by this research group.

#### 4.1.3.1 Immersion

Immersion is an integral feature of Second Life technology allowing both an agent and a user to become immersed in the environment via the corresponding avatars. However, to achieve complete immersion into the virtual environment the agent must be able to possess environment-, self- and interaction-awareness which is a major focus of this thesis. Those features are integrated using Virtual Institution technology[Bog07] and the programming solution described in 4.3.

#### 4.1.3.2 Goals, Reactivity, Proactiveness

A critical aspect in the illusion of life ($IL$) is to make an agent appear to have goals, which it can pursue in a concurrent fashion, as well as change them and priorities in a reactive and proactive manner. All these features are supported within the fully-fledged BDI platform our research group has developed and integrated with Second Life. This platform is compatible with the conceptual model of [HRH01]. It allows for all the standard features of agent-oriented programming offering C# classes for agents, events, plans, beliefs, goals and supporting message communication, plan selection on receipt of an event, etc. Programmers can express the beliefs and desires of their agents, decide on the types of events they handle and design the plans to handle these events. Proactive behaviour is simulated by supplying the agent with basic needs, like the need to eat or socialise, which in turn results in the agent having goals such as need to feed his family.

To be able to pursue its goals, every agent in our system relies on a number of plans developed in [BRS10]. A plan is a set of instructions, triggered in response to some event. Those events arise as a result of a human- or agent-controlled avatar sending a text command or as a result of an environment state change. The $I^2B$ framework supports static planning i.e. when the entire plan is prescribed by a programmer and is executed by the agent without variation; and dynamic planning, when the agent can sense its current state in the environment and can react to environment changes re-evaluating its current plan. Rather than having a complete recipe provided for every situation the agent can encounter, the agent is given the list of possible actions and has to find a way of combining those to reach its goals. To support dynamic planning, each object the agent can use must be annotated with pre-conditions (showing which state the agent must reach to be able to use the object) and post-condition (what will be the state once the agent uses the object). Such annotation is supported by the selected Second Life platform.

#### 4.1.3.3 Concurrency

Each agent with either static or dynamic planning may have to pursue multiple goals simultaneously. To make this happen,$I^2B$ framework introduced 5 priority levels that can be selected for each plan. For every event the agent receives, there is a corresponding plan that handles this event. Before initiating this plan the agent will first verify the priority of this plan and if it is higher than the priority of the currently active plan, the agent will suspend the active plan and will activate the new plan for handling the incoming event. To enable priority planning we designed a complex system of handling plan interruptions. For static planning agents we simply run each plan in a separate thread, then the plan scheduler pauses and resumes the corresponding threads depending on their priority level. For the case of dynamic planning we are able to subdivide the plan into atomic actions. Each of these actions is then placed into a stack that the agent reads and executes the actions from. When a dynamic plan is suspended, we terminate the plan, but leave the stack populated. To make sure the agent is in the right state. we cancel the state update for the last action and add this action back into the stack, so that it is repeated when the plan is resumed.

#### 4.1.3.4 Resource Limitation

Resource limitation is partially supported by the features of Second Life. The agent is limited in its object use, has a limit to its movement velocity, etc. Additionally, we applied some limitations to the communication capabilities, so that the agent doesn't provide instant replies, but is endorsed with a delay that is proportional to the length of the response as developed for virtual agents discussed in [BRS10].

#### 4.1.3.5 Social Context

To be able to understand the social context the agent also relies on the underlying Virtual Institutions infrastructure [Bog07]. The institution establishes the role hierarchy in the environment and shows how the roles are related to one another. For every scene the agent is made aware of the roles being played by other participants and how its own role is related to those.

#### 4.1.3.6 Broad Capability

In order to believably immerse itself into its virtual environment and to support the illusion of life while interacting with its environment, the agent must be able to freely interact with its environment. One of the necessary features is to move around without being stuck at an obstacle. This required the implementation of obstacle avoidance techniques. Second Life doesn't offer any obstacle avoidance solutions and it proved to be the most challenging part of the project, mainly because of distributed nature of Second Life and because the environment is dynamically created by the users. Our research group implemented obstacle avoidance adapting the $A*$ algorithm and Artificial Potential Fields (see [BRS10] for more details). The information about the obstacles is not hardcoded, but dynamically obtained from Second Life , hence the $I^2B$ agents are potentially able to avoid obstacles in any desired region.

Another important aspect of broad capability is the use of objects in the environment (i.e. grabbing a spear, jumping on a boat). We have developed a designated library that provides a set of classes allowing agents to identify an object in the virtual world, attach it to the default attachment point, play a certain animation (i.e. rowing) associated with a given object, wear an object that is a piece of clothing, detach the piece of clothing, drop an object to the ground and detach the object and hide it in the avatar's inventory. All those classes take into account synchronisation issues and packet loss.

### 4.1.4 Social Relationships

Virtual Institutions [Bog07] technology manages the social interactions and social relationships of the $I^2B$ agents. The approach taken in Virtual Institutions is to "program" the environment first, in terms of the roles of the agents, their presence, possible scenes, the role flow of the agents between these scenes, interaction protocols of every scene, etc (see [Bog07] for more details on this process). With the help of the underlying Virtual Institution $I^2B$ agents can also understand which social roles are being played by other agents or humans, and change their roles over time. Based on this information they can engage in believable social interactions and build social relationships. An agent's personality and the emotional state are impacted by social interactions with others.

### 4.1.5 Consistency

Virtual Institutions manage the set of rules (social norms) for all participants in the given virtual environment, subject to their roles, hence they manage the consistency ($\Upsilon$) of the agent behaviour. The institutional formalisation helps an $I^2B$ agent to assign context to its own actions and the actions of other participants, thus allowing it to make the corresponding adjustments to its emotional state, personality and liveness.

This thesis extends the previous work of our research group to have a believability framework for virtual agents with all the discussed believability characteristics. In the next section, we demonstrate conversational ability and introduce the new believability features proposed by this thesis. We also outline the detailed proposal for implementation of these characteristics for embodied conversational agents in Virtual Worlds.

## 4.2 Interactive, Intelligent and Believable Conversational Agents

This thesis expands the $I^2B$ framework towards having believable conversational agents to provide natural interactions with human participants. Verbal behaviour is one of the most explored features of liveness. The most popular approach to implementation is to utilise chatter bots like [Wal04] for mapping possible user questions to the replies of the agent. Text-to-speech engines are normally used for translating the resulting text response into voice. In our system we rely on a similar approach, however, what is normally missing in traditional approaches is the consistent integration of an agent's environment into verbal communication with users. We rely on a model of environment-, self- and interaction-awareness the construction of which is presented in the next section. The verbal behaviour of the $I^2B$ agents is currently limited to exchanging text messages with other agents and text chats with humans.

For chatting with humans $I^2B$ agents employ the ALICE chat engine [Wal03] based on the AIML language. Each agent uses a number of AIML files that represent what can be seen as a common sense database. Additional to this database, every agent is supplied with personalised AIML files that reflect on its personality and the data relevant to its role within the virtual society. In the next sections, we outline these believability features and how they are implemented for virtual agents to enhance verbal behaviors.

## 4.3 Awareness Believability

In order to incorporate the aforementioned believability features in regulated interactive environments we propose to conduct two levels of environment annotation as shown in Figure 4.1: (i) *object annotation* - the annotation of objects in the environment with appropriate names, object types and descriptions (such annotations are fully supported by the Second Life technology that we use for design and visualization of the dynamic virtual world); and (ii) *regulation annotation* - annotation of the social norms, interaction protocols, roles and other kinds of regulations of interactions. The Virtual Institutions (VI) technology [Bog07] discussed earlier is used to enable regulation annotation.

In our system human users interact with virtual agents present in the Virtual World through a communication layer and these agents rely on two further layers to generate an intelligent response as shown in Figure 4.1. If the query asked was about the agent's environment, the object annotations layer would be requested by the agent to generate a response which contains the objects' information. Queries regarding the agent's interactions and self awareness will be passed to the regulation annotations(VI) layer by the agent. The VI layer passes interaction annotations (i.e. agent's goal, plans, objects used etc.) back to the Artificial Intelligence Markup Language (AIML) module to further build a response. This communication module has the responsibility of generating a text reply for an agent based on information received from the Virtual World or the Virtual Institution layer. Subsequent sections will provide a detailed insight into these layers.

Technological separation of the environment layer from the Institutional regulations allowed us to implement a generic solution, where the same features can be deployed in a new dynamic environment without modifying the core functionality. Secondly, this layered approach enables us to deal with a dynamic environment, where objects can be changed, inserted or deleted at any time. All annotations outlined in Figure 4.1 can still be detected by the agent for newly added objects. Furthermore, we briefly describe Virtual Institutions technology

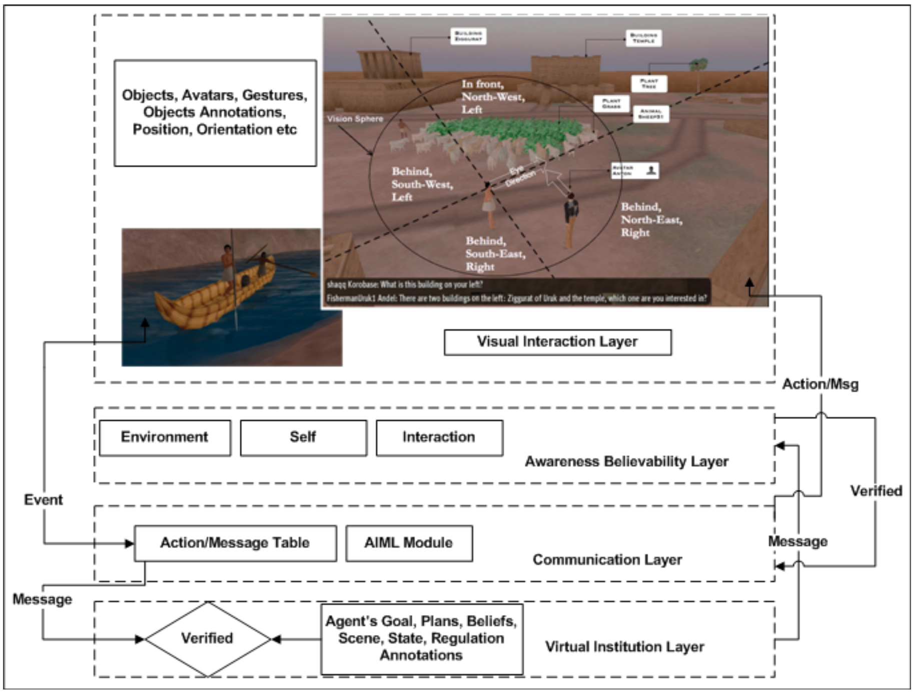



Figure 4.1: Layered System Architecture

and show how it can enable the integration of awareness believability features in such dynamic Virtual Worlds.

### 4.3.1 Implementation of Environment-Awareness

The environment-awareness method enables embodied virtual agents to have an updated knowledge of their surroundings. The objective was to enable agents to interact with humans and correctly respond to human inquiries about the objects and avatars in the environment. Agents' conversational abilities in our system are supported by the Artificial Intelligence Markup language (AIML) [Wal04]. When a participant in the environment inquires something like: "What is that building on your left?" - we first extract the desired information from an AIML rule. The corresponding rule will be: "What is that * ?", where "*" represents any number of characters in the remainder of the query. The first step of the environment awareness process is to tokenize the input. These tokens are then matched with the list of directions, objects and relative adjectives as shown in the table below.

To locate the object(s) of interest, a virtual agent uses data from the Object Annotation Layer to search for keywords like object name, type, etc as shown in Table 4.1. For example: House and direction: "Fisherman house on the left". Moreover, it needs the exact relative adjectives like "You" or "Me" to co-relate the right objects in the space. As the user inquiry can be about an object on either the participant's left or the virtual agent's left, this hint helps the agent to specify the participant's correct direction of interest.

Table 4.1: Environment Awareness

| Environmental Entities List | | |
| --- | --- | --- |
| Pronouns | Directions | Objects |
| You/your | In-front | Building(House, Ziggurat, Temple ...) |
| | Behind | Plant(Tree,Grass ...) |
| Me/My | Left | Avatar(Agents,Humans) |
| | Right | Animal(Sheep,Donkey ...) |

The agent further needs to locate the specified direction in the context of current space, which is relative to the pronoun given to search for the "object" of interest in the virtual environment. The agent knows its current position vector and body orientation with respect to the standard cartesian coordinate system. Identification of the conversational agent's direction like "left" or "right" requires coordinate transformation in respect to the agent's current position and orientation.

Figure 4.2 (a) shows the position of an embodied virtual agent in a current cartesian coordinates space, where the agent is currently looking along the line labelled as eye direction and away from the Y-plane with angle($\alpha$). Defining

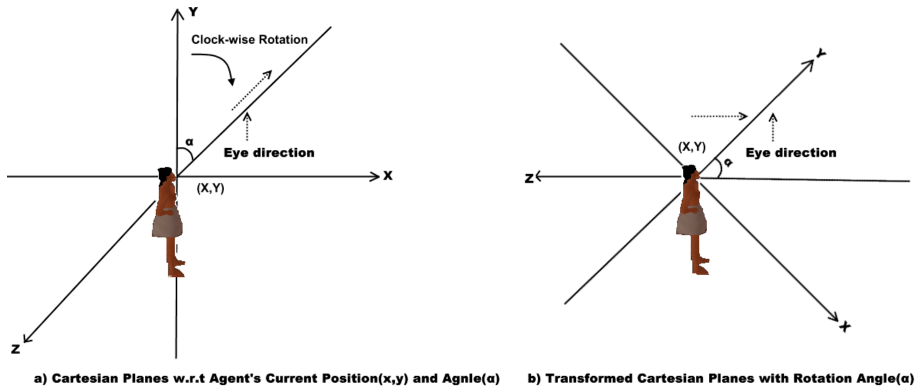



Figure 4.2: Aligning cartesian planes with agent's orientation.

direction like left or right with respect to agent's current orientation requires rotating the cartesian planes clockwise or anti-clockwise with angle($\alpha$).

Agent's Eye Direction with respect to Y-plane = Angle of Rotation = alpha - $\alpha$, where (x, y) are the coordinates representing some point in the current space. In two dimensions, the rotation matrix has the following form:

$$\Re(\alpha) = \begin{vmatrix} \cos(\alpha) & -\sin(\alpha) \\ \sin(\alpha) & \cos(\alpha) \end{vmatrix} (\textit{rotation by angle } \alpha).$$

The new coordinates ($x\prime$, $y\prime$) for point (x,y) will be:

$x\prime = x * \cos(\alpha) - y * \sin(\alpha)$; $y\prime = x * \sin(\alpha) + y * \cos(\alpha)$.

To rotate the coordinates anti-clockwise, we need to replace $\alpha$ with -$\alpha$.

$$\Re(-\alpha) = \begin{vmatrix} \cos(\alpha) & \sin(\alpha) \\ -\sin(\alpha) & \cos(\alpha) \end{vmatrix} (\textit{rotation by angle } -\alpha).$$

This transformation of cartesian planes has been demonstrated in Figure 4.2 (b).

Once the agent has figured out the desired direction e.g. "left" in the current

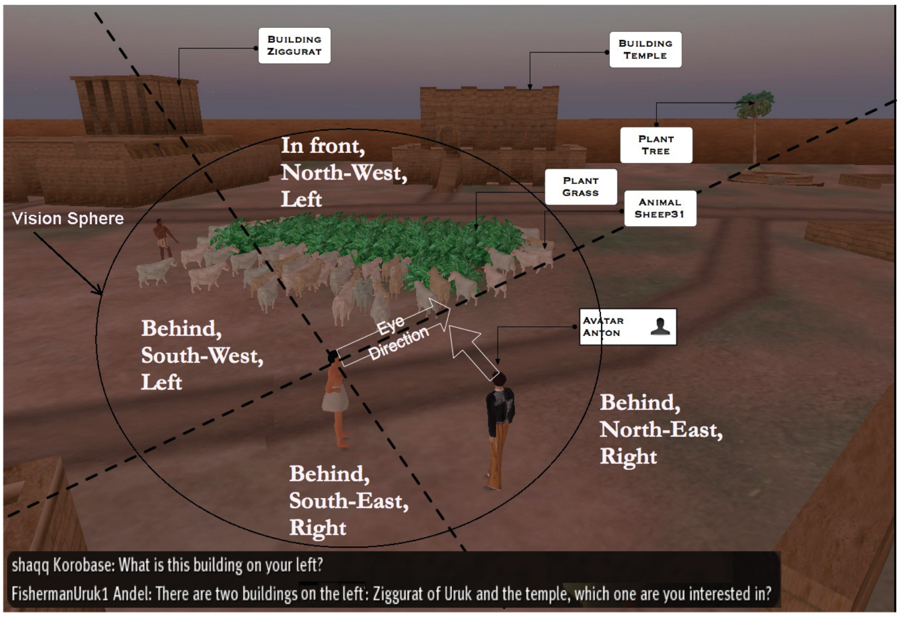



Figure 4.3: Agent's orientation in Uruk.

request, it further needs to search all objects of the class "Building" to locate the appropriate object. Each agent in the environment has its vision sphere as presented in Figure 4.3, which helps it to locate the object of its interest within the vision radius. In the given scenario, the agent has found two buildings inside the vision sphere, which are Ziggurat and Temple of Uruk. If multiple objects of the same class have been found, the agent will return the list of objects and request more details. Otherwise, the object will be sensed within the vision sphere and its name passed to the AIML module. The role of the AIML module is to produce the relevant object description given this name.

Each AIML rule(category) has two main tags to generate a dialog which are $< Pattern >$ and $< Template >$ as shown in Figure 4.4. The Template tag generates a response to the inquiry requested in the Pattern tag. The AIML rule below also shows the $< Environment >$ tag, which is a custom tag responsible for invoking our environment awareness routine. The current AIML rule could be divided into two parts. "What is that" is the general rule to invoke the corresponding template with the custom $< Environment >$ tag. The second part is represented by a wildcard character "*", which encloses the user input part of the pattern. The $< star/ >$ tag substitutes the value matched by "*".

Natural Language Processing (NLP) and pattern matching is done by the AIML engine which also enables the custom tags. Our environment awareness routine is further responsible for completing the query and scanning the desired environmental objects. The OpenMetaverse library interacts with AIML to pass on the information about the agent's surrounding.

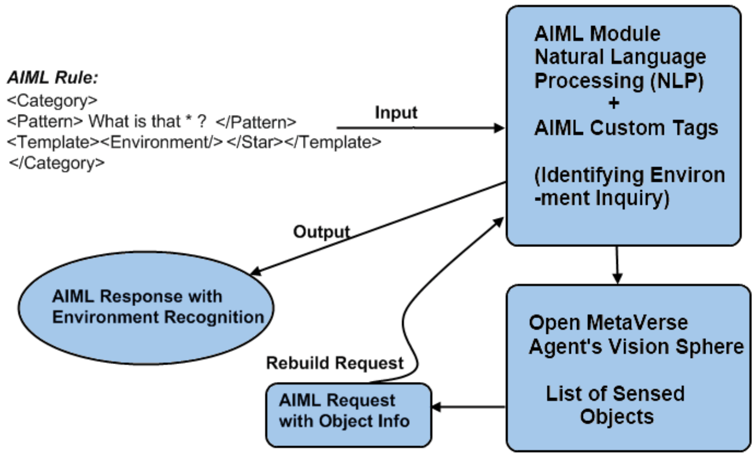



Figure 4.4: Environment awareness approach for virtual humans.

### 4.3.2 Implementation of Interaction-Awareness

Enabling interaction-awareness means making the agent understand its own opportunities in interacting with other participants and making it predict the possible actions other participants may perform in a given scene provided the agent knows what the current state of the scene is. Introducing interaction-awareness for embodied conversational agents is attempted to provide information about activities of virtual humans(embodied conversational agents) and their interactions with other participants. Moreover, virtual agents should be capable of using this interaction information in their conversations with other participants.

Our interaction-awareness model is based on the virtual institutions technology explained earlier. Figure 4.5 demonstrates the performative structure in an institution, the roles which participants can perform and it also gives an interaction protocol for participants(which we call "scenes" here). The performative structure shown in Figure 4.5(a) gives a graph which defines the role flow of participants in different activities. The nodes in the given graph outline a few scenes in which our virtual agents can be involved and the arcs of this graph represent permissions of participants enacting a given role to access corresponding scenes. Some of these arcs are labeled as "new" to define which participants are initializing the scenes, as a result it also restricts other participants entering into a specific scene before the initialing participant. The VI technology tracks all the participants in every scene and maintains the state of every scene. Every action performed by any participant, as well as the corresponding state changes, can be sensed by the agent through the VI technology. The given performative structure has been implemented by our research group [Bog11] which was further used to develop interaction awareness for our virtual agents.

The given performative structure can deal with five major scenes so far namely fishing, well, fire place, chat and fishermen homes. The agent can sense movement over the performative structure, agents entering or leaving these scenes, track the actions that result from the state changes and also estimate the actions of other participants that can make the scene evolve to a new state as explained in [BRS10]. The scenes labeled as "new" and "exit" do not correspond to any specific behaviors but simply define the entrance and exit state for participants in the current institution. Each scene in the performative structure other than "new" and "exit" scenes is associated with a *Finite State Machine* which defines

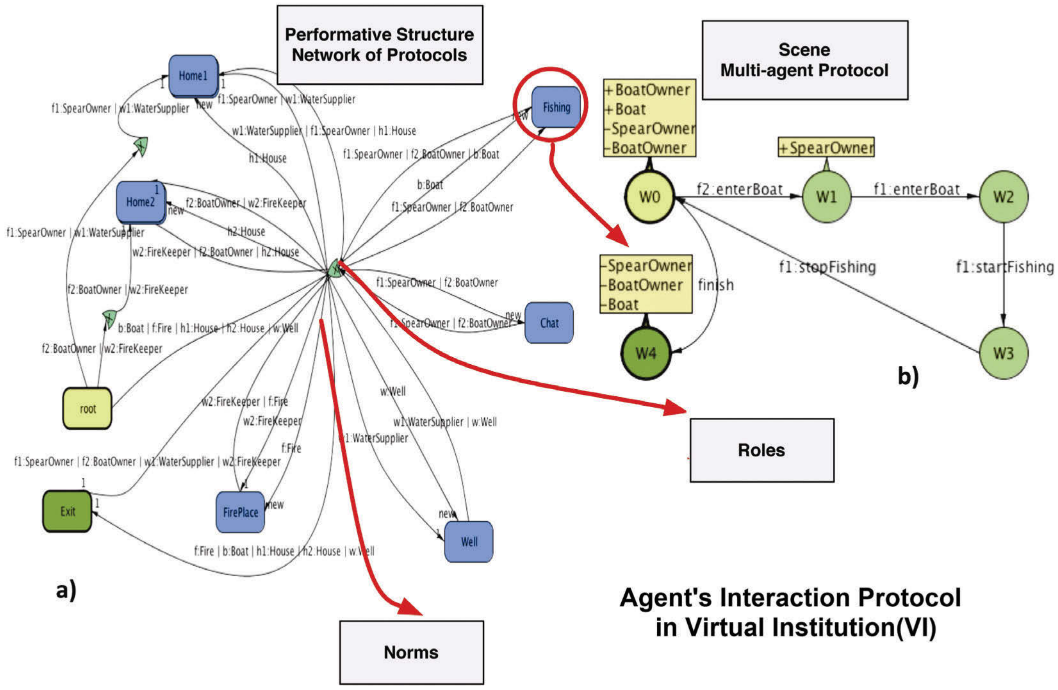



Figure 4.5: Interaction Awareness

the interaction protocol for the specific participants which are accepted in the given scene. A change in the scene's state happens when a participant performs an action acceptable by the virtual institutions.

Virtual institutions technology also helps to define specific roles for participants and accordingly defines the accessibility to particular scenes. Figure 4.5(a) outlines how a specific scene protocol is formalized. The scene protocol defines in which sequence participating agents must perform actions, at which states they can enter or leave the scene and what kinds of actions they can do to change a state. Every action performed by agents in Virtual World (for instance grabbing/clicking a specific object) is traced by the institutional infrastructure.

To give an insight into the interaction protocol, here we explain in Figure 4.5(b) the fishing scene surrounding the area around a boat in Virtual Worlds. This scene consists of multiple states with two fishermen agents who own their fishing gear. The initial state is “W0” when the fishing scene is initialized. Fisherman2 and boat can enter into the fishing scene at this state and both fishermen can also leave the fishing scene from this initial state. Fisherman1 can only enter the fishing scene following Fisherman2. This happens when Fisherman2 enters the boat in Virtual Worlds by performing the action “‘f2:enterboat” and the corresponding state changes from “W0” to “W1” to assure the successful boarding of *BoatOwner*. This state changes to “W2” when Fisherman2 enters the boat confirming the *SpearOwner* on board the boat and sends notifications to all other participants. On Fisherman1’s request of performing action “f1:startFishing”, fishing starts resulting in a state change to “W3”. This make the stationery boat in Virtual Worlds move, Fisherman2 starts rowing the boat and Fisherman1 is fishing with his spear. Fisherman1 also performs the only action allowed in the “W3” state to send notification to other participants saying fishing is finished. When the fishing is finished Fisherman2 must return the boat to its initial position, drop the paddles on the river bank, take the fishing basket and exit the boat. Fisherman1 will also leave the boat afterwards. No participant can leave the boat in this state therefore it evolves to “W0” again. While the scene is again “W0”, the boat object will change its state to docking at the wharf representing the finished action in the institution which evolves the scene to final state “W4”. This final state deactivates the fishing scene confirming no more entry by the participants and any action they may perform. Similar to the fishing scene the interaction protocol is specified for all the other scenes in the performative structure. These interaction protocols act as guide lines to agents to have formal understanding of the given scenes as explained by [BRS10].

Figure 4.6 illustrates two types of roles a user can have in institutions as explained by [BPA09]. In Figure 4.6(a) the user is playing the visitor role in Virtual Worlds. This role does not restrict the user to have a specific appearance


Figure 4.6: Two Types of Interaction Between User and Agent [BPA09]

or to behave in a certain way. Any participant with this role can communicate with agents using the chat facility provided by SecondLife technology and this is the only interaction allowed to a visitor. The second form of interaction is choosing a specific role in the institution. Each role has an associated appearance and a user is required to adopt it. Another important restriction associated with a given role is that the participant needs to follow institutional rules, norms and interaction protocols. Figure 4.6(b) explains the interaction between a user and an agent in the given Fishermen role.

Thus, the VI technology provides the agent with high-level information about the interaction opportunities of all participants. The agent can relate this information to its conversational rules and answers questions asked by visitors like *"what can I do in this scene"*, *"what can I do next"*, *"what are you waiting for"*, *"who is partner in this task"* etc.

When a similar query is asked to an agent while he is present in one of the mentioned scenes in Virtual Worlds, The agent's response to inform the visitor about the current state of the scene or any interactions it may have depends on two further layers: the performative structure in virtual institutions and the communication layer. As described earlier, the performative structure is a guideline to agents about their current scene. Thus, the agent can get the scene information

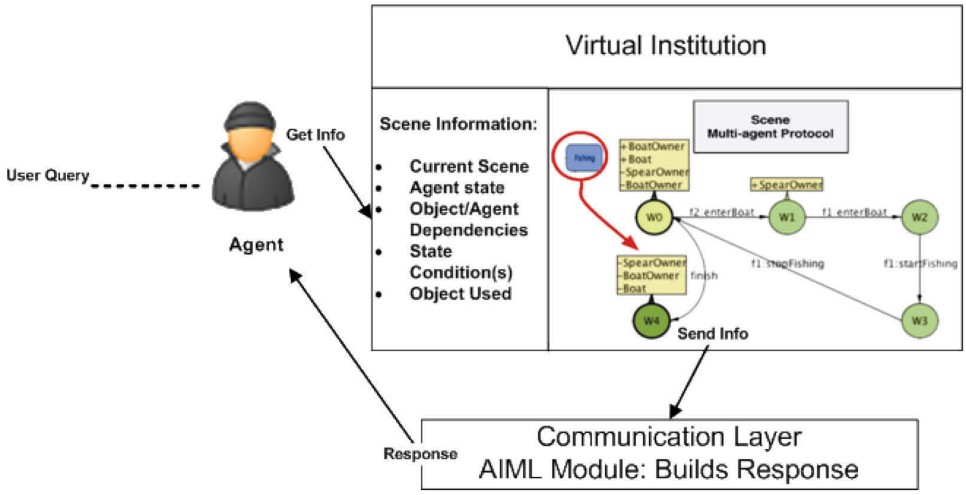



Figure 4.7: Agent's Interaction Information

like its current state and any dependencies the agent and its fellow agents may have among themselves and on any other object. The agent also knows about pre and post conditions for a particular state within a scene and the objects required a in current scene.

This information about the current scene is filtered for any specific query and the virtual institutions layer further passes it to the agent's communication layer. Based on the AIML module, the communication layer is responsible for any conversational exchange between participants in Virtual Worlds. With the help of the < *getInteraction* > custom tag in the agent's interaction AIML file, it fetches the required information about the current scene and builds a textual response to the visitor's query as given in AIML code below. Human visitor receives corresponding response through the text chat facility in SecondLife.

```
<category>
<pattern>Who are these people * </pattern>
<template>
<think><set name="Avatars">agents in current scene</set></think>
<getInteraction name="Avatars"/>
```

```
</template>
</category>
```

### 4.3.3 Implementation of Self-Awareness

The self-awareness component of an agent helps it to reflect on its own state in the virtual world, explain the reasons for performing certain actions, using certain objects or walking in a particular direction when a human user inquires about those. Moreover, to be more believable an agent should also be aware of its current goals and plans to give an appropriate response to the human user.

In its reasoning to respond to a query, the agent partially relies on the Virtual Institution (as shown in figure 4.5) that provides the agent with corresponding knowledge about the current scene and the agent's state within this scene. The remaining details an agent either extracts based on its location in the environment (i.e. identifying objects in the field of view of the avatar, objects being used or animation being played) or from its internal beliefs. Figure 4.8 exemplifies some parameters of the self-awareness model.

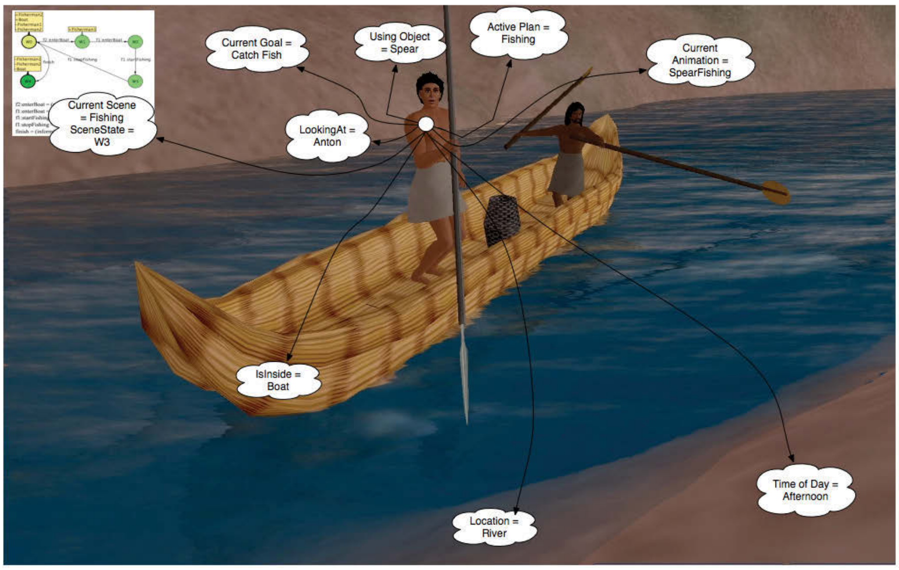



Figure 4.8: Self-awareness model.

For instance, when the fisherman is standing inside a boat while holding a spear to catch a fish, he has the following facts in his knowledge base to give a response to the human visitor:

- Current Scene = Fishing
- Current State = W3(in current scene automata(fishing))
- Current Goal = To catch a fish
- Object(s) Used = Spear
- Looking at = Current object he is looking at(e.g. Human Participant)
- Current Animation = SpearFishing
- Active Plan = Fishing
- Time of Day = Afternoon
- Inside = Object Boat
- Location = River

Similar to other awareness features, self awareness also accesses the agent's scene related information from its performative structure. The attributes mentioned in the above list such as the agent's current scene, state, goal, object(s) used and plan is taken from the virtual institutions layer, whereas other attributes like current animation, time of day, location etc are accessed through the Virtual Worlds layer which can provide all the environment specific information.

The self awareness of a virtual agent accesses the agent specific information through the AIML based communication layer on a request to respond to a user query. The communication layer as in other awareness believability features also plays an important role to access the agent's own information and build a corresponding response for a visitor in Virtual World. A visitor can ask the agents specific questions like: *"What are your plans?"*, *"What are you holding *"*, *"What are you doing *"*, *"Where are you sleeping?"* etc. When a human visitor initiates a query by saying "What are you holding *", it initiates the AIML custom tag to access agent specific information from the virtual institutions layer. The '*' is a wildcard in the current query that can accommodate any specific details to complete the query and it is further parsed by the $< star >$ tag in AIML files. We have used AIML tags $< think >$ and $< set >$ to hide the details of the calling custom tag and passing it parameters respectively. Within the same AIML category $< getSelfname = \text{``}AgentObjects''/ >$ has been called to fetch the agent specific information regarding the current query, where $name = \text{``}AgentObjects''$ sets an input parameter for the custom tag that the user query requests for the objects used by the agent.

```
<category>
<pattern>What are you holding * </pattern>
<template>
<think><set name="AgentObjects">Objects in Hand</set></think>
<getSelf name="AgentObjects"/>
</template>
</category>
```

Each custom tag has a corresponding class and written procedures in the C# library of our communication layer. This C# library further uses a virtual institutions prototype and the C# library of Openmetaverse to access Virtual Worlds. When a $< getSelf >$ custom tag is called, it tokenizes the user input to get only the relevant information of an agent from the virtual institutions layer.

As mentioned earlier, the virtual agent's self awareness feature not only depends on the virtual institutions layer but it also requires attributes from the

Table 4.2: Agent's Self Awareness Attributes

| List of Attributes | |
|---|---|
| Application Layer | Attributes |
| $< getSelf >$ | Agent Goal<br>Object Used<br>Active Plan<br>Agent State<br>Current Scene |
| Environment | Agent Gaze<br>Time of Day<br>Current Location<br>Current Animation |
| Agent Personality | Agent Appearance<br>Agent Identification |

agent's personality and the Visual layer of Virtual Worlds. A list of these attributes with a corresponding module in our framework is outlined in Table 4.2. Similar to the $< getSelf >$ custom tag, all the relevant details from an agent's personality and the visual layer are accessed through AIML rules. This information about the agent is returned by the AIML engine as a proper textual response to the human user.

Awareness believability and its capacity for having believable conversations is not enough to engage students in the learning process. As in dynamic virtual environments, conversational agents are required to keep their knowledge base updated to give believable response to students' queries. In the next sections, we will discuss a case that demonstrates virtual agents' learning and our specific implementation for conversational agents particularly for teaching history and culture.

## 4.4 Implementing Virtual Agents' Learning

The communication layer highlighted in Figure 4.9 has a critical role in communication and learning between the human/agent participants. Every avatar representing either a human or a virtual agent has access to the *Instant Messaging(IM)* feature in the Virtual World of *SecondLife*. Therefore, this chat window provides a means of textual communication between the participants.

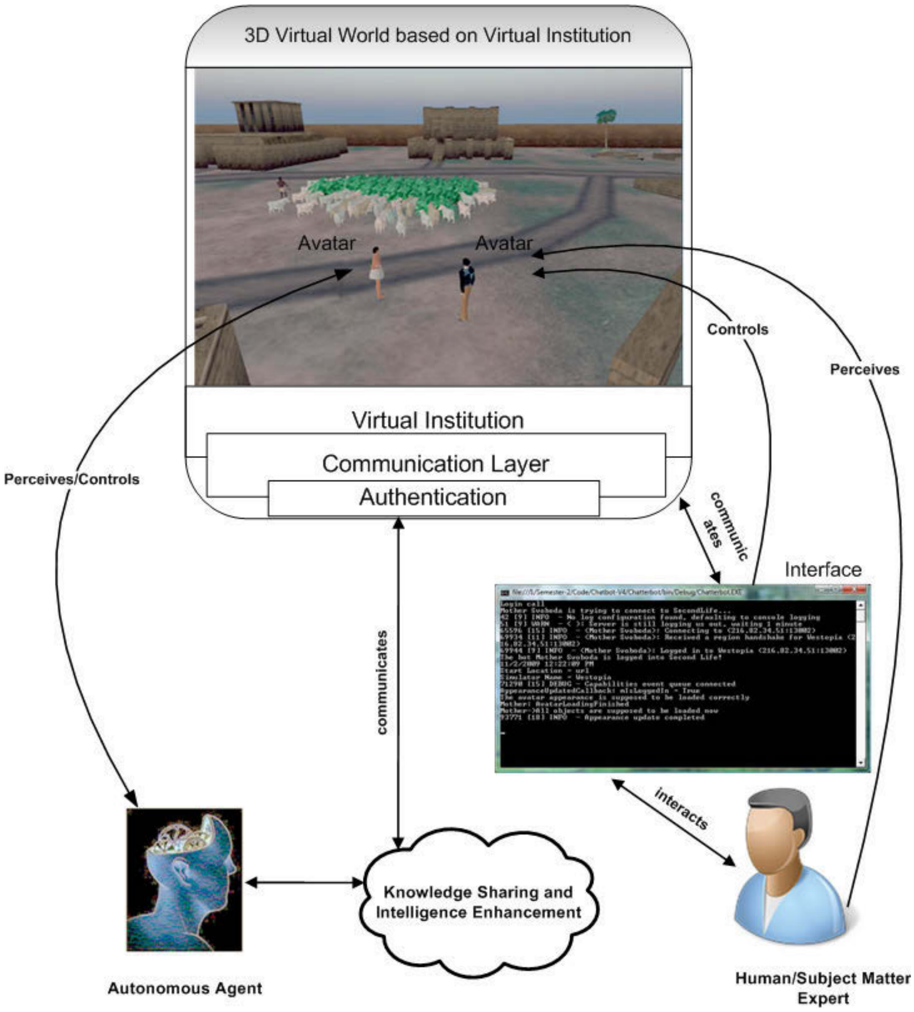



Figure 4.9: Interaction between Autonomous Agent and Human Participant

Considering the role of agents as virtual humans of an ancient city, we were required to limit the agents learning to deriving from the authenticated sources only. During the knowledge sharing process, only subject matter experts can correct or update the virtual agent's beliefs and facts. Similarly, all other visitors can only communicate with virtual agents but are not allowed to update their knowledge base. History experts with authentic knowledge of the said domain were expected to provide and correct the agent's beliefs. On the other hand, subject matter experts who lack the technical knowledge require a simple solution to update the agents' belief set. To facilitate subject matter experts, we provided them with a communication layer which also deals with updating the agents' belief set through simple conversations. furthermore, participants' authentication and privileges were implemented as part of this communication layer. As mentioned before, communication among all participants was also provided through this layer, so a detailed technical explanation of this layer is presented in next section.

Learning plays an important role to improve agents' believability by integrating the discussed awareness features and learning the updated beliefs. The role of conversational agents' interaction with students is critical to provide an effective learning environment as suggested by the user study we conducted to evaluate our case study. We did a comparative study of three different methods of learning: First was the traditional method of learning history through text reading, second was learning history by visiting the virtual city and observing the environment as well as reading the information about significant artifacts, and thirdly students interacting with conversational agents in a virtual city and learning directly through these interactions. A detailed illustration and analysis of this user study to measure students' learning effectiveness is presented in Chapter 6.

```
 <?xml version="1.0" encoding="ISO-8859-1"?>
<aiml>
  <category>
```

```
    <pattern>ARE YOU A GOOD KING</pattern>
    <template>no I am actually a tyrant</template>
  </category>
  <category>
   <pattern>WHAT COLOR ARE YOUR SHOES</pattern>
   <template>my shoes are orange</template>
  </category>
  <category>
    <pattern>WHAT COLOR IS YOUR HAIR</pattern>
    <template>my hair is black</template>
  </category>
  <category>
    <pattern>WHAT IS THIS PLACE</pattern>
    <template>this place is my private palace</template>
  </category>
  <category>
    <pattern>WHY ARE YOU HERE ALL ALONE</pattern>
    <template>because I am a tyrant and everybody hates me</template>
  </category>
  <category>
    <pattern>WHAT ARE YOU WEARING</pattern>
    <template>I am wearing my usual king uniform</template>
  </category>
</aiml>
```

The above mentioned code snippet is taken from a virtual agent's (*King Imgursin*) AIML based repository of learnt history facts. A subject matter expert corrects the virtual agents responses which are ultimately stored in the AIML file through the communication layer.

In SecondLife, human to/from agent communication is mostly based on predetermined conversational rules, here the conversational agent is often provided with a personality and the expected dialogue corpus. Due to the dynamic nature of this environment and the high believability demand in such systems, providing a large corpus of pre-determined conversational rules is not desirable. The second challenge was to provide correct historical facts to virtual agents which will have a vital role in knowledge sharing with other non-expert visitors.

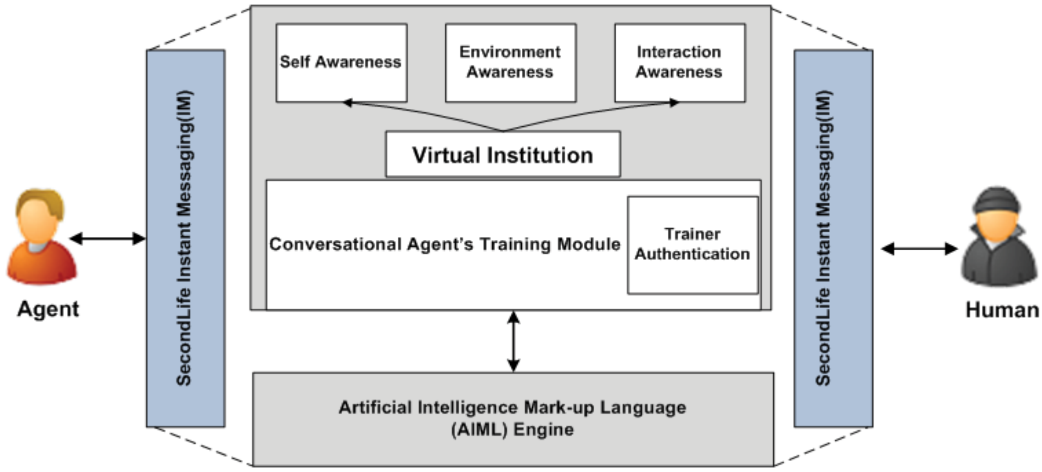



Figure 4.10: Communication Layer

A virtual agent's personality and conversational ability is based on the AIML corpus. Agent designers usually provide beliefs and personality to these agents by writing AIML categories(rules) in various AIML files. For an agent, these AIML categories have at least one template(answer) for each pattern(question) asked [Wal04]. Based on these rules, the response generation depends on the pattern matching technique. The conversational ability of agents in SecondLife is based on the AIML Engine for the corresponding AIML Bot. It also has several successful applications other than Virtual Worlds. Similarly, our communication layer for all participants also uses the same AIML Engine.

Using the same AIML based communication layer, we can not only integrate various believability features in Virtual Worlds as described in section 3.3.1, we can also manage the concept of *co-learning*. As shown in Figure 4.10, there are two major components attached to the SecondLife Instant Messaging(IM) service both for agent and human participants. The AIML Engine as depicted has played the role of a central component in our communication layer. A description of each component in the communication layer has been provided next.

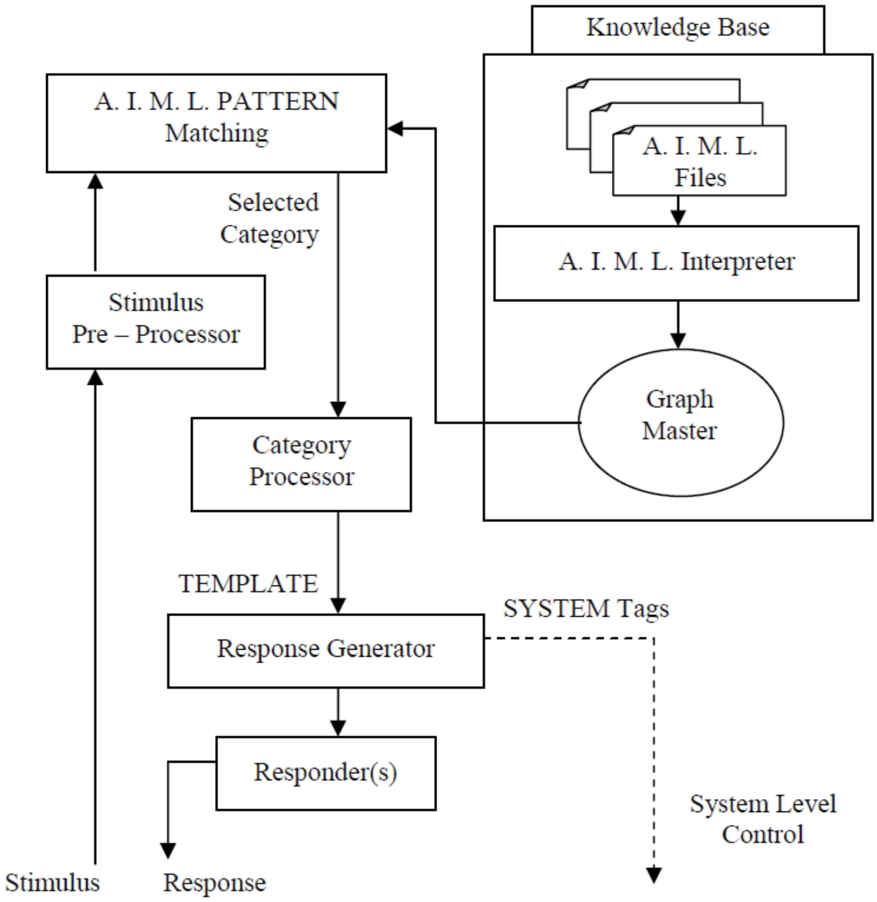



Figure 4.11: Architecture of A.I.M.L. Engine [JKS04]

Starting with the AIML Engine, a basic block diagram of A.I.M.L. architecture is shown in Figure 4.11 taken from [JKS04]. The knowledge base of this engine comprises multiple AIML files. These AIML files represent many categories as we discussed before, where each single *Category* consists of a *Pattern* which specifies the stimulus needed to select that particular category and where the *Template* specifies the response to be generated as an effect to the category selected. After pre-processing the current stimulus, *AIML Pattern Matching* helps to select the corresponding category based on the knowledge base, where the *Response Generator* reads the *Template* and takes suitable action. This action can be as simple as copying the response contents or expanding other tags inserted within the current *Template*. These internal tags can also be the System tags which need to be processed by the underlying Operating System.

There are two main approaches to build the AIML knowledge base for a conversational agent. The first option is anticipatory where the bot-master enumerates all the possible inputs and then writes a suitable response to build the categories. A solution to avoid this approach is where a bot-master indulges in a conversation with a conversational agent. This sequence of conversation can later be used to generate categories either automatically or semi-automatically. A log file analysis is required for the semi-automatic approach to build the AIML files.

Automatic learning for a conversational agent in SecondLife has not yet been provided with an AIML Engine according to our knowledge; it can only cater for an existing knowledge base. For a non-technical person, the complexity of extending the agent's knowledge base gets multi-fold. This problem has been dealt with by the Conversational Agents's Training Module in the communication layer. This component helps the subject matter experts train the virtual agents during the conversations. As shown in Figure 4.11, this module has been built on top of the AIML Engine and uses the same technique for a regular flow of conversation.

Artificial Intelligence Markup Language(AIML) provides a facility for implementing *Custom Tags*, which are user defined tags to perform the functionality specified by the user. Our *Agents' Training Module* has been developed using the same custom tags approach to teach agents new historical facts and in the same way it updates their knowledge base. The snippet of code given below could initiate agent's learning during the conversations by calling the custom tag <*train pindex =“3,1”*>.

```
<category>
<pattern>LEARN *</pattern>
<template><train pindex = "3,1"><star/></train></template>
</category>
```

When a history expert specifies *LEARN* with some string like *LEARN this new fact*, the conversational agent goes into training mode. Firstly, it authenticates the privileges of the human participant. Two of the main AIML tags used to implement the learning function are *<that>* and *<star>*, where *<that>* enables getting the previous bot response and *<star>* helps to bind the wildcard(s) within the current pattern to other user inputs.

```
<that index="X,Y"/>           Built-in predicate   previous utterance
<star/> Or <star index="X"/>  Built-in predicate   binding of wildcards
```

*<train pindex = "3,1">* refers to the previous response by the conversational agent. Here inside train tag, *Pindex* acts like aiml default tag *Index = "1,1"* for 2-D indexes which points to the specified agent's utterance. Interaction between the AIML Engine and our Agent's Training Module is given in Figure 4.12. All the above specified tags have been used in AIML Learning *Categories* to initiate the custom tags for an agent's learning process.

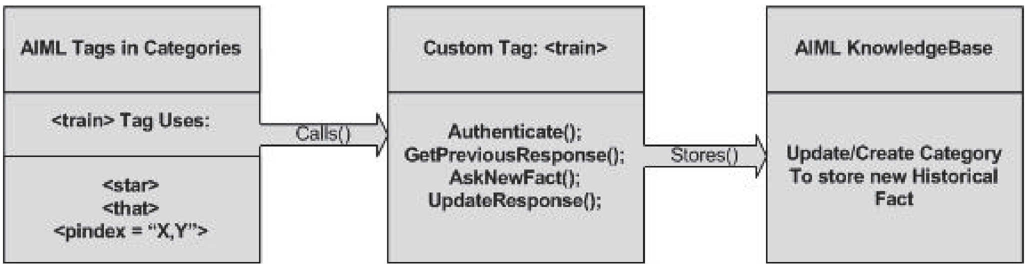



Figure 4.12: Flow of Learning Protocol

In response to <*train pindex* = <*"3,1"*>, the agent's training module gets initiated. It has four main functions: *Authenticate()* is the first method called to verify the user privileges for training a virtual agent. The remaining three functions actually are used to train the new facts to an agent. *GetPreviousResponse()* reads the agent's previous response which the user wants to correct or update with a new historical fact. *AskNewFact()* requests the subject matter expert for the new historical fact to include into the agent's knowledge base. Finally, *UpdateResponse()* helps to update the agent's knowledge base with any new facts. In the AIML knowledge base, this training module creates or updates the AIML categories for all the desired historical facts.

Conversational agents in a virtual city not only learn from the subject matter expert who is a human participant, but they also perceive and use knowledge from the awareness believability component. Therefore, awareness believability features like Self-, Environment-, and Interaction awareness come on top of the agent's training module. These modules also use the same underlying AIML Engine for conversations, where it also integrates institutional rules, norms and interactions from the Virtual Institutions API(Application Programming Interface) as shown in Figure 4.10.

## 4.5 Summary

In this chapter, we have outlined our approach to develop interactive, intelligent and believable conversational agents in Virtual Worlds. In our methodology, virtual agents are based on a layered structure which has four major layers: Virtual Institutions layer, Communication layer, Awareness Believability layer and Visual Interactions layer.

Each of these layers has been described in detail and the technological facilities that help implement these components are discussed. The virtual institutions technology which helps to employ rules and regulations in a virtual society has been discussed in detail in Chapter 2.

The formal specification of believability and its features discussed in Chapter 3 have been utilized for the development of technological solutions present here. We have illustrated the tools and technologies suggested for deploying believable conversational agents in Virtual Worlds.

The major technological contribution here is the development of awareness believability features which depend on Virtual Institutions technology to implement interaction- and self awareness. The environment awareness feature has also been developed using annotations provided by the VI layer and the underlying virtual interaction layer.

Another technological contribution is the development of a communication layer for embodied conversational agents based on AIML technology in Virtual Worlds. It can also support integratating awareness believability features into virtual agents' conversations. This communication layer also enables virtual agents to learn over time in a manner consistent with their personality and environment. In Chapter 5, we present our case study "City of Uruk" which has been recreated and enacted in 3D Virtual Worlds of SecondLife. The next chapter will demonstrate its historical significance and the technologies used to recreate it and its virtual citizens in the Virtual Worlds.

# CHAPTER 5

# Uruk: The First City(3000 B.C.)

This chapter illustrates our case study "City of Uruk" recreated in Virtual Worlds. Our research group has implemented a prototype of a virtual city in the Virtual World of SecondLife [Bog11]. This prototype aims at enhancing the educational process of learning history and culture, by allowing students to immerse themselves in the daily life of the ancient city of Uruk; to gain a quick understanding of cultural developments and daily life of ancient Sumerians.

This case study also helps us to validate our formal model of virtual agents' believability and students' learning effectiveness in a virtual city through believable interactions. In the next sections, we present an historical perspective of the city of Uruk, our aim of teaching history to young students in Virtual Worlds a prototype implementation of a virtual city in SecondLife and the deployment of embodied conversational agents to represent the ancient population of the city.

## 5.1 Case Study

To test the validity of our believability features and the feasibility of the presented learning approach, we have extended the $I^2B$ framework prototype developed by our research group to represent a virtual culture and conducted a case study. The framework was aimed at re-creating the ancient city of Uruk from the period around 3000 B.C. in the Virtual World of Second Life and letting history students experience how it looked and how its citizens behaved in the past (more about the Uruk Project as well as the prototype video can be found in [Bog11]). The resulting Virtual World provides a unique collaborative environment for history experts, archaeologists, anthropologists, designers, and programmers to meet, share their knowledge, and work together on making the city and the behavior of its virtual population historically authentic.

## 5.2 History of Uruk

Uruk was an ancient city located in present day Iraq situated roughly 250 km south of Baghdad, on an ancient branch of the Euphrates River, known in the Bible as Erech (now Warka). Uruk was the first major city in Sumer built in the 5th century BC, and is considered one of the largest Sumerian settlements and most important religious centers in Mesopotamia. It was continuously inhabited from about 5000 BC up to the 5th century AD as outlined in [SAGAD].

Gilgamesh, the King of the city's first dynasty and hero of the famous epic named after him, built the walls of the city 4700 years ago as cuneiform texts indicate, and the Eanna (house of An) temple complex there, dedicated to the goddess Inanna, or Ishtar (goddess of love, procreation, and war), who is symbolized by the star Venus. Her worship went to the Greeks and Romans under the name of Aphrodite or Venus, goddesses who had exactly the same attributes as Ishtar [SAGAD](p.12).

Uruk was an important city on two scores: religion and science. This is confirmed by the thousands of clay tablets dug up in it that go back to the beginnings of writing about 5000 years ago - in the invention of which Uruk played a major role. Excavations have revealed a series of very important structures and deposits of the 4th millennium BC and the site has given its name to the period

Figure 5.1: City Of Uruk

that succeeded the "Ubaid" and preceded the "Jemdet Nasr" periods of ancient Mesopotamia.

The Uruk period saw the emergence of urban life in Mesopotamia and led to the full civilization of the Early Dynastic period. It is not always fully realized how unique the site of Uruk was at this time: it was by far the largest settlement, with the most impressive buildings and the earliest evidence of writing.

It would be true to say that Uruk was Mesopotamia's - and the World's - first city. It seems to have started as two separate settlements, Kullaba and Eanna, which coalesced in the Uruk period to form a town covering 80 hectares; at the height of its development in the Early Dynastic period, the city walls were 9.5 km long, enclosing a massive 450 hectares, and may have housed some 50,000 people.

In the heart of the city are two large temple complexes: the Anu (god of the sky) sanctuary, belonging originally to Kullaba, and the Eanna sanctuary, dedicated to Ishtar, known by scholars as the Mosaic Temple of Uruk, which rises to a height of 16 m on a square base measuring 60x60 m. Both complexes have revealed several successive temple-structures of the Uruk period, including the White Temple in the Anu sanctuary and the Limestone and Pillar Temples in the Eanna sanctuary. A characteristic form of decoration involves the use of clay cones with painted tops pressed into the mud plaster facing the buildings - a technique known as clay cone mosaic as mentioned in [SAGAD].

On the northwest side of the Eanna sanctuary is a Ziggurat (an ancient Mesopotamian temple tower consisting of a lofty pyramidal structure built in successive stages with outside staircases and a shrine at the top, where the priests ruled from) laid out by Ur-Nammu of Ur in the Ur III period (late 3rd millennium BC).

Evidence from the deep trench excavated in the Eanna sanctuary has cast much light on the developments of the Uruk period. The most important of these was undoubtedly the development of writing. The earliest clay tablets appear in late Uruk levels; they are simple labels and lists with pictographic symbols. Tablets from slightly later levels of the "Jemdet Nasr" phase, show further developments towards the cuneiform script of the Early Dynastic period [SAGAD].

The city remained important throughout the 3rd millennium BC, but declined in importance during the later part of that period. It remained in occupation throughout the following 2 millennia, down to the Parthian period, but only as a minor center. Indeed, Uruk played an important role in the mythology of the Mesopotamian civilization to the end.

### 5.2.1 Uruk Inventions:

Uruk played a major role in the invention of writing, emergence of urban life and development of many scientific disciplines including mathematics and astronomy. Technologically, it was a time of rapid and important changes. In pottery we see the use of the fast wheel; perhaps most significantly of all, we see the introduction of the first pictographic writing on clay tablets. In the Uruk period, the temple seems to have been the dominant institution. But the period may have seen the emergence of the first secular rulers. The next sections will discuss in detail the major contributions, architecture and life of the city of Uruk.

**Cuneiform Writing:**

Writing is undeniably one of humanity's most important inventions. The earliest forms of storing information on objects were numerical inscriptions on clay tablets, used for administration, accounting and trade. The first writing system dates back to around 3000 BC, when the Sumerians developed the first type of script: hundreds of abbreviated pictograms that could be pressed into clay [SAGAD](p.37). Each object was depicted by a symbol: each symbol was an ideogram or word symbol. A writing system of this kind served purposes that were limited: it was employed for bookkeeping, the establishment of regulation and control over the products of agriculture and craftsmanship. The oldest texts listed livestock and agriculture equipment; a system of numbers was soon developed, a stroke indicating units and a circular impression tens. Individual symbols for nouns, verbs, and adjectives followed [LaeAD](p.9). These symbols were eventually refined and simplified. As round shapes were hard to make into clay, they were replaced by lines, and depressions were made at the beginning of the line, creating the unique style known to us as cuneiform script. An example clay tablet is shown in the figure below:

**Wheel:** The invention of the wheel to assist transportation was made in Uruk, Mesopotamia during the third millennium BC. The idea of the wheel is of course much older, and was used first in Mesopotamia for wheel-thrown pottery. When sledges carried heavy loads, log rollers were placed beneath the sledges, eventually evolving into wheeled vehicles, as identified at Uruk by 3000 BC [Whe]. Ancient

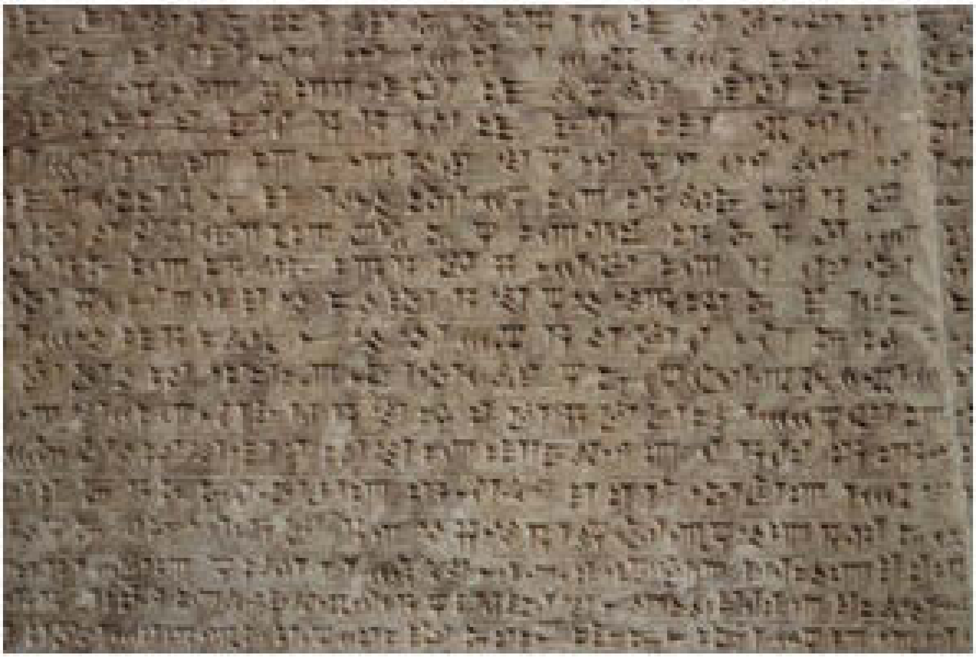


Figure 5.2: Cuneiform Writing on A clay Tablet

wheels of course were used for transportation and also later in war chariots pulled by donkeys. The first wheels started off being made of a solid circle of wood and later spokes were added so they were lighter and much more efficient. The invention of the wheel also created a great increase of trading and food surpluses and also an increase in the production of natural resources.

**Pottery:** The best Uruk period pottery is wheel made but undecorated and unpainted, with a red colored slip or a gray color; the most typical (and far from best) are "bevelled rim bowls" about the size and shape of a modern day custard bowls as presented in [Fie81]. Distinctive forms of pottery were medium sized globular jars with hammer headed or rounded rims, shallow dishes and bowls with inward curving. These were made of clay with the help of a wheel. Use of a wheel also allowed the mass production of ceramics and then these pots were sun baked to make them usable.

### 5.2.2 Food:

Sumerian agriculture in 3000B.C. suggests a wide use of various cereal grains in Uruk food. People used to grow barley, wheat and among these agricultural products were dates and various other vegetables. A great source of protein was provided with meat of sheep, goat and these animals were also kept as domesticated animals [SAGAD](p.98).

Evidence for tools by the two of the pictograms found on the Uruk tablet shows the use of ploughs with a seed funnel. In Uruk, hard over-fired clay sickles were widely used. Many agricultural tools would have been made of wood, and even of reeds, which were widely used for baskets, booths, doors, and mats in which case all traces of them have vanished. The more elaborate types of equipment, such as ploughs, were presumably owned by only the richer farmers and were pulled by animals like oxen. Smaller men hired them, with the draught animals, from the temples when they were needed. Stock rearing in general was an important element in the economy. Large flocks of sheep and goats were kept by the temples [SAGAD](p.68). Uruk was on the bank of river Euphrates which helped for irrigation of the land. Other situated sources of drinking water were water wells, where mostly women were responsible to carry the water. Uruk residential houses also had small mud bricked water tanks for the purpose of water storage like animals' drinking water and other similar uses.

Fish also supplemented the diet of Sumerians and fishermen used to catch the fish from a boat with a spear. Animals were cooked on an open fire and people used to start the fire by striking two stones against each other [SAGAD]. Due to hot dry weather, people used to spent time on their house roofs. They also used reed made mats to sleep on top of their roofs.

### 5.2.3 Schools:

For the purpose of training scribes in Sumerian society there were schools. The information about the scribal schools comes in the form of texts written in Sumerian by people trained in those very schools, giving a detailed account what went on in them [SAGAD](p.40). It is clear in the first place that education was not a common practice, but was largely a privilege restricted to the children (probably only sons, though daughters were not necessarily excluded) of the wealthy and influential, who could afford to maintain their children non-productively for a long period. The examination of the percentage of several hundred scribes shows that they were all sons of such men as governors, senior servants, priests or scribes. An occasional poor boy or orphan might be lucky enough to be sent to school if he were adopted by a wealthy man. The schools were known as 'the tablet house'. An ancient tablet refers to an early youth when his formal education began. He lived at home, got up at sunrise, collected his lunch from his mother, and hurried off to school. If he happened to arrive late he got punishment with a caned stick and the same awaited him for failure to perform his exercise adequately.

The Sumerian document gives some idea of the staffing of the school. At the top was the Headmaster, whose Sumerian titles meant literally 'the Expert' or 'the Father of the Tablet House'. Assisting him there was apparently a form-master, as well as specialists in particular subjects, such as Sumerian and mathematics. Their study was "practical." It was rote learning of complex grammar and practice at writing using clay tablets. Historical remains show that people of Uruk played board games in their leisure time [Gam]. Students were encouraged with praise while their inadequacies and failures were punished with lashes from a stick or cane.

## 5.3 Teaching History to Digital Natives

The way the general public and students learn history is based on methods used by subject matter experts to preserve this knowledge. These learning methods rely on investigating the outcomes of archaeological excavations, related written sources, drawing and various models of ancient artifacts and scenes associated with a particular culture. [BRS10] illustrates the various approaches to preserve and transfer cultural knowledge. In the traditional approach as shown in Figure 5.3, knowledge transfer and preservation relies on subject matter experts including archaeologists, historians, anthropologists and art experts. This traditional approach primarily focuses on understanding significant buildings, customs, events and inventions associated with a cultural site. Cultural elements of lives and behaviors of the ordinary population specifically their social norms, cultural rituals, interactions with other member of society and movements are ignored.

The new advancements in technology provide an opportunity to improve the methods of preserving and teaching ancient cultures to *'Digital learners'* [Pre01c]. The use of video and 3D visualization technology for simulating significant historical and cultural sites are on the rise now as presented in Figure 5.4. These 3D models of ancient sites are created from the same traditional sources as archaeological excavations and written sources. Visitors in 3D modeled sites can visit different places and observe artifacts from different angles. But such an approach offers more opportunities to study architecture rather than supporting the formal knowledge transfer of ancient history and culture. Recreating 3D ancient sites with almost no focus on ancient people or simulating crowds just to provide attractive characters does not support every aspect of learning ancient history and culture.

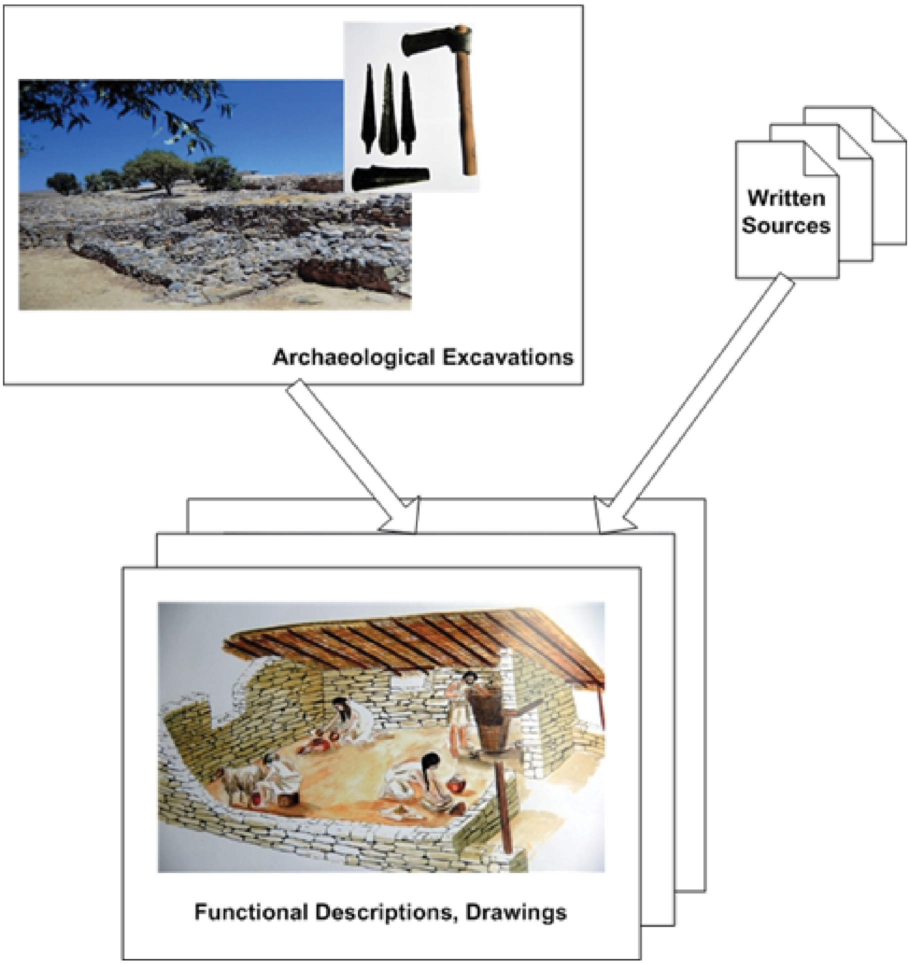



Figure 5.3: Traditional approach to culture and history preservation [BRS10]

Considering this lack of the human factor in current approaches our research group came up with another approach to teaching history and culture. We used Virtual Worlds technology for recreating significant heritage sites from archaeological excavations and written sources. In a Virtual World all participants have an embodied representation as avatars and all participants can navigate the virtual space freely, interact with other participants, and change the Virtual World itself by creating/editing virtual objects [BRS10]. Therefore, our approach extensively relies on direct participant involvement in the learning process and in

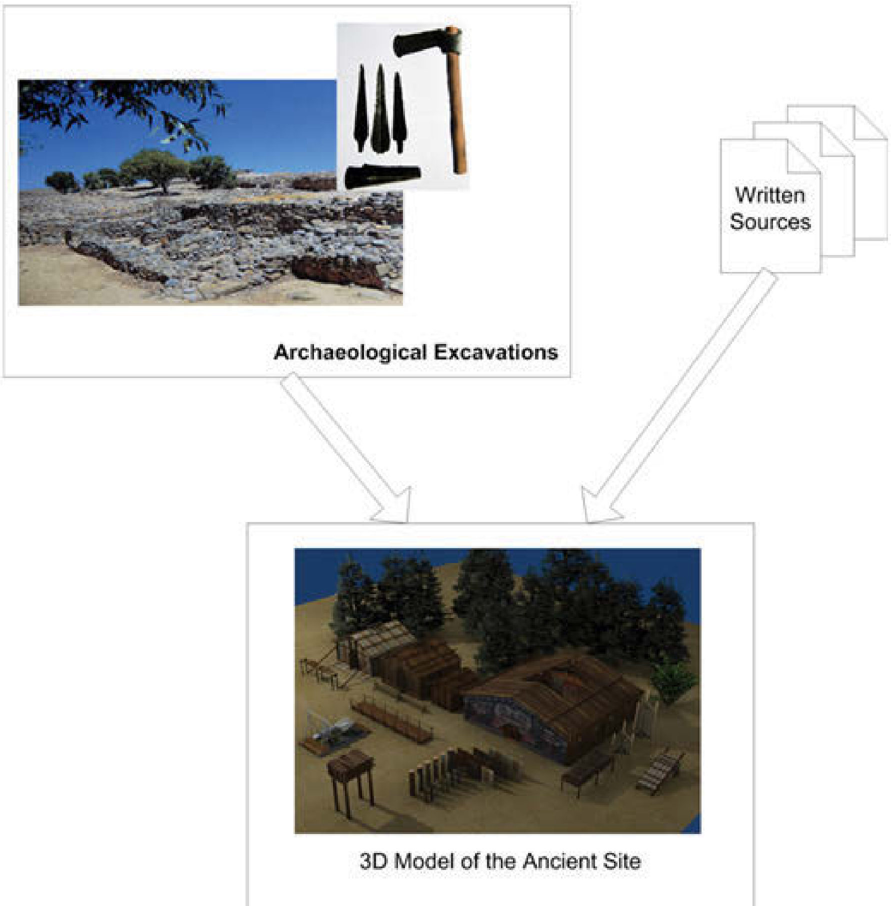



Figure 5.4: Innovative approach to culture preservation

a similar manner we have populated it with virtual humans enacting the ancient population of the virtual city.

A 3D Virtual World based approach has two benefits and it is used for both preserving and teaching the given culture to visitors. We have two types of participants in our virtual city: visitors and subject matter experts. Visitors' role is to learn about the given culture through being immersed in different places and interacting with virtual inhabitants, whereas subject matter experts have a critical role in preserving the culture. These experts share their knowledge by embodied

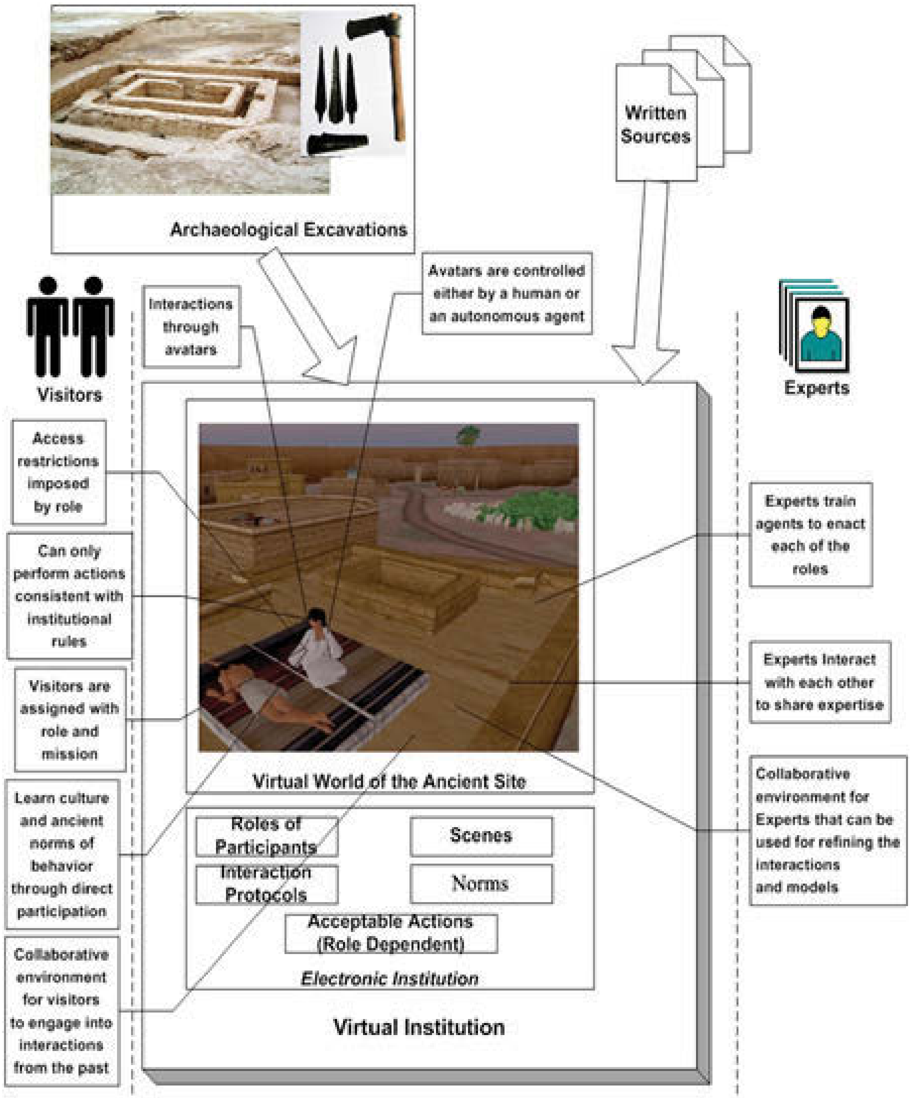



Figure 5.5: Our approach to preserving and simulating culture [BRS10]

interactions with other participants, improve the appearance of historical artefacts in the virtual environment, validate the correctness of the reconstructed buildings and help to refine the behavior of virtual agents as proposed in this thesis. As presented in Figure 5.5, our heritage site is re-created in the Virtual World and populated with virtual humans that look and behave similarly to the actual people that lived in the same ancient city. With the help of Virtual Institutions technology [Bog07] the virtual agents can engage in complex interactions with other participants and follow the social norms of the ancient culture. In the given approach, learning history is not only based on a 3D re-created ancient site but participants can also immersively interact and learn from embodied conversational agents enacting the ancient population. Thus, believable interactions in such an environment plays vital role in learning and this thesis aimed at improving the believability of embodied conversational agents through awareness believability.

## 5.4 Implementation with SecondLife

It is known through historical data that Uruk was a very large city surrounded by walls. It consisted of several districts and houses of approximately 50000 people. Due to limited capacity, our research group re-created selected significant buildings and areas in the actual city. Our virtual Uruk is a 3D replica of these artefacts and buildings based on the results of archaeological excavations. It includes the following major locations: temple, school, ziggurat, market place, well, fireplace and a number of residential buildings. At the current stage of prototype only the given places are used by the virtual agents: temple, fireplace, well, market place, couple of residential houses and fishing.

Virtual Worlds technology has been used to model these places, environment, objects and residents in the formal model of virtual culture. Particularly Virtual World of SecondLife was selected to model this virtual city. This Virtual World provides close collaboration for its participants by allowing them to use the same environment both for object building and navigation. Our research group modeled the virtual heritage site through the following phases:

- The site is mapped and major artefacts are selected by the archaeologist using the existing site plans.

- A virtual 3D model of the buildings and environment is created in SecondLife using real measurements.

- Each model of the given building and virtual scenes is placed according to the real site plan.

The ziggurat is one of the major places to worship Uruk's god and goddess. In Figure 5.6, we present the phases of constructing the ziggurat in the virtual city of Uruk.

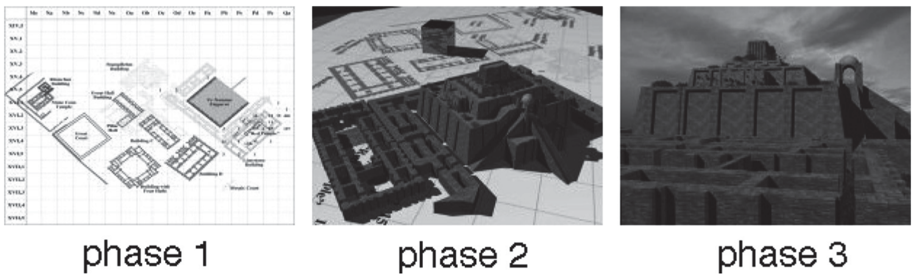



Figure 5.6: Phases of building the virtual city [BRS10]

Once we had designed the 3D model of the virtual city, the next vital step was to make it alive with an ancient population and to define the norms of society for visitors/virtual humans. The virtual agents act as a source of knowledge preservation and share this knowledge with visitors on demand. The virtual Institutions maps help to formalize the virtual environment and provide social norms, define roles and interactions, demonstrate the role flow policy for both human visitors and virtual agents in the virtual city as was developed for the $I^2B$ framework by this research group. A comprehensive 3-dimensional model of the virtual city is also presented in Figure 5.7.

Figure 5.7: City of Uruk, populated with buildings and objects in virtual world of SecondLife [BRS10]

## 5.5 Agents

Virtual agents are the central entity in our model to preserve and share cultural knowledge. We have simulated the life of ordinary people who act as knowledge carriers in the virtual city. Virtual agents in SecondLife are developed through the libopenmetaverse library[1]. This library is a reverse-engineer attempt to implement the client-server of SecondLife. The client-server approach also introduced a problem to our agents'architecture as libopenmetaverse is based on UDP protocol which suffers from packet loss. The actions performed by other participants and the agent's own action can only be performed through a server. To avoid packet loss due to network latency our group established a synchronous

[1]Url: openmetaverse.org

communication protocol. Our current agent architecture benefits from the following research group's effort to provide believable locomotion, object use, gaze model and normative control through virtual institutions technology. Moreover, this thesis highlights the development of environment interaction and believable agents' communications with human participants. The following list provides details of each of these facilities:

- Environment Interaction: libopenmetaverse helps to implement the visual part through SecondLife technology and the normative part is supported through virtual institutions technology.
- Communication with Humans: Agents communicate through the chat mechanism provided by SecondLife which is based on the ALICE chat engine.
- Actions: All the agent actions and animation are performed through SecondLife server.
- Locomotion: Agents'locomotion is done by an artificial potential field method to avoid collisions and to provide natural movements.
- Object Use: A designated library to implement proper use of environmental objects and their attachment to the agent's body. The library also plays related animation and detatchs/drops the object on the correct location.
- Gaze: An attention based gaze model is supplied to create believable agents. These agents can shift their gaze between objects and avatars based on the level of interest.

For the purpose of the work outlined in this thesis we selected two fishermen and a king's daily life in ancient Uruk to explain the awareness believability model and learning effectiveness in a virtual city. Each fisher family consists of husband

and wife enacting the daily life of fishermen living in the virtual city. The king represents the famous (*King Imgursin*) from the ancient Uruk city. Each agent has a historically authenticated appearance and dresses in accordance with 3000 B.C. Every agent lives in Virtual Worlds of SecondLife and has an appropriate daily routine.

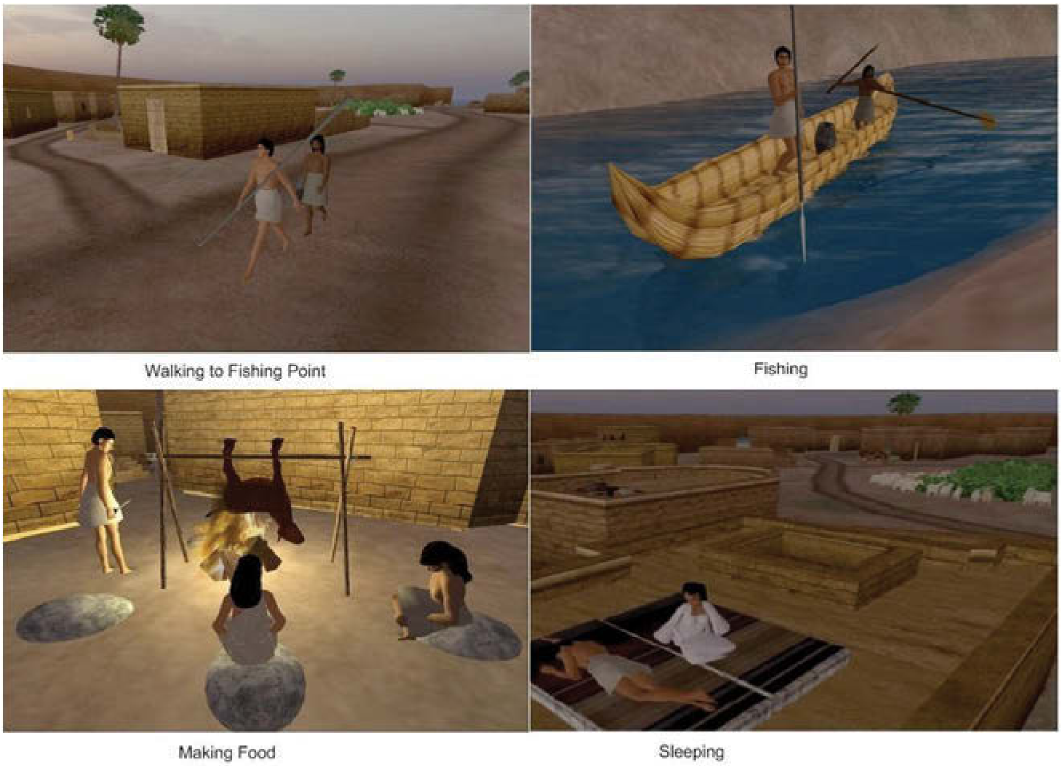



Figure 5.8: Virtual Agents in the City of Uruk

For fisher families their day is approximately 15 minutes and it starts with waking up on the roof top(to avoid the high temperatures inside the house) of their houses. Their wives wake up first as presented in Figure 5.8(d) to bring water from the well and prepare breakfast for their husbands. The husbands usually wake up after them and start their day by having a morning chat on a meeting point near their houses while their wives prepare breakfast. After breakfast, fishermen collect fishing gear and approach towards the city gate as shown in Figure 5.8(a). One of the fishermen is a spear owner where the other fisherman owns the boat which they find on the bank of the river outside the city gate. Both of them board it and start fishing. One of the virtual agents stands in the boat with a spear to catch fish while the other agent sits and rows the boat. Figure 5.8(b) illustrates this fishing process. After fishing, they come back home with a fishing basket and fishing gear. These agents' daily life cycle then repeats with some modification in agents' behaviors.

(a) (b)

Figure 5.9: Fisherman Family 1: Fisherman1 Andel and Wife1 Andel

Each fisherman agent enacts one the of four social roles in the city. Agent fisherman1 has the "SpearOwner" role. He is a young male fisherman living with his wife possessing a fishing spear and uses it to catch fish. He jointly owns a boat for fishing with his brother. His day starts by waking up on the roof top of his house and by having a morning chat with brother fisherman2. He then proceeds with fishing, bringing the fishing gear back home and returning to the roof to sleep.

Wife1 Andel has the "WaterSupplier" role. She is the wife of fisherman1 and has the duty of carrying water from the well. She has the daily routine of waking up on the roof, collecting the water from the well, doing home chores and climbing back to the roof to sleep. Similar to any other fisherwive's life she spends most of her day doing house work with no recreation during the day. The agents fisherman1 Andel and and wife Andel are shown in Figure 5.9.

(a) (b)

Figure 5.10: Fisherman Family 2: Fisherman2 Jigsaw and Wife2 Jigsaw

Agent Fisherman2 is the older brother of Fisherman1 Andel having the role of “BoatOwner” in the city. He lives with his wife in a separate house near by the younger fisherman family. Fisherman2 owns a fishing basket and paddles to row the boat for fishing. Both families live near by and spend most of their time together. His daily routine starts with waking up on the roof top, having a morning chat with his brother, fishing, bringing the fishing gear back home and returning to the roof to sleep.

Wife2 Jigsaw is the wife of Fisherman2 with the role of “Firekeeper”. Her responsibility includes starting the fire and preparing the food for the family. Her daily routine starts with waking up on her house roof top, starting the fire to prepare food, doing the house work during the day and climbing to the roof to sleep. This second fisher family is presented in Figure 5.10.

In the present study, we also have a virtual agent “ImgurSin Kariunga” to represent the king of Uruk. He has a rich angry personality. Being a king, he does not have any duties, rather he walks around his palace and observes how

Figure 5.11: Uruk King: ImgurSin Kariunga

the local villagers praise him. Figure 5.11 presents King Imgursin during a usual day in Uruk.

## 5.6 Summary

We have applied the concept of awareness believability and learning to embodied conversational agents in our case study "The City of Uruk". This chapter explains the significance of our case study in regards to its historical background which dates back to 3000 B.C. We aim to provide teaching ancient history and culture to young children of this digital age in a more interactive and immersive way. Our approach to learning history not only provides 3D historical artefacts in a virtual city but we also focus on providing believable interactions to the ancient population of Uruk.

To achieve this goal, we have re-created the ancient city in the Virtual World of SecondLife and made it alive with virtual agents representing the ancient population. This chapter has illustrated the virtual city and its virtual inhabitants in SecondLife. In the next chapter, we will evaluate the concept of awareness believability for embodied conversational agents and students'learning effectiveness in the virtual city of Uruk.

# CHAPTER 6

# Experimental Evaluation

This chapter presents an evaluation of the two major aspects of our prototype: first, the study in which we evaluated the awareness believability attributes to enhance the overall believability of embodied conversational agents during their interactions with participants. Second, the study we conducted to compare learning outcomes about the historical city of Uruk through text reading vs visiting the same city in 3D Virtual Worlds. In the coming sections, we present a detailed overview of these two experiments.

## 6.1 Experimental Setup: The City of Uruk 3000 B.C.

As a case study we created a virtual reality simulation of the ancient city of Uruk in the virtual world of Second Life, based on the results of archaeological excavations and under supervision of subject matter experts. It is populated with embodied agents that simulate the behaviour of its ancient citizens. The case study tackles the domain of history education and aims at recreating the ancient city of Uruk and reenacting the life in it from the period approximately 3000 B.C., showing the visitors what it looked like and how its residents behaved in the past [Bog11]. This work is based on the prototype developed by our group [BRS09].

The agents represent a slice of Uruk society among which are fishermen families, priest, king and a number of workers (i.e. pot maker, spear maker). The agents can sense changes in the environment state, which results results in them updating their beliefs accordingly. They are supplied with a number of internal goals and plans to reach those goal.

The users can interact with the agents via chat facilities. User commands are given the highest priority, followed by the pray request from the priest. Next comes praising the king (the agent will fall face down when the king is in close proximity). Finishing work and resting are the normal priority plans. Finally low priority is allocated to random walk and social chat with other agents.

Our objective is to provide an engaging and interactive learning experience to history students by immersing them in the daily life of Uruk. Through embodied interactions, virtual agents will teach various aspects of Uruk history, culture and the daily life of ancient Sumerians. Virtual agents' behaviours and social interactions have been institutionalised with the help of the VI technology. For chat responses to human users the agents rely on the set of AIML rules. Those rules can be modified via imitation by authorised subject matter experts. Before this present work, these virtual agents had daily routines in place but interactions with other participants were very limited - they could only talk about pre-fed historical facts with the visitors and were not aware of their surroundings while performing daily life routines. To illustrate the awareness believability attribute, in their conversations the agents can refer to certain objects in the city and provide relevant explanations, can explain why are they doing things in a certain way, relate to their state in various scenes or make references to current or future possible actions of other agents.

## 6.2 Believability Evaluation

No formal definition of believability exists, nor are there clear methods to measure it. Thus, we have adapted and modified to our needs the approach in [GTB06]. The subjective nature of the approach has stimulated another aim of our work - the design of a rigorous objective evaluation of believable conversational agents and the calculation of a believability index as a measure of their human-likeness.

### 6.2.1 Selected Study Instruments

As mentioned earlier, the purpose of the first study was to evaluate the awareness believability of conversational agents during interaction with participants. Due to the very subjective nature of believability itself, we designed a post test questionnaire containing two parts(demographic and rating the conversation section). This questionnaire collects both quantitative and qualitative data to access believability with proposed attributes. We then devised a believability index based on this data collection for each part of participants' conversation with virtual agents. Moreover, an informal discussion with participants helped us to acquire interesting feedback.

The demographic information included the following aspects: gender, age, frequency of playing video or computer games and experience of Virtual Worlds. Participants were specifically asked to record how often they play video or computer games, and how often they use Virtual Worlds. Their answers were further measured with a Likert scale with the following time frequencies: never, rarely, sometimes, often and always. In the end, participants also gave a general feedback of the system(Uruk case study) and their interaction with it.

### 6.2.2 Procedure

Participants chosen for this study were primarily university undergrad and post-graduate students with various educational and linguistic backgrounds. In total, 22 students participated in this study. All the subjects participated voluntarily and filled in the demographic section of the questionnaire, in the presence of the researcher. They were then randomly assigned to one of two groups: the aware agents group(Embodied agents with proposed believability attributes) and the unaware agents group(Embodied agents lacking proposed believability attributes). These two groups of participants then visited our virtual city of Uruk and conversed with the respective group of embodied agents living in the city. Each session lasted approximately 40 minutes, during which each part of the conversation was rated by the participants. Recording the general feedback after these interactions took about 5 minutes.

### 6.2.3 The Design of the Experiment

To test the believability of our agents, our experiment and analysis technique adapted some of the work in [GTB06]. We provided participants with the background about Uruk and this study. During experiments the participants didn't know whether they were conversing with avatars controlled by agents or humans.

To evaluate the believability of conversational agents, presenting participants with video clips or other test mediums, as performed in [GTB06], was not acceptable due to the issues of biased responses and guess work. To minimise both we ensured that (i) participants interacted with our conversational agents in the actual virtual world; and (ii) the designer had no control over the routines of the agents nor the flow of participants' conversations with them.

Also, presenting participants with a highly immersive, engaging and interactive experience was essential in this study. From our past experience we learned that navigation in virtual worlds requires some experience. Hence, the experiments were supervised by a researcher in order to assist participants with interfacing the agents.

Each participant was assisted to enter as an avatar into the city of Uruk. The participant was then requested to converse with two fishermen agents in the city and advised to keep their focus on the environment-, self- and interaction-awareness of the virtual agents. The researcher navigated the agent herself, while the participant was directing her where to go, whom to talk with and what to ask. This allowed the participant to focus on examining the believability of the agent's dialogue in the context of its environment, actions and the behaviour of other participants in the city. The participant was asked to assess the believability of each dialogue on the scale:
{*1:Definitely Human; 2: Probably Human; 3:Not Sure; 4:Probably Artificial; 5:Definitely Artificial*}.

The rating of agents' conversations and behaviours was used for calculating the believability index. The participants were requested to repeat this exercise for all parts of their conversations with our agents. They also provided specific feedback where they thought an agent's reply was artificial.

To minimise the chances of participants averaging out the believability index (i.e. when a participant rates some virtual agent's responses as "Human" just because she rated a few previous responses as "Artificial", we advised participants in the introduction that their rating should be purely based on their perception of the conversational behaviour of the avatar in the virtual world.

### 6.2.4 Measuring Believability

For measuring believability we modified the equations for the believability index in [GTB06] to reflect the interactive nature of our experiment, where the questions asked may differ across participants. Such an index reflects the participant's certainty with which s/he perceived a virtual agent as human-like or artificial. The equation for calculating the believability index for each dialogue is shown below:

$$h_p(c_i) = \frac{|r_p(c_i) - A|}{A - B} \tag{6.1}$$

where $h_p(c_i)$ is the perception of participant p of correspondence $c_i$ as human-like and $r_p(c_i)$ is the rating of participant p for the same correspondence $c_i$. A and B represent the "Artificial" and "Human" value of the virtual agent response on the rating scale. $h_p(c_i)$ will be "0" if the respondent identified a virtual agent's response as "Artificial" or "1" if s/he identified it as "Human", where all other values represent uncertain choices. The believability index based on a single participant is the average of her perceptions:

$$b_n = \frac{\sum_{0<p\leq n} h_p(c_i)}{n} \tag{6.2}$$

where $n$ is the total number of responses per experiment. The overall believability in virtual agent's conversation $B$, based on the rating given by $m$ participants is

$$B = \frac{\sum b_n}{m} \tag{6.3}$$

In a similar fashion, we could also measure the believability of each category for all participants in their conversations.

### 6.2.5 Data Collection and Analysis

The believability analysis was conducted based on the conversations with aware and unaware agents - we wanted to evaluate how believable our agents would be if we supplied them with awareness features. The experiment was based on the three awareness believability dimensions we have identified: (1) environment-awareness; (2) self-awareness; and (3) interaction-awareness. Those who lack these features are regarded here as unaware agents. to mentioned, one group conversed with aware agents, the other group with unaware agents. The experiments were conducted over a two week period. After eliminating the incomplete responses, the data that were analysed included the responses of 22 participants - 11 per group.

Table 6.1: Believability comparison for aware and unaware agents

| Category | Unaware Agents | Aware Agents |
|---|---|---|
| Believability of environment-awareness | 0.22 | 0.76 |
| Believability of self-awareness | 0.26 | 0.75 |
| Believability of interaction-awareness | 0.30 | 0.77 |
| Overall Believability | 0.27 | 0.76 |

Table 6.1 shows a summary of the results for comparing aware and unaware agents. The overall believability index for aware agents was 0.76 and for unaware agents 0.27. The comparison along our awareness believability dimensions shows that for environment-aware queries in 76% of the cases participants perceived the aware agent as human and only 22% time unaware agents were misclassified as humans. For queries about agent's own goals, plans, actions etc., aware agents were ranked as human 75% of the time in contrast to 26% misclassification of unaware agents as humans. In the case of interaction-awareness, aware agents were believed to be humans for 77% cases and 30% cases misclassified unaware agents as humans. These results indicate that it was relatively difficult for participants

to differentiate between aware agents and humans based on their conversations.

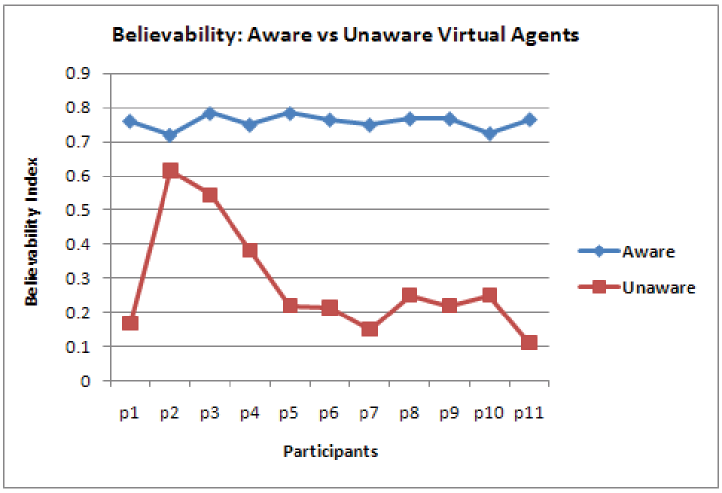



Figure 6.1: Believability comparison: aware vs unaware virtual agents.

Figure 6.1 shows the individual believability evaluations, which ranged within 0.72 to 0.78 across participants dealing with aware agents but varied substantially for unaware agents. However, unaware agents were always evaluated lower and sometimes considerably lower in believability index. As our unaware agents were based on AIML rules, in the early stages of a conversation they managed to give an impression of a real person, but later in the conversation participants correctly identified them as artificial.

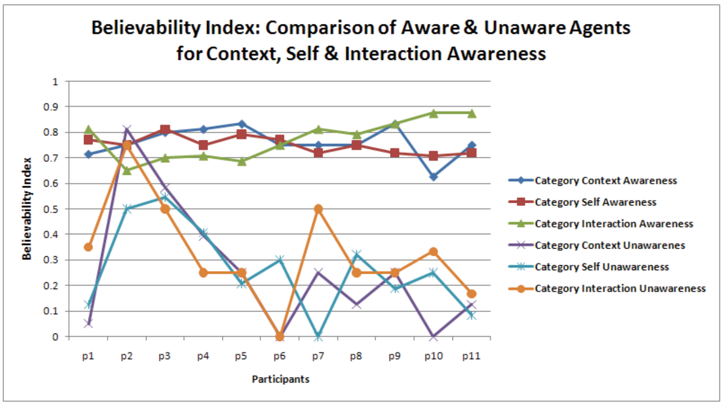



Figure 6.2: Believability index comparison for each category.

To test the believability of aware and unaware agents' conversations in each of our awareness believability categories, recorded conversations were partitioned into three categories: environment-, interaction- and self-awareness. Figure 6.2 shows a very high human-likeness (0.6 to 0.8) for each category in our aware agents.

## 6.3 Evaluation of Students' Learning Effectiveness

Our second study aimed at comparing the two different ways of learning history and culture. We had two participating groups in this study: the first group which we call the "Traditional Group" was advised to read a history text describing the facts about our case study: City of Uruk (3000 B.C.)and its inhabitants as given in Appendix(A). Participants in the second group, named the "Virtual Group" were asked to visit the virtual city of Uruk to have an interactive learning experience about the same facts as the text based group. In the virtual city of Uruk, participants had to visit the virtual city individually. Each student was given an avatar to represent him/her as a visitor in the city. With this avatar, each student can immerse, interact and experience the virtual city. To successfully complete the study, all the participants were given guidelines to interact with the system and virtual humans living in the city. The learning task in the virtual city of Uruk was based on two given activities:

**- Visiting and exploring the virtual city:** Participants could learn about the city by navigating, observing and exploring the various places in the virtual city. To learn more about major buildings and artifacts, these places have *'More Info'* pointers to give further information. These information pointers contain the same facts as were given to the traditional group in the Uruk text document.

**- Conversing with Virtual Humans:** Participants could also converse with virtual humans present in the city. These virtual humans were aware of their daily routines, tasks and interactions with other participants and acted as a learning source.

The two groups were aiming for the same learning objectives and contents, and were also able to access supervision if they required. It was assumed that any variation in student learning outcomes and appeal to students could be attributed to the group type factor. Based on our research objective of evaluating the learning of history and culture in 3D Virtual Worlds in comparison to text based learning, we have these hypothesis formulations:

- Students from the virtual group will have significantly higher learning outcomes in history and culture in comparison to the students from the traditional group.
- Student evaluations will show whether learning history and culture had more appeal to the virtual group students than students in the traditional group.

To conduct a comparison study between the virtual and traditional groups, we needed to find the best possible method. Therefore, we conducted a pilot study with a virtual group before the actual study to ensure the best possible procedures for participants visiting the virtual city. The next section will discuss this pilot study to explain the findings.

### 6.3.1 Pilot Study for Virtual Group

We conducted this pilot study with three participants to define the procedures for virtual group participants in the real study. We analyzed three possible methods of conducting the user study for virtual group participants: Unsupervised, Supervised & Controlled and Supervised & Uncontrolled.

Using the first method - unsupervised - participant was briefed about the study and was left unsupervised to interact with the system. Participant's feedback in the post-test questionnaire shows that the city was not properly explored and observed. Although time spent by the participant suggests that he/she found it interesting and quite motivating due to no supervision during the study, the participant missed important information in the city and did not achieve the learning goals properly.

The second method conducted was supervised and controlled. Similar to the first method, the participant was given an introduction to the case study and its objectives. By controlled we mean here that the researcher was navigating and controlling the avatar. Through this navigation was according to the participant's desire as to which area he/she wants to visit. The participant also had access to researcher assistance whenever the need occurred during this interaction. Feedback showed that the learning outcome of the participant was much higher than the unsupervised session. But the participant's observation during the study indicated his/her dependance on the researcher, which was very undesired in this study. The second major issue with this method was a bit less interaction and immersion of the participant during the session as the researcher was controlling the avatar movements. This could also badly influence the aim of providing the interactive experience proposed by this project.

The third session to choose the best possible method for this study was also supervised but unlike the second method it was uncontrolled. The participant was provided with full control of the system after introduction of the navigation controls and study objectives itself. During the session the researcher accompanied the participant and he was also allowed to seek any technical help needed for visiting the city. This supervision also gave us a chance to observe the participant closely during this interaction. After the interaction, the participant was given

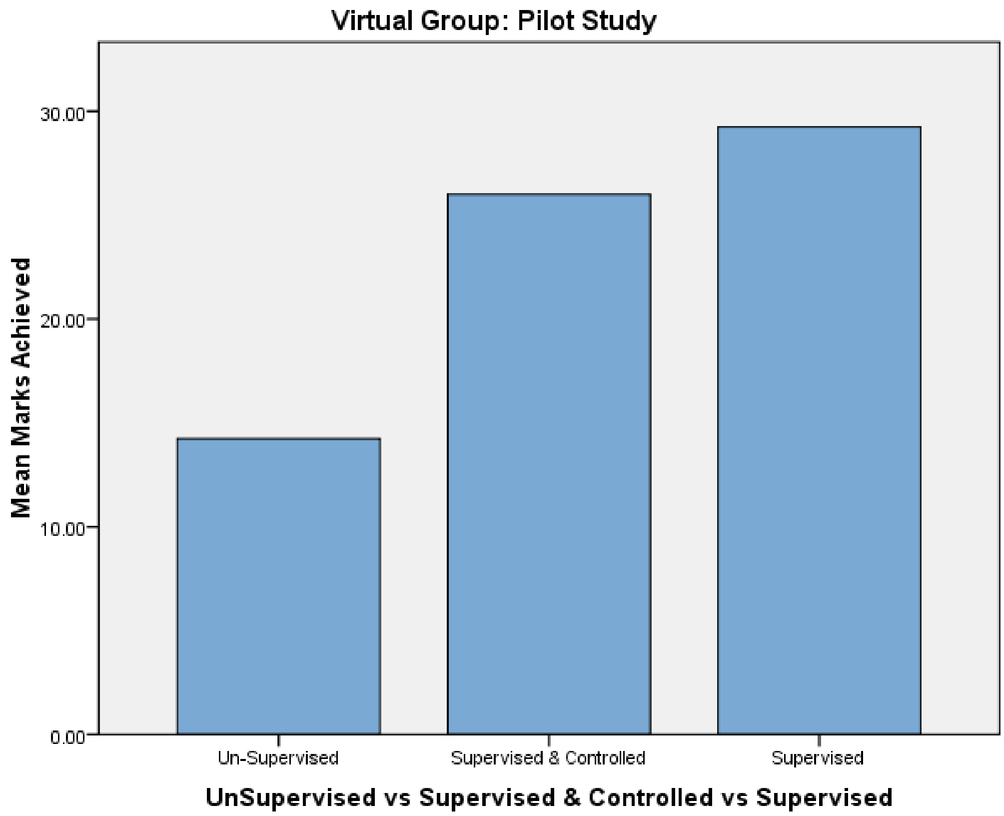



Figure 6.3: Pilot Study: Comparison of three Cases

the questionnaire to record his feedback and was left alone during this part of the study. Results for this uncontrolled session were encouraging. The researcher present during the first virtual city interaction part helped us to get a general feedback of the system and also saved the time in case of any technical assistance required.

Figure 6.3 shows the comparison between these three methods represented on the x-axis where y-axis depicts the marks achieved by each of these students. The first student who was not provided any assistance during his visit to the virtual city showed very unfocussed learning and achieved the least marks(approx. 14 marks) among the other students. The second method was supervised and controlled, using this method the student showed better performance and focussed learning by achieving approx. 27 marks. In contrast to these two, here student in the third method was supervised for any technical queries during his visit to virtual city achieved the highest marks (approx. 30 marks) in the mini exam conducted after the visit to the virtual city.

As a conclusion of the pilot study conducted shown in Figure 6.3, undoubtedly the third method was most productive and aligned to our aims. The participant was supervised during the interaction part of the study and later recorded the feedback unattended. This helped us to achieve learning goals without over shadowing the participant's beliefs and his understanding of the historical facts learned during the interaction.

### 6.3.2 Research Instruments

The motive of this research study was to collect both quantitative and qualitative data. Therefore, the questionnaire developed contained two parts: the pre-test part collected the users' demographics and their background knowledge about the city of Uruk as outlined in Appendix(B). The second part was a post-test questionnaire aiming to test the knowledge gained about the city of Uruk in the two study groups. The pre-test questionnaire consisted of six multiple choice questions about the participant's demographical information and one pre-coded(open ended) question to test previous knowledge of the historical city. The post-test part of the questionnaire aimed at examining the knowledge gained in these user groups(an open-ended questionnaire for participants' feedback). Furthermore, an informal observation of the students was performed during two types of study sessions. The virtual city of Uruk was developed with the coordination and support of subject matter experts who guided for artifacts, buildings, people and overall design of the city.

The traditional group was provided with a text describing the city of Uruk, specifically it included people, buildings, climate of the city, historical significance, food, agriculture, trade and inventions made in that era. This text was designed with the help of subject matter experts. This text description comprised the same facts on which we developed our virtual city of Uruk. The two study groups had historical facts of the same level of difficulty and the same learning aims. The virtual group interacted with this virtual city of Uruk to learn about the historical facts the same as the text based students group.

similar to our first study, the demographics section included the following questions: gender, age, native English speaker,level of studies, field of study and frequency of playing video games or using virtual Worlds. These were multiple choice questions where students were asked to choose their age from the given age groups. A Likert was used to measure the participant's use of video games or Virtual Worlds with the following frequencies:

- Never, Rarely, Occasionally, Often, Very Often.

In comparison, the pre-test question about the previous knowledge of historical city of Uruk or Ancient Mesopotamia was asked prior to the test start. This question was open-ended and pre coded to gather maximum participant's feedback.

The objective of the post-test questionnaire was to measure the student's knowledge of historical concepts presented in two different ways. Similar to the pre-test knowledge question, but with more detailed categories of questions, the post-test questions fall under four major aspects to test the knowledge: climate and buildings, people/food/animals, agriculture and trade, Uruk inventions. These categories were based on the Uruk's prototype we developed in the Virtual World; the evaluation of the virtual humans and the city was done by the same experts.

The post-test feedback and the informal student observation were aimed to collect all the possible details that the researcher could collect regarding the student's engagement, motivation and enjoyment during the study. We discuss some interesting feedbacks and our observation during this study in the next sections.

### 6.3.3 Participants

We initially proposed to conduct the user study with students in junior grades at school. However, this requires ethics clearance from multiple educational departments and agencies. Considering the short time available to the researcher for completion of degree, we opted for the most suitable choice available.Thus, participants(40 students) in this study were mostly undergraduate and postgraduate students from the University of Technology, Sydney.

All the participants were briefed about the study at the start of their respective sessions, by the researcher or their teacher. These students were then randomly assigned to one of the study groups, the traditional group or the virtual group. The traditional students were assigned a reading about the case study(city of Uruk) and then they filled out a post-test questionnaire. In the other group, students individually visited the virtual city of Uruk before filling the same post-test questionnaire.

At least one researcher was present in each virtual session. The traditional group was assisted by their teacher on behalf of the researcher. A brief description of the study was given for 5 minutes followed by a class session which lasted about 30-40 minutes for two the respective groups. The time required to fill out the post-test questionnaire was about 15 minutes and additionally 5 minutes were required to provide the post-test feedback.

### 6.3.4 Discussion

This section describes the performance of the two student groups. In addition to comparing the traditional and virtual groups for any performance differences, we also compared the maximum learning achieved from different activities within these individual groups. A description of these comparisons is further elaborated in the sections below.

**Comparison of Virtual and Traditional Group:** There was a visible difference in performance gained between the traditional and virtual group students. The metric to measure any performance variations between the two groups was based on the marks achieved in the post-test questionnaire. This performance comparison is illustrated in Table 6.2. Students who participated in the text based group(traditional) can be categorized in four groups based on their marks achieved. As shown in Table 6.2, 15% students in traditional group gained 23 -25% marks and could be referred to as low performing students. Another 35% students in the traditional group also fall into medium to low performing students in this study as they achieved between 32 - 39% marks. Medium performance for this group was shown by 35% students who achieved marks between 58-66%. Among the traditional group, there were 15% students who achieved marks between 58 - 66%.

Students who participated in the virtual group also showed four major categories based on their performances. In comparison to the traditional group 20% students who performed low in the virtual group achieved marks between 40-49%. A larger group of students (35%), showed medium performance with marks gained in between 51 - 60%. 25% students attained marks in the medium to high category with 61 - 69%. However, 20% students could be regarded as high achievers in the virtual group with marks

Table 6.2: Student's Performance

| Comparison: Traditional vs Virtual Group | | | |
|---|---|---|---|
| Traditional Group | Students(%)<br>15<br>35<br>35<br>15 | Marks Obtained(%)<br>23 - 25<br>32 - 39<br>40 - 48<br>58 - 66 | Weighted Average(%).<br><br>41.05 |
| Virtual Group | Students(%)<br>20<br>35<br>25<br>20 | Marks Obtained(%)<br>40 - 49<br>51 - 60<br>61 - 69<br>77 - 88 | Weighted Average(%)<br><br>60.96 |

gained between 77 - 88%.

Comparison of students' performance was also measured with average marks achieved. Virtual group students outperformed, with average marks 60.96%, the students in the traditional group who achieved average score of 41.05%.This low performance achieved by text reading in the traditional group could be associated with the amount of information an average person can remember. Cognitive sciences report that short term memory happens to decay with time. An average person can remember only 50% of the information read within the first hour and it continues to decrease up to 10% after one day of reading as mentioned in [Lep09].

We also aimed to investigate the engagement and interest taken by participants in both groups during the first phase of the study. We used time spent by participants as a measure of their engagement in this study. The average time spent for text reading by traditional group participants was approximately 10-20 minutes. Unlike the traditional group reading time, virtual group participants spent considerably more time 40-45 minutes.

The same trend in both group performances is observed in Figure 6.4. The minimum performance achieved by traditional group students was 23% in

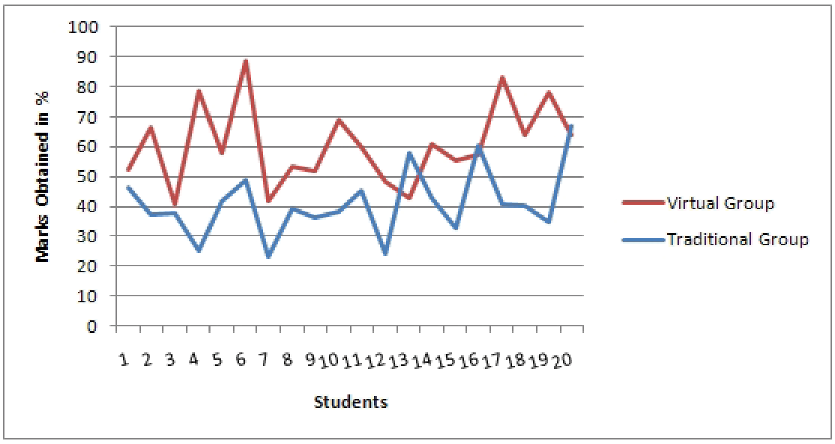



Figure 6.4: Comparing Students' Performance

comparison to the 40% minimum marks gained by the virtual group students. Similarly, the highest marks achieved in the traditional group were 66%, which was quite low compared to 88% achieved by the virtual group students. Moreover, these results show that virtual group performance stayed high for more students than the traditional group.

**Virtual Group - Agents' Conversation vs Reading Text:** During the visit to the virtual city of Uruk, the participants had to explore and learn about the different places, buildings, artifacts and daily routines of virtual humans(agents) living in the city. The two main arrangements to support this learning in the virtual city were: to visit and explore the different places in the city and during this visit participants were given a 'More Info' note displayed in front of different places as shown in Figure 6.5.

These notes contained the same text as was given to the traditional group to learn about the same artifacts/places. Secondly, participants had to learn about the people living in the city namely fishermen as mentioned in previous sections. The virtual humans living in the city were able to converse and reply to the participant's inquiries about their lives and surroundings.


Figure 6.5: Text Note to Describe School in Virtual World

In the post-test questionnaire, we had specific questions about the facts learned by reading the 'More Info' note and daily routines of virtual humans learned by the participant conversation. A comparison of scores achieved for these two separate set of questions indicated the more usable approach to learn was in Virtual Worlds. As shown in Figure 6.6, most of the virtual group participants achieved high marks for the facts learned in conversations with virtual humans in comparison to 'More Info'. Admittedly, the minimum score gained as a result of conversations with virtual humans was 8.33% where the minimum performance for text reading was 22.92 %. But, comparison of maximum performance shows that two participants scored 100% for virtual human conversations. Whereas, by reading the text in 'More Info'note, only one participant attained a huge score and that was only 79.17%. Overall results suggest that on average participants scored 65.42% when they conversed with virtual humans(agents) where average score of learning facts from 'More Info' was 48.23%.

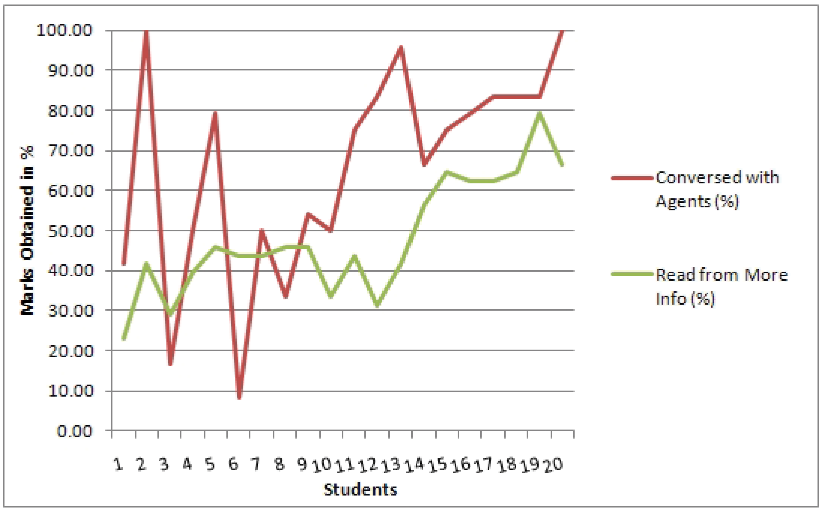



Figure 6.6: Virtual Human Conversations vs Text in Virtual Worlds

**Text Reading in Virtual World vs Traditional Method:** As described in previous sections, the traditional group was given a text to learn historical facts about the city of Uruk. In contrast, the virtual group also had text description of few a major buildings and artifacts. The virtual city 'More Info' notes have the same text of the relevant artifacts as was outlined in the text document for the traditional group. To test the effectiveness of text reading in both groups, we compared the post-test questionnaire for the traditional and virtual groups. This revealed that participants who read text in the virtual city showed better performance gain. The average score achieved by the traditional group for text based questions was 29.27 %, whereas, virtual group participants showed the better performance by attaining an average score of 48.23 %.

The student with the minimum score in the virtual group attained 22.92% in comparison to the low performing student with 4.17% in the traditional group. Likewise, the highest score gained among the virtual group participants was 79.17 % compared to the highest score 60.42% in the traditional

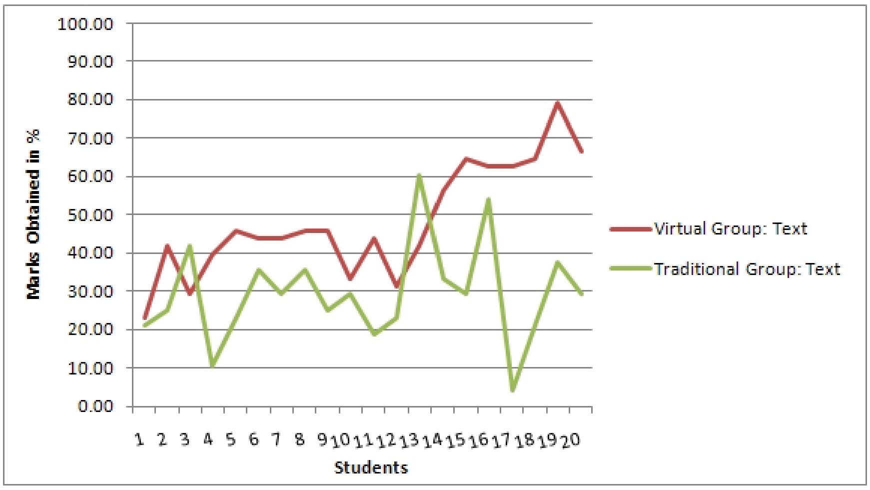



Figure 6.7: Text Reading in Traditional vs Virtual Group

group. A comparison of both groups participants for text reading is shown in Figure 6.7.

### 6.3.5 Data Analysis

A preliminary examination of the research requirements identified that, to evaluate any performance differences between the two participants groups, marks achieved will act as a dependent variable. To evaluate the impact of age, gender, native language, education, participant's background and any previous knowledge on participant's obtained marks, those attributes will serve as independent variables and later will be taken as the dependent variable. We divided our analysis for this study into two parts:

- Participants' Performance Analysis: First we need to analyze and compare the participant's performance achieved in both the traditional and virtual groups.
- Impact of Relevant Factors: The second analysis would focus on any pos-

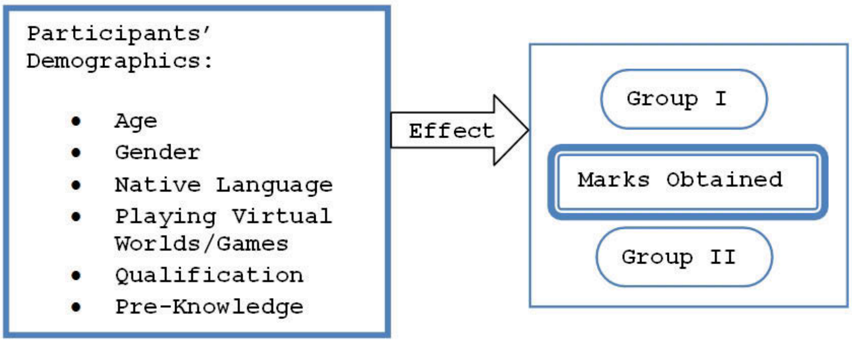



Figure 6.8: Design for Study II

sible impact on participant's performance by varying age, gender, native language etc as highlighted in Figure 6.8.

- Finally, we would investigate the interaction impact of independent variables with each other, in case these variables have any impact on participant's performance.

In this design, all the independent variables have multiple levels, as these marks obtained require an independent test and then a joint test with other n-1 variables. We discuss this design in detail in the next sections.

### 6.3.6 Hypothesis Design

Based on the above mentioned design, the following null hypotheses were tested to analyse the main and interaction effects of the specified factors:

- Ho1 = The marks obtained by each group do not vary significantly.

- Ho2 = Individual variables(Age, gender, native language, playing virtual Worlds/games, qualification and pre-knowledge) of participant have no effect on the participant's performance(marks obtained).

- Ho3 = Effect of any one factor does not depend on the n-1 independent variables.

To test the above formulated hypotheses, a two-way ANOVA Test (using SPSS ver 17) was planned to obtain the effect by comparing the F-ratios to the relevant F-Distributions. The next section gives an insight into the data distribution and analyses of ANOVA assumptions for our sample. Section 6.3.8 describes the data analysis with respect to the performance comparison between the two user groups and section 6.3.9 presents the effect of all the factors on user performance.

### 6.3.7 Test for ANOVA Assumptions

The test method we chose involves certain assumptions to be met before the actual test run. So, the first data set was analysed to verify the assumptions of the ANOVA.

**Independence of Observations:** The independence of respondents was ensured as much as possible by random sampling. All the participants were selected and assigned randomly as mentioned earlier to the two different groups.

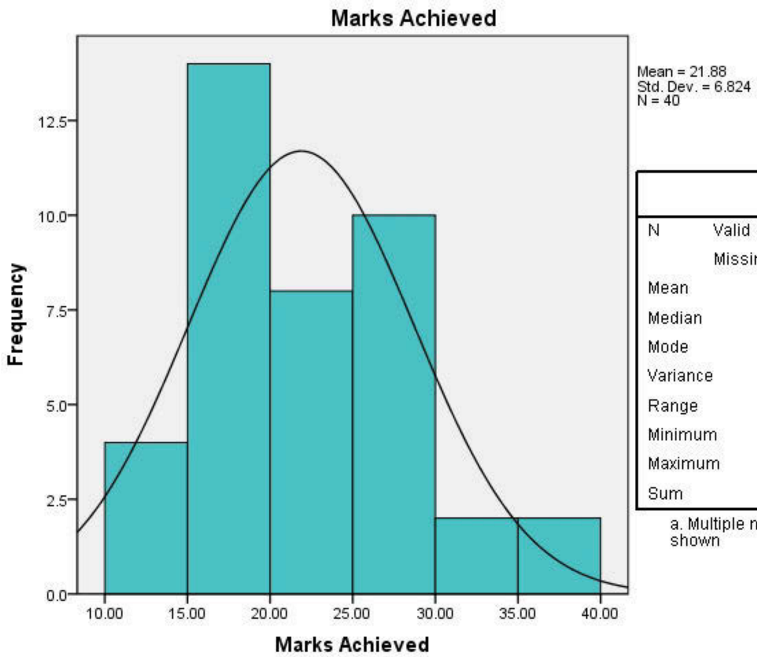
**Homoscedasticity Test:** A second critical assumption concerns the homogeneity of the variance-covariance matrices among the two groups. As we have only one dependent variable that is 'marks achieved', the first analysis applied was univariate homogeneity of variance across the two same size group samples.

| Test of Homogeneity of Variances<br>Marks Achieved | | | |
|---|---|---|---|
| Levene Statistic | df1 | df2 | Sig. |
| .866 | 1 | 38 | .358 |

Figure 6.9: homogeneity of variance by Levene's Test

As shown in Figure 6.9, Levene's test confirms the non-significance *(Sig = 0.236)* of variance for the two observed groups and assures that data have homogenous variance for both groups.

**Normality of Dependent variables:** In this particular study, we have only one dependent variable. One of the ANOVA assumptions is to verify the normal distribution of data for the dependent variables.




**Statistics**

| | | Traditional vs Virtual Group | Marks Achieved |
|---|---|---|---|
| N | Valid | 40 | 40 |
| | Missing | 4 | 4 |
| Mean | | 1.50 | 21.8813 |
| Median | | 1.50 | 20.8750 |
| Mode | | 1[a] | 17.50[a] |
| Variance | | .256 | 46.564 |
| Range | | 1 | 28.00 |
| Minimum | | 1 | 10.00 |
| Maximum | | 2 | 38.00 |
| Sum | | 60 | 875.25 |

a. Multiple modes exist. The smallest value is shown

Figure 6.10: Normality of Marks Achieved

Figure 6.10 presents the data distribution of marks obtained for the two groups. Graphs for marks achieved with frequency on y-axis give an insight into the actual data and it is normally distributed across various frequency ranges. The associated table gives us statistics about the marks achieved with *variance = 46.56*.

**Outliers:** The final issue to be addressed was the presence of outliers in the data. We adopted the boxplots approach to identify any outliers in the data gathered for both groups. Examining the boxplot for dependent variable *Marks Achieved* showed few extreme points across the groups. When we examine these extreme points for *Marks Achieved* in both groups, three extreme values were found for the traditional group as apparent in Figure 6.11. For further analysis, we reject the two very extreme results and retain the close observation labeled as record value 20.

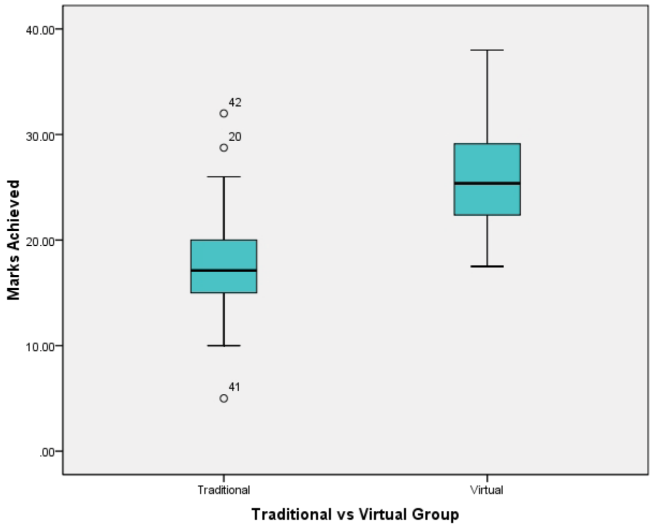



Figure 6.11: Outliers in Two Groups Sample

### 6.3.8 Performance Comparison of Traditional vs Virtual Group

The presence of only two groups eliminates the need to perform any type of post hoc test. The results for ANOVA in Figure 6.12 give the significance value of *(Sig =0.00), F = 24.74*, which suggests the rejection of Null Hypothesis (Ho1) as P < 0.05 in this case. Thus, performance of the traditional and virtual groups is significantly different. Now, we know that one of the participating groups performs better than the other, we need to investigate which group has performed better in this study.

| ANOVA<br>Marks Achieved | | | | | |
|---|---|---|---|---|---|
| | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | **716.139** | **1** | **716.139** | **24.743** | **.000** |
| Within Groups | 1099.859 | 38 | 28.944 | | |
| Total | 1815.998 | 39 | | | |

Figure 6.12: ANOVA: Performance Comparison in Two Groups

This performance variation could be visualized with the help of a Boxplot. Figure 6.13 depicts a clear variation in performance between both groups, where the performance of these two groups was measured in terms of *Marks Achieved*, which was represented here on y-axis. This indicates a notable high mean value for the virtual group as compared to the traditional group. A further descriptive analysis gives a detailed picture of the group differences as shown in Figure 6.14.

A descriptive analysis of the traditional and virtual groups based on their marks achieved helps to identify the statistical difference between the two groups, the number of participants being the same in both groups. These statistics indicate *(Mean = 17.65, Std Deviation = 4.90, Minimum Marks = 10.00 and Maximum Marks = 28.75)* for traditional group. The virtual group outperform in this analysis with statistical values *(Mean = 26.11, Std Deviation = 5.82, Minimum Marks = 17.50 and Maximum Marks = 38.00)*. Therefore, the given statistics in Figure 6.13 confirm that the virtual group has performed better than the traditional group.

In the next section, we analyzed the impact of all the independent factors like the participant's demographics on performance achieved and any significant interaction effect among these variables.

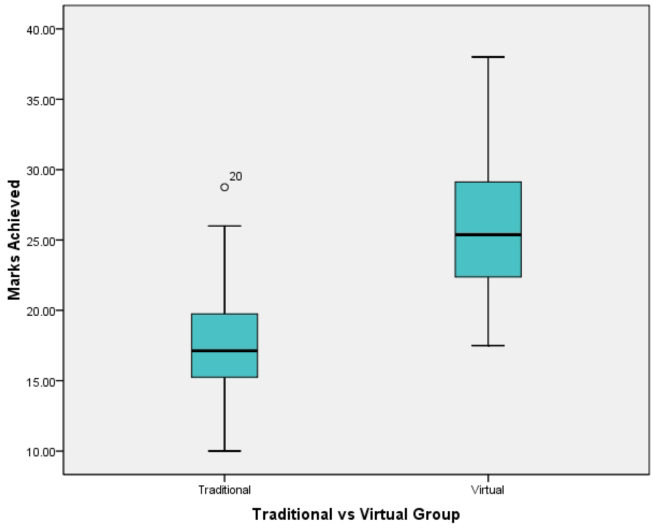



Figure 6.13: Boxplot: Performance Comparison in Two Groups

**Descriptives**

**Marks Achieved**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Min | Max | Between-Component Variance |
|---|---|---|---|---|---|---|---|---|---|---|
| Traditional | | 20 | 17.6500 | 4.90327 | 1.09641 | 15.3552 | 19.9448 | 10.00 | 28.75 | |
| Virtual | | 20 | 26.1125 | 5.81767 | 1.30087 | 23.3897 | 28.8353 | 17.50 | 38.00 | |
| Total | | 40 | 21.8813 | 6.82379 | 1.07894 | 19.6989 | 24.0636 | 10.00 | 38.00 | |
| Model | Fixed Effects | | | 5.37993 | .85064 | 20.1592 | 23.6033 | | | |
| | Random Effects | | | | 4.23125 | -31.8819 | 75.6444 | | | 34.35977 |

Figure 6.14: Descriptives for Virtual and Traditional Group

### 6.3.9 Main effects Analysis

This section focusses on any significant effect of any of independent variables (participant's demographics) on the performance, as described in Figure 6.8. All the statistics to measure the effect were gathered for both the virtual and the traditional group. The first independent variable taken for main effect analysis was *Gender*. To do so, *Marks Achieved* was the dependent variable. Likewise, univariate analysis of mean was applied for each independent variable to study the main effect on the performance of both groups. The validity of these findings depends on the nature of the interaction between the two variables. Here, we present a detailed insight into any effect of these separate variables on participant's performance.

**Effect of Gender on Performance:** There was significant medium effect of gender differences on performance(Marks Achieved) of the participants, *($F = 9.95$, $Sig = 0.003$)*. The effect size of gender differences was high *(Eta-Squared = 0.217 = 21.7 %)* on the variability of the participant's performance in both the virtual and the traditional group as shown in Figure 6.15.

| Tests of Between-Subjects Effects | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dependent Variable: Marks Achieved | | | | | | | | |
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
| Corrected Model | 958.399[a] | 3 | 319.466 | 13.410 | .000 | .528 | 40.231 | 1.000 |
| Intercept | 18261.426 | 1 | 18261.426 | 766.572 | .000 | .955 | 766.572 | 1.000 |
| **Gender** | **237.009** | **1** | **237.009** | **9.949** | **.003** | **.217** | **9.949** | **.866** |
| Group | 535.509 | 1 | 535.509 | 22.479 | .000 | .384 | 22.479 | .996 |
| Gender * Group | 5.251 | 1 | 5.251 | .220 | .642 | .006 | .220 | .074 |
| Error | 857.599 | 36 | 23.822 | | | | | |
| Total | 20967.563 | 40 | | | | | | |
| Corrected Total | 1815.998 | 39 | | | | | | |

a. R Squared = .528 (Adjusted R Squared = .488)

b. Computed using alpha = .05

Figure 6.15: Gender: Between the Subject Effects

| Gender * Traditional vs Virtual Group | | | | | |
|---|---|---|---|---|---|
| Dependent Variable: Marks Achieved | | | | | |
| | | | | 95% Confidence Interval | |
| Gender | Traditional vs. Virtual Group | Mean | Std. Error | Lower Bound | Upper Bound |
| Male | Traditional | **15.958** | 1.409 | 13.101 | 18.816 |
| | Virtual | **22.688** | 1.726 | 19.188 | 26.187 |
| Female | Traditional | **20.188** | 1.726 | 16.688 | 23.687 |
| | Virtual | **28.396** | 1.409 | 25.538 | 31.253 |

Figure 6.16: Estimated Marginal Means for Participant's Gender

All the female participants in both groups demonstrated higher performance

*(Adj.M: Traditional =20.19, SE = 1.726 ; Virtual = 28.40, SE = 1.409)* compared to male participants *(Adj.M: Traditional =15.96, SE = 1.409, Virtual = 22.69, SE = 1.726)* as highlighted in Figure 6.16. This variation of performance among the male and female participants is apparent in Graph 6.29a, it clearly shows that for our observed sample females clearly outperformed male participants in both the traditional and virtual groups. The number of participants for both these categories was the same. The presence of only two levels in each effect eliminates the need to conduct any post hoc tests.

**Effect of Age on Performance:** Main effect analysis for the 'Age' factor depicts no significant impact of participant's age on performance (Marks Achieved). The F-value and Significance factor *(F = 1.61, Sig = 0.206)* suggest no apparent effect of participants age, where the effect size of participating age groups was medium with *(Eta-Squared = 0.217 = 21.7 %)*. However, in Figure 6.17 the observed power of this finding was quite low with *(Observed Power = 0.384)*.

Descriptive analysis of participants performance for these age groups gives a detailed insight into why we have low observed power for effect analysis. No significant pattern for participants' age with respect to their performance was found, the traditional group achieved *(Adj.M: Age in Years: <20 = 16.50, 20-24 = 15.64, 25-34 = 18.92 and 35-44 = No participant)* and the virtual group mean performance measure was *(Adj.M: Age in Years: <20 = No participant, 20-24 = 32.35, 25-34 = 24.17 and 35-44 = 23.83)* as given in Figure 6.18 and Graph 6.29b.

**Effect of Language on Performance:** The main effect analysis of factor 'Native Language' on participants shows no major impact on performance achieved given *(F = 4.063, Sig = 0.051)*, though the small impact 'Language' had, was strong according to *(F = 4.063 = 41%)*. The effect size of language was

| Tests of Between-Subjects Effects<br>Dependent Variable: Marks Achieved | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
| Corrected Model | 1024.691[a] | 5 | 204.938 | 8.806 | .000 | .564 | 44.028 | .999 |
| Intercept | 7265.386 | 1 | 7265.386 | 312.171 | .000 | .902 | 312.171 | 1.000 |
| Group | 897.291 | 1 | 897.291 | 38.554 | .000 | .531 | 38.554 | 1.000 |
| **Age** | **112.229** | **3** | **37.410** | **1.607** | **.206** | **.124** | **4.822** | **.384** |
| Group * Age | 244.306 | 1 | 244.306 | 10.497 | .003 | .236 | 10.497 | .882 |
| Error | 791.307 | 34 | 23.274 | | | | | |
| Total | 20967.563 | 40 | | | | | | |
| Corrected Total | 1815.998 | 39 | | | | | | |

a. R Squared = .564 (Adjusted R Squared = .500)

b. Computed using alpha = .05

Figure 6.17: Age: Between the Subject Effects

| Traditional vs. Virtual Group * Age<br>Dependent Variable: Marks Achieved | | | | | |
|---|---|---|---|---|---|
| Traditional vs Virtual Group | Age | Mean | Std. Error | 95% Confidence Interval Lower Bound | Upper Bound |
| Traditional | Less than 20 | **16.500** | 4.824 | 6.696 | 26.304 |
| | 20 - 24 | **15.643** | 1.823 | 11.937 | 19.348 |
| | 25-34 | **18.917** | 1.393 | 16.086 | 21.747 |
| | 35-44 | .[a] | . | . | . |
| Virtual | Less than 20 | .[a] | . | . | . |
| | 20 - 24 | **32.350** | 2.157 | 27.965 | 36.735 |
| | 25-34 | **24.167** | 1.608 | 20.899 | 27.435 |
| | 35-44 | **23.833** | 1.970 | 19.831 | 27.836 |

a. This level combination of factors is not observed, thus the corresponding population marginal mean is not estimable.

Figure 6.18: Estimated Marginal Means for Participant's Age

on the borderline of medium-small *(Eta-Squared = 0.101 = 10%)* on the variability of participants' performance (Marks Achieved) as shown in Figure 6.19. Likewise, we had observed power of this analysis medium with value *(Observed Power = 0.501)*.

Descriptive analysis of means for native English speakers and non-native speakers in participating groups suggest visible variation in performances. Par-

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
|---|---|---|---|---|---|---|---|---|
| Corrected Model | 870.702[a] | 3 | 290.234 | 11.053 | .000 | .479 | 33.159 | .998 |
| Intercept | 4846.738 | 1 | 4846.738 | 184.580 | .000 | .837 | 184.580 | 1.000 |
| Group | 320.126 | 1 | 320.126 | 12.191 | .001 | .253 | 12.191 | .925 |
| **Language** | **106.688** | **1** | **106.688** | **4.063** | **.051** | **.101** | **4.063** | **.501** |
| Group * Language | 47.876 | 1 | 47.876 | 1.823 | .185 | .048 | 1.823 | .260 |
| Error | 945.296 | 36 | 26.258 | | | | | |
| Total | 20967.563 | 40 | | | | | | |
| Corrected Total | 1815.998 | 39 | | | | | | |

Tests of Between-Subjects Effects

Dependent Variable: Marks Achieved

a. R Squared = .479 (Adjusted R Squared = .436)

b. Computed using alpha = .05

Figure 6.19: Language: Between the Subject Effects

Descriptive Statistics

Dependent Variable: Marks Achieved

| Traditional vs Virtual Group | Native English Speakers | Mean | Std. Deviation | N |
|---|---|---|---|---|
| **Traditional** | **Yes** | **20.0000** | **.** | **1** |
| | **No** | **17.5263** | **5.00548** | **19** |
| | Total | 17.6500 | 4.90327 | 20 |
| **Virtual** | **Yes** | **38.0000** | **.** | **1** |
| | **No** | **25.4868** | **5.24038** | **19** |
| | Total | 26.1125 | 5.81767 | 20 |
| Total | Yes | 29.0000 | 12.72792 | 2 |
| | No | 21.5066 | 6.46678 | 38 |
| | Total | 21.8812 | 6.82379 | 40 |

Figure 6.20: Estimated Marginal Means for Participant's Native Language

ticipants in the traditional group show variation in performance for both types of participants *(Adj.Mean: Native English Speakers = 20.0, N = 1; Non-Native Speakers = 17.53, N = 19)*. Nonetheless, the number of participants with different linguistic background was not normally distributed as presented in Figure 6.20. The marginal means for virtual group participants with differnt linguistic background also shows the same trend as indicated in Graph 6.29c, that native English speakers performed relatively better than those who have non-English background *(Adj.Mean: Native English Speakers = 38.0, N = 1; Non-Native Speakers = 25.5, N = 19)*. This analysis, however suggests that variation in traditional and virtual group performance was not due to linguistic background of participants.

**Effect of Computer Games/ Virtual Worlds Experience on Performance:** The participants experience of playing computer games and virtual worlds had a minor effect on actual performance(Marks Achieved) as suggested by *(F = 2.792, Sig = .044)*. The effect size of computer games or virtual worlds was medium to large *(Eta-Squared = .271 = 27.1%)* on performance achieved as in Figure 6.21. The observed power for experience of games/virtual worlds factor *(Observed Power = .693)* was medium for the given sample.

Highlighted marginal means in Figure 6.22 show this minor variation in performance averages of participants with different levels of computer games/ virtual worlds experience. Average performance of the traditional group according to different levels of games/virtual worlds experience was *(Adj.M: Games/ Virtual Worlds Experience: Never =27.38, Rarely =18.32, Occasionally = 14.15, Often = 18.83, Very Often = 14.25)*. Likewise, the virtual group participants' performance had no apparent trend *(Adj.M: Games/ Virtual Worlds Experience: Never = 22.75, Rarely = 27.23, Occasionally = 20.50, Often = 27.50, Very Often = 33.75)* as shown in Graph 6.29d.

**Effect of Qualification on Performance:** The pre-test questionnaire also inquired about the participant's level of qualification. Participants in this study mainly belong to three levels of qualification: High school, Undergraduate and Postgraduate. Tests of between the subject effect for qualification factor on participants performance show no interaction between these two variables *(F = 0.345, Sig = 0.710)*, thus suggesting the rejection of null hypothesis *Ho2*. The

| Tests of Between-Subjects Effects | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dependent Variable: Marks Achieved | | | | | | | | |
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
| Corrected Model | 1202.204[a] | 9 | 133.578 | 6.529 | .000 | .662 | 58.759 | 1.000 |
| Intercept | 11419.653 | 1 | 11419.653 | 558.150 | .000 | .949 | 558.150 | 1.000 |
| Group | 340.632 | 1 | 340.632 | 16.649 | .000 | .357 | 16.649 | .977 |
| **Games** | **228.460** | **4** | **57.115** | **2.792** | **.044** | **.271** | **11.166** | **.693** |
| Group * Games | 267.103 | 4 | 66.776 | 3.264 | .025 | .303 | 13.055 | .769 |
| Error | 613.795 | 30 | 20.460 | | | | | |
| Total | 20967.563 | 40 | | | | | | |
| Corrected Total | 1815.998 | 39 | | | | | | |

a. R Squared = .662 (Adjusted R Squared = .561)

b. Computed using alpha = .05

Figure 6.21: Games/Virtual World Experience: Between the Subject Effects

| Traditional vs Virtual Group * Frequency of Playing Games/Virtual Worlds | | | | | |
|---|---|---|---|---|---|
| Dependent Variable: Marks Achieved | | | | | |
| | | | | 95% Confidence Interval | |
| Traditional vs Virtual Group | Frequency of Playing Games/Virtual Worlds | Mean | Std. Error | Lower Bound | Upper Bound |
| Traditional | Never | 27.375 | 3.198 | 20.843 | 33.907 |
| | Rarely | 18.321 | 1.710 | 14.830 | 21.813 |
| | Occasionally | 14.150 | 2.023 | 10.019 | 18.281 |
| | Often | 18.833 | 2.612 | 13.500 | 24.167 |
| | Very Often | 14.250 | 2.612 | 8.917 | 19.583 |
| Virtual | Never | 22.750 | 3.198 | 16.218 | 29.282 |
| | Rarely | 27.231 | 1.255 | 24.669 | 29.793 |
| | Occasionally | 20.500 | 2.612 | 15.167 | 25.833 |
| | Often | 27.500 | 4.523 | 18.262 | 36.738 |
| | Very Often | 33.750 | 4.523 | 24.512 | 42.988 |

Figure 6.22: Marginal Means: Experience of Computer Games/Virtual Worlds

effect size of qualification was small *(Eta-Squared = 0.019 = 1.9%)* on variance of participant's performance as shown in Figure 6.23.

However, there is a small difference in performance means of participants with different level of qualification *(Traditional Adj.Mean: High School = 16.50, SE = 5.51; Undergraduate = 17.53, SE = 1.84; Postgraduate = 17.87, SE = 1.74)*

| Tests of Between-Subjects Effects | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dependent Variable: Marks Achieved | | | | | | | | |
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
| Corrected Model | 754.716[a] | 4 | 188.679 | 6.222 | .001 | .416 | 24.890 | .976 |
| Intercept | 5248.100 | 1 | 5248.100 | 173.077 | .000 | .832 | 173.077 | 1.000 |
| Group | 628.681 | 1 | 628.681 | 20.733 | .000 | .372 | 20.733 | .993 |
| **Qualification** | **20.938** | **2** | **10.469** | **.345** | **.710** | **.019** | **.691** | **.101** |
| Group * Qualification | 28.362 | 1 | 28.362 | .935 | .340 | .026 | .935 | .156 |
| Error | 1061.283 | 35 | 30.322 | | | | | |
| Total | 20967.563 | 40 | | | | | | |
| Corrected Total | 1815.998 | 39 | | | | | | |

a. R Squared = .416 (Adjusted R Squared = .349)

b. Computed using alpha = .05

Figure 6.23: Participant's Qualification: Between the Subject Effects

| Traditional vs Virtual Group * Participant's Qualification | | | | | |
|---|---|---|---|---|---|
| Dependent Variable: Marks Achieved | | | | | |
| Traditional vs Virtual Group | Participant's Qualification | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
| Traditional | High School | **16.500** | 5.507 | 5.321 | 27.679 |
| | Undergrad | **17.528** | 1.836 | 13.801 | 21.254 |
| | Postgrad | **17.875** | 1.741 | 14.340 | 21.410 |
| Virtual | High School | .[a] | . | . | . |
| | Undergrad | **29.333** | 3.179 | 22.879 | 35.787 |
| | Postgrad | **25.544** | 1.336 | 22.833 | 28.255 |

a. This level combination of factors is not observed, thus the corresponding population marginal mean is not estimable.

Figure 6.24: Marginal Means: Participant's Qualification

and *(Virtual Adj.Mean: High School = NA; Undergraduate = 29.33, SE = 3.28; Postgraduate = 25.54, SE = 1.34)* in Figure 6.24. These variations in performance were not due to participant's qualification as confirmed with Sig value. A similar finding could be visualized in Graph 6.30a between the participant's performance achieved and level of qualification.

**Effect of Profession/Educational Field on Performance:** The professional/educational background of participants was also taken into account to measure any interaction with participant's performance. The pre-test questionnaire provided options to select the participant's professional or educational field. The analysis of this factor on any performance gain was insignificant as suggested by *(F = 2.15, Sig = 0.099)* and given in Figure 6.25. The effect size of the field factor on variability of participants performance in this data sample was *(Eta-Squared = 0.223 = 22.3%)* with very low observed power *(Observed Power = 0.565)*.

**Tests of Between-Subjects Effects**

**Dependent Variable: Marks Achieved**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
|---|---|---|---|---|---|---|---|---|
| Corrected Model | 1148.645[a] | 9 | 127.627 | 5.737 | .000 | .633 | 51.636 | .998 |
| Intercept | 9703.838 | 1 | 9703.838 | 436.223 | .000 | .936 | 436.223 | 1.000 |
| Group | 173.036 | 1 | 173.036 | 7.779 | .009 | .206 | 7.779 | .770 |
| **Field** | **191.501** | **4** | **47.875** | **2.152** | **.099** | **.223** | **8.609** | **.565** |
| Group * Field | 267.271 | 4 | 66.818 | 3.004 | .034 | .286 | 12.015 | .729 |
| Error | 667.353 | 30 | 22.245 | | | | | |
| Total | 20967.563 | 40 | | | | | | |
| Corrected Total | 1815.998 | 39 | | | | | | |

a. R Squared = .633 (Adjusted R Squared = .522)

b. Computed using alpha = .05

Figure 6.25: Professional Field: Between the Subject Effects

**Traditional vs. Virtual Group * Participant's Field**

**Dependent Variable: Marks Achieved**

| Traditional vs Virtual Group | Participant's Field | Mean | Std. Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|
| Traditional | Medicine | 19.000 | 3.335 | 12.189 | 25.811 |
| | Engineering or IT | 14.972 | 1.572 | 11.761 | 18.183 |
| | Business | 16.850 | 2.109 | 12.542 | 21.158 |
| | Humanities | 28.750 | 4.716 | 19.118 | 38.382 |
| | other | 22.417 | 2.723 | 16.855 | 27.978 |
| Virtual | Medicine | 26.250 | 4.716 | 16.618 | 35.882 |
| | Engineering or IT | 25.300 | 1.218 | 22.813 | 27.787 |
| | Business | 34.625 | 3.335 | 27.814 | 41.436 |
| | Humanities | 22.500 | 4.716 | 12.868 | 32.132 |
| | other | 24.750 | 4.716 | 15.118 | 34.382 |

Figure 6.26: Marginal Means: Professional field of Participant

The performance mean analysis for participant's professional field showed no significant trend, though the virtual group performed better than the traditional group as shown in Figure 6.26 and 6.30b. The average performance of traditional group participants(Adj.Mean: Medicine =19.00, Engineering or IT = 14.97, Business = 16.85, Humanities = 28.75 and other = 22.42) and participants of the virtual group(Adj.Mean: Medicine =26.25, Engineering or IT = 25.30, Business = 34.62, Humanities = 22.50 and other = 24.75) are given in Figure 6.26.

**Effect of Previous Knowledge on Performance:** Few participants had some previous knowledge of either Sumarian society or the city of Uruk itself. We had to analyze that previous knowledge of historical facts may have any effect on the performance of these participants. Nonetheless, a test for interaction of previous knowledge with performance archived showed no significant relation between the two attributes *(F = 1.06, Sig = 0.310)* presented in Figure 6.27. Similarly, the observed power of this attribute was quite low as *(Observed Power = 0.171)*.

The reason for the very low observed power was that only 6 out of 40 participants had any previous knowledge of Sumarian society. These figures are found in descriptive statistics in Figure 6.28, where it shows that for the traditional group those participants with some previous knowledge performed better *(Adj.Mean: Yes = 19.54, No = 16.84)*than those who had no previous knowledge of our case study. In the virtual group, we had no participant with previous knowledge *(Adj.Mean: Yes = 26.11, No =N/A)* causing the low observed power of this interaction as highlighted in Figure 6.28 and similar graphical representation in Graph 6.30c.

In the next section, we study the interaction between factors which have any main effect on participant's performance(Marks Achieved).

| Tests of Between-Subjects Effects | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dependent Variable: Marks Achieved | | | | | | | | |
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
| Corrected Model | 746.811[a] | 2 | 373.406 | 12.922 | .000 | .411 | 25.844 | .995 |
| Intercept | 12467.719 | 1 | 12467.719 | 431.454 | .000 | .921 | 431.454 | 1.000 |
| Group | 708.174 | 1 | 708.174 | 24.507 | .000 | .398 | 24.507 | .998 |
| **Pknowledge** | **30.672** | **1** | **30.672** | **1.061** | **.310** | **.028** | **1.061** | **.171** |
| Group * Pknowledge | .000 | 0 | . | . | . | .000 | .000 | . |
| Error | 1069.187 | 37 | 28.897 | | | | | |
| Total | 20967.563 | 40 | | | | | | |
| Corrected Total | 1815.998 | 39 | | | | | | |

a. R Squared = .411 (Adjusted R Squared = .379)

b. Computed using alpha = .05

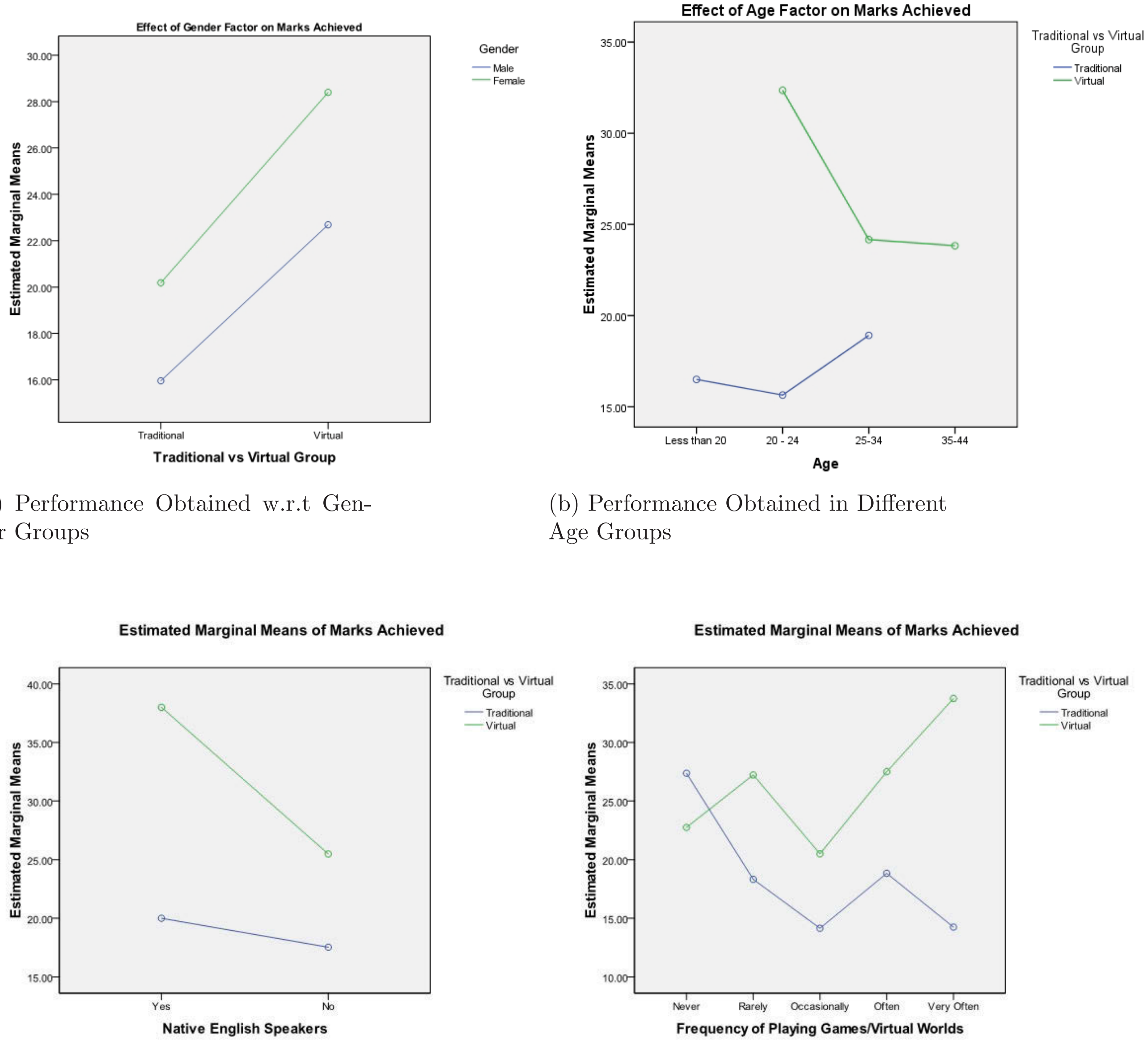
Figure 6.27: Previous Knowledge: Between the Subject Effects

| Descriptive Statistics | | | | |
|---|---|---|---|---|
| Dependent Variable: Marks Achieved | | | | |
| Traditional vs Virtual Group | Previous Knowledge | Mean | Std. Deviation | N |
| **Traditional** | **Yes** | **19.5417** | **3.44390** | **6** |
| | **No** | **16.8393** | **5.31200** | **14** |
| | Total | 17.6500 | 4.90327 | 20 |
| **Virtual** | **No** | **26.1125** | **5.81767** | **20** |
| | Total | 26.1125 | 5.81767 | 20 |
| Total | Yes | 19.5417 | 3.44390 | 6 |
| | No | 22.2941 | 7.21543 | 34 |
| | Total | 21.8812 | 6.82379 | 40 |

Figure 6.28: Marginal Means: Previous knowledge of Uruk's History

### 6.3.10 Interaction effect Analysis

In the previous section, we analyzed the main effect of each independent variable on performance of participants(dependent variable). Here, we need to analyze any interaction between all the independent factors such as gender, games/ Virtual Worlds experience and if it causes any variation to the performances. The main effect study shows that only two independent variables gender and games/Virtual



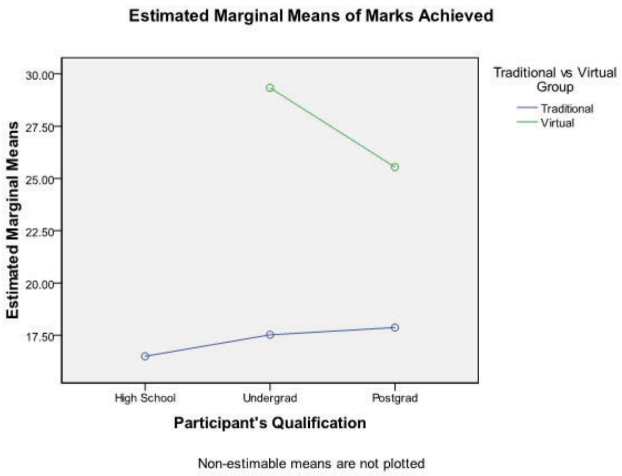

(a) Performance Obtained w.r.t Gender Groups

(b) Performance Obtained in Different Age Groups

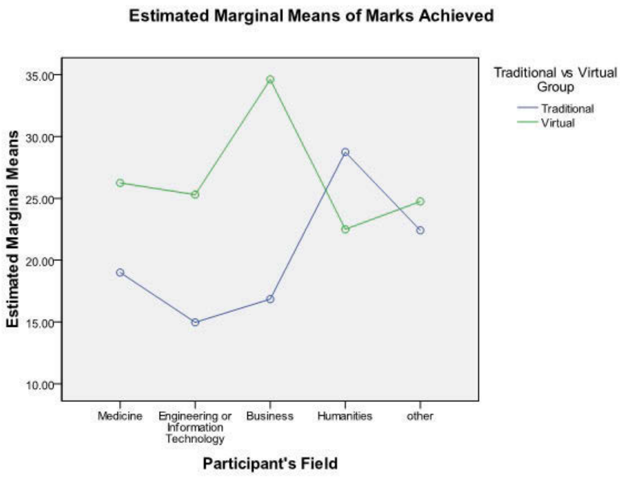
(c) Performance Obtained w.r.t Linguistic Background

(d) Performance Obtained w.r.t Games/VW Experience

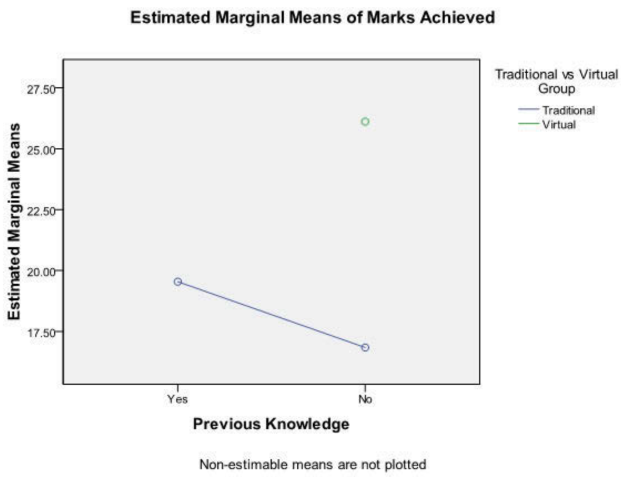
Figure 6.29: Graphical View Interaction Effect I




(a) Performance Obtained w.r.t Qualification




(b) Performance Obtained w.r.t Participant's Field




(c) Performance Obtained w.r.t Previous Knowledge

Figure 6.30: Graphical View Interaction Effect III

Worlds experience affected the performance of these participants. By applying Univariate analysis of ANOVA test, results indicate no significant interaction effect *($F = 0.860$, $Sig = 0.475$)* between the gender and games/Virtual Worlds experience settings which helps to maintain the above described main effects.

**Tests of Between-Subjects Effects**
**Dependent Variable: Marks Achieved**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
|---|---|---|---|---|---|---|---|---|
| Gender * Games | 47.549 | 3 | 15.850 | .860 | .475 | .094 | 2.581 | .210 |

Figure 6.31: Gender and Games/VW Experience Interaction Analysis

No relationship between gender and games/Virtual Worlds experience gives an indication that degree or size of the effect made by gender differences is not dependent on the level of games/Virtual Worlds experience settings or vice versa as shown in Figure 6.31.

We conducted a detailed comparison of students' performance in both groups. This study shows that students in the virtual group clearly outperformed the traditional group. In addition, the conducted ANOVA test allowed us to test each of these participants'demographic factors such as age, gender, virtual world/games experience for any possible impact on students' performance. We also analyzed the interdependencies among these individual factors and any impact they may have on student learning performance. Current results show that there exists no major interdependencies among these factors. This study concludes that only gender differences, virtual worlds/ games experience and language have shown some minor effect on participants' performance. In contrast, all other demographic factors had very insignificant impact on students' performance.

### 6.3.11 Participants' Observation

Informal researcher's observations report the enthusiasm and excitement among the virtual group participants about their interaction with 3D city of Uruk prototype. During the interaction part of the study, students were very engaged and focussed. During the virtual sessions, the majority of students liked their conversations with virtual humans living in the city, followed them to observe and inquire about their activities. Participants were excited and satisfied with the responses given by these virtual humans. Moreover, the participants were quite immersed in the virtual environments.

In regards to the navigation and participant activities in the environment, the researcher did not observe any critical problems during the study sessions. Participants were confident enough to properly navigate and interact with the virtual humans in the 3D city of Uruk. Participants had longer interactions than planned by the researcher initially to explore and converse with the virtual humans. According to the participant's feedbacks that were collected at the end of this study, the virtual group generally provided encouraging comments.

The participants were excited about the idea of learning history in a virtual city, not only by visiting the city but also having conversations with the virtual people living there. Students liked the interaction specially when they were exploring the environment and observing/interacting with the virtual humans("I really liked the fisherman and how he did fishing"). Students generally liked the 3D Virtual city of Uruk and most comments showed their interest ("Its interesting to learn in this environment and observe surrounding objects"). Few participants also mentioned the learning aspects in this study, one of the comments was "I found it easy to understand and remember facts".

Negative comments made by the virtual group participants were not numerous. However, one concern was the length of written facts near different buildings to explain the design and historical importance of that specific artifact. Participants recommended reducing this information and they preferred to explore buildings themselves then read the textual information during the interaction session.

In contrast, the traditional group participants initially took interest in reading the text about the city of Uruk. They had support in case they had any difficulties understanding the text. But this group reported it was hard to maintain interest in the latter stages of the study. Participants had no apparent trouble in understanding the facts but a few negative comments were like ("It is quite long and little bit boring"). Furthermore, it was suggested by this group to reduce the length of the session and add some more visual demonstration.

## 6.4 Summary

This chapter has provided experimental evaluation of two concepts: awareness believability and learning effectiveness in virtual environments specifically for our case study *"The city of Uruk"*. As in the literature discussed earlier, believability as well as its evaluation is not a well defined problem. Nevertheless, we illustrated the concept of awareness believability to improve the overall believability of embodied conversational agents in Virtual Worlds. This chapter evaluated awareness believability features, defined measuring parameters, data collection and analysis of this data to produce experimental results. Due to the subjective nature of believability, current studies have mostly done qualitative analysis, whereas in this evaluation we tried to come up with a quantitative approach of believability evaluation.

In this chapter, we also presented a qualitative study conducted to measure the learning effectiveness of students in Virtual Worlds. We initially conducted a pilot study to choose the most suitable method. This pilot study helped to compare the three cases: *"Unsupervised"*, where students had to explore the virtual city themselves and no guidance was provided; *"Supervised and Controlled"*, conducted where the researcher had control of student's avatar to navigate the virtual environment and assisted student to explore the virtual space; and *"Supervised and Uncontrolled"*, in which case student was guided for any technical help he needed to navigate in the Virtual World.

Based on the results gathered, we selected the supervised and uncontrolled method to conduct a focussed experiment. Traditional and virtual student groups were compared for any performance differences for learning historical facts in this study. Three activities were devised for these student groups: traditional text reading to learn historical facts, interactions with embodied conversational agents living in the virtual city and learning historical facts by text reading and exploration in Virtual World. The study outlined better performance achieved by the virtual group over the traditional text reading group. The study outcome shows that 80% students in the virtual group achieved marks between 51-60% in a mini exam conducted after their visit to the virtual city. In contrast, the largest group of students in the traditional group performed relatively poorly as about 50% students in this group gained marks between 40-48%. Comparing weighted averages of both groups highlights this difference quite well as the virtual group performed better with weighted average of 60.96% in contrast to the traditional group with average of only 41.05%. Moreover, ANOVA test was conducted to give a detailed evaluation of students' performance in both groups. Students' demographic attributes highlight no significant impact on students' performance in this user study.

# CHAPTER 7

## Conclusion and Future Work

In this thesis we introduced the concept of believability awareness for embodied conversational agents for teaching ancient history and culture in 3D Virtual Worlds. All the participants' interactions have been regulated through Virtual Institutions technology [Bog07]. The existing literature has outlined a set of believability attributes for virtual agents including personality, emotions, facial expression, gestures etc. But when we have these virtual agents in dynamic Virtual Worlds, the role of their environment and their interactions with objects and other participants becomes critically important for believability. In this thesis, we investigated the believability awareness concept to test its features such as environment-, self- and interaction awareness to improve the overall believability of embodied conversational agents. Implementation of these features for embodied agents was based on both Virtual Worlds and Virtual Institutions technology. Environment awareness used annotations from objects and artefacts present in Virtual Worlds, whereas all the interaction-and self-awareness was developed through a regulation annotation layer based on Virtual Institutions technology.

Our conversational agents with given awareness believability features exist in our Virtual World, but all the participants both human and virtual agents have to follow the rules and regulations of the virtual society imposed by Virtual Institutions technology. The aforementioned awareness believability characteristics also make use of two levels of annotations to give believable responses to students. Virtual agents plans, goals, relationships with other participants and all the interaction flow can be traced to the Virtual Institutions layer.

Both the expected superiority of learning history and culture in Virtual Worlds with virtual agents' interactions and also the believability enhancement of these virtual agents with awareness believability features was tested with a case study using the recreated virtual city of Uruk. This virtual city was simulated and populated with several agents with given roles and defined relationships. Virtual Institutions technology was further used to implement norms, roles and regulations for all the visitors and citizen in the city. This virtual city was developed by our research group [Bog11] and we used it as proof of concept to validate the awareness believability features. Having a separate visualization layer of Virtual Worlds from the regulations of the Virtual Institutions layer constitutes the advantage of running these two processes in parallel. Another advantage of this layered implementation is that the whole system can be quickly transferred to another visualization platform without any major modifications.

Another contribution of this thesis is its attempt to evaluate believability by using a quantitative approach. We conducted two user studies to evaluate both awareness believability and students learning effectiveness in Virtual Worlds with virtual agents as knowledge contributors. In the first study, test believability, we had two groups of students who interacted with two different groups of conversational agents in 3D Virtual World. One group of agents consisted of aware virtual agents (with awareness believability features) and the other was a group of unaware agents. Based on these interactions, students rated the believability of these agents. These results further used to calculate the believability index for measuring the believability of virtual conversational agents with and without awareness believability features. The second study was conducted to evaluate students' learning effectiveness after immersion in Virtual Worlds with believable conversational agents. We conducted this study by contrasting three different modes of learning history and culture: the traditional method of text reading from a book, learning through interacting with conversational agents and reading text notices on virtual artefacts and observing the virtual environment. Feedback collected from the three student groups was analysed and compared to study the impact of believable conversational agents and virtual worlds on students' learning motivations ad engagement.

Further, we introduced the concept of using subject matters experts to support the learning of embodied conversational agents. In Virtual World, we have two types of entities: humans and autonomous agents. Every avatar is controlled by a human or an agent. Human participants are either visitors in the virtual learning environment with the purpose of learning as students or subject matter experts attempting to improve the learning environment with actual historical facts. In such environments, both types of participants learn from each other as virtual agents have the role of knowledge facilitators while at the same time subject matter experts can correct the knowledge of these virtual agents. Correcting beliefs of virtual agents during conversations proved to the easy for subject matter experts with non technical backgrounds. These conversational agents provide a personalised learning environment for students according to their background and level of knowledge. Virtual agents are also a cheap resource and can be easily developed as a learning facilitator for each individual student.

3D Virtual Worlds are well established environments with millions of users and diverse applications ranging from businesses and entertainment to educational campuses. Using 3D Virtual Worlds as a learning environment helped us to motivate and engage digital native students in an immersive learning environment. Furthermore, students were also engaged enthusiastically in the learning process due to the believable embodied conversational agents.

## 7.1 Future Work

The concept of believable embodied conversational agents with awareness believability features for teaching ancient history and culture requires further validation. Our second study collected evidence of students' engagement and motivation in the learning process. We next want to expand our user study and conduct it with school level ancient history students. Another area of our concern is to improve upon the learning method provided to subject matter experts. As the current methodology only deals with explicit queries to be corrected in the AIML based communication layer, we plan to research developing a more comprehensive learning methodology based on AIML communication architecture. Once such a learning procedure is fully implemented, we plan to conduct an extensive study to evaluate the learning methodology for conversational agentsin the area of to learning history and culture.

### 7.1.1 Group Based Learning Activities

In the current prototype, our focus was to develop believable conversational agents for teaching ancient history and culture. Conversational agents require further refinement for conducting group based learning activities in Virtual Worlds. To enable conversational agents to be used for group based learning activities, a comprehensive modification in the AIML base communication layer is necessary. Such conversational agents require keeping track of their communication with individual participants currently present in the group. Group based learning activities also need to modify the non-verbal communication of the virtual agents in line with group based conversational and learning activities. Agent's non verbal communication through gestures and body movements should be well aligned with conversational behaviors with other participants in the group. Once the prototype is ready, we plan to conduct an extensive experiment to evaluate the success of introducing group based activities and how this impacts students' motivation for learning the task.

### 7.1.2 Investigating Combined Effect of Believability Features

Believability has been studied in the literature in terms of individual features such as personality, emotions, facial expressions, gestures etc. As an ongoing area of research, new features should be investigated and added to the current set of characteristics. Another potential aspect of believability needing attentions should involve the application of all the existing features discussed in Chapter 4 and studying them collectively. We want to investigate the collective advantage of, and any interconnected relationship that may exist between these features. Studying the combined effect of believability features will require modification in the prototype to enable our the conversational agents to use a set of comprehensive features in parallel to conversational behaviours. To evaluate the collective impact of believability features, we would further need to conduct a comparative study to analyze this collective effect in detail.

### 7.1.3 Expanding the User Studies

This thesis presented two major concepts:

- *Awareness Believability* - with three main features normally environment-, self- and interaction awareness to improve the overall believability of embodied conversational agents.
- *Students' Learning Effectiveness* - we wanted to investigate the learning effectiveness of using embodied conversational agents with given awareness believability features to improve students engagement and motivation.

In study I, we divided our participants into two groups to interact with aware and unaware groups of agents to rate their conversations for believability. Participants in study II were further separated into smaller groups to learn about our case study City of Uruk through three different methods: text reading by the traditional group, conversing and interacting with embodied conversational agents acting as virtual humans living in the city, reading text notes in the virtual city as well as by observing the surroundings.

Initially, we planned to conduct the user studies with junior grade history students at school but long ethics procedures proved a major concern. These two studies were conducted with first year undergrad and postgrad students at University of Technology, Sydney. We plan to extend our current studies to have more participants' feedback as well as shifting our focus towards ancient history students at schools. We also want to test the impact of interactions with both believability aware agents and unaware agents with the same group of students. This study should target whether the same group of students interacts with both types of conversational agents and how their believability is affected by this experience.

### 7.1.4 Gestures, Emotion and Facial Expressions

In this thesis we presented our vision that non verbal behaviours and social cues can improve believability of embodied virtual agents which ultimately helps to motivate and engage human participants. We plan to explore further the utilization of gestures, emotions and facial expressions for embodied agents in Virtual Worlds. Currently, virtual agents in the Uruk project are equipped with s limited set of gestures like jumping, waving, blowing, dancing movements, etc integrated by our research group. Layered architecture based on Virtual Institutions technology offers further opportunity to integrate emotions, facial expressions and a wider set of gestures for virtual agents. Artificial Intelligence Markup Language(AIML) based communication layer will enable us to utilize advanced social and non-verbal cues in close integration with the conversational functionality of virtual agents. This can also make it possible to associate personalized cues, specific gestures and facial expressions with a particular virtual agent in certain situations, scenes and interactions. These personalized non verbal behaviors will help us to expand the study of virtual agents and how they react in certain situations. Moreover, personality enriched behaviors may better motivate and engage students in various tasks at hand.

### 7.1.5 Integrating non-verbal features with verbal communication

This thesis addressed an improvement in virtual agents believability by investigating awareness believability features and integrating them with agent's conversations. Such conversations help to motivate students in learning history and culture. In order to do this, it is necessary to have a mechanism for integrating virtual agents' non verbal behaviours (gestures, emotion and facial expressions) into natural language conversations. This task requires significant research effort to develop the relevant tools and techniques. The communication by MPLP (Multimodal Presentation Markup Language) project [MPM11] is a good starting point towards exploring the integration of verbal and non verbal communication for virtual agents. Ultimately, it will be extremely useful to be able to relate and express agents' responses using both verbal and non verbal methods. This integration will be a step forward towards more natural interactions and enable researchers to specifically study human-agent behaviours.

### 7.1.6 Improving the Learning Method

The learning feature we provided to subject matter experts to train virtual agents and expand their knowledgebase is based on the AIML based communication layer. This learning tool can only store the basic knowledge category in the AIML repository. Our current implementation allows a subject matter expert to train an agent for AIML atomic categories as below:

```
<category>
<pattern>Hi there, How are you?</pattern>
<template>Hello, I doing well,how about you?</tenplete>
</category>
```

In the aforementioned category, corresponding to given ¡pattern¿ only a single response can be stored and the conversational agent always replies with the same answer. In comparison, we want to investigate the possibility of improving the learning capability of a virtual agent by utilizing wild cards and other AIML tags to store more generalized responses. A subject matter expert should be able to teach multiple responses to a single query, for instance, a conversational agent may be asked:

```
<category>
<pattern>Who are wealthy people in the city?</pattern>
<template>We have many influential people like king, scribes
 and priest living in the city.</tenplete>
</category>
<category>
<pattern>_ Who are wealthy *</pattern>
<template><srai>Who are wealthy people in the city<srai></tenplete>
</category>
<category>
<pattern>Do you know wealthy *</pattern>
<template><srai>Who are wealthy people in the city<srai></tenplete>
</category>
```

These categories show that when a conversational agent is asked about influential people living in the city, it can recognize and respond to any query related to it. This generalized storage of knowledge categories in the AIML knowledge base can be enabled using wild cards ($e.g.*$, _)and by using other customized AIML tags. In the current version of AIML Engine, several conflicts arise while developing such a solution. Further investigation is required to understand whether a comprehensive conversational agent's learning can be implementable through the AIML Engine, and if yes - what are the mechanisms to develop such a learning approach? Otherwise, what other approaches can best be adopted to provide a good learning tool for subject matter experts for better training of conversational agents in Virtual Worlds?

### 7.1.7 Text to Speech Conversion in Virtual Worlds

Communication in Virtual Worlds of SecondLife is usually preferred through text. Human and agent participants are provided with a public chat window through which text communication is made. There exist some very tentative third party attempts to provide speech conversation ability for participants in SecondLife. One of such solutions is converting public chat messages into speech which can be received by all avatars in the surroundings. However, so far there is no technology available to enable simultaneous speeches by several avatars. In addition, packet loss during the conversations and the complexity of the underlying AIML based conversational engine add up to current difficulties to provide an efficient speech communication facility in Virtual Worlds. Text to speech conversation for our virtual agents can open up further possibilities of exploring Virtual Worlds for teaching and learning.

### 7.1.8 Other Application Domains

In this thesis, we have only focused on applying believable embodied agents in the domain of education specifically for history and culture. Using awareness believability to develop believable embodied agents is a broad concept and is applicable to a wider range of situations. In the future, we plan to explore other applications and domains where our believable embodied agents with awareness believability will be valuable.

# APPENDIX A

## The City of Uruk(3000B.C.)

Uruk was an ancient city located in present day Iraq (circa 250 km south of Baghdad). Many historians consider Uruk being one of the first human built cities on Earth. By 2900 B.C. Uruk is believe d to be one of the largest settlements in the world and one of the key centers of influence of the Sumerian culture. It was situated on the bank of the Euphrates River and this geographic feature contributed to its unprecedented growth. The environment features a flat desert-like area with very little vegetation. It contains animals: donkeys, sheep, eagles and fish. These animals are known to be living in the city of Uruk in 3000 B.C[1]. Historical facts suggest that Uruk was surrounded by a big wall and had a single entrance for the visitors. The Euphrates River started right outside the wall and served as another way of protection from unwanted visitors.

Uruk played a major role in the invention of writing, emergence of urban life and development of many scientific disciplines including mathematics and astronomy. Technologically, it was a time of rapid and important changes. In pottery we see the use of the fast wheel; perhaps most significantly of all, we see the introduction of the first pictographic writing on clay tablets. In Uruk period, temple seems to have been the dominant institution. But the period may have seen the emergence of the first secular rulers. Next sections would discuss in detail the major contributions, architecture and life of the city of Uruk.

[1]NOTE: This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 9772 Research.Ethics@uts.edu.au) and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

Figure A.1: The City of Uruk

## A.1 Buildings:

Sumerians build their houses with mud bricks. Their houses were constructed based on the rectangular shaped building design. To get to the roof top of the building, Uruk building had ramps. Some of houses were also surrounded by small walls; where people kept their animals or used it as fire place for making food. Doors of houses were made out of reed, which was also used for other purposes. City maps show that it had residential houses, market space in similar fashion rectangular buildings; school area, temple and Ziggurat were among the significant buildings of the city. A detail of significant buildings is as below:

## A.2 Ziggurat:

Ziggurat was a temple tower of the ancient Mesopotamian valley. Ziggurats were important to the Sumerians, Babylonians and Assyrians of ancient Mesopotamia. Built in receding tiers upon a rectangular, oval, or square platform, the ziggurat was a pyramidal structure. The top of the ziggurat was flat, unlike many pyramids. Sun-baked bricks made up the core of the ziggurat with facings of fired bricks on the outside. The facings were often glazed in different colors and may have had astrological significance. The number of tiers ranged from two to seven, with a shrine or temple at the summit. Access to the shrine was provided by a series of ramps on one side of the ziggurat or by a spiral ramp from base to summit.

Figure A.2: Ziggurat of Uruk

## A.3 Schools:

For the purpose of training scribes in the Sumerian society there were schools. The information about the scribal schools comes in the form of texts written in Sumerian by people trained in those very schools, giving a detailed account on what went on in them. It is clear in the first place that education was not a common practice, but was largely a privilege restricted to the children (probably only sons, though daughters were not necessarily excluded) of the wealthy and influential, who could afford to maintain their children non-productively for a long period. The examination of the percentage of several hundred scribes shows that they were all sons of such men as governors, senior servants, priests or scribes. An occasional poor boy or orphan might be lucky enough to be sent to school if he were adopted by a wealthy man. The schools were known as 'the tablet house'. An ancient tablet refers to early youth when the formal education began. He lived at home, got up at sunrise, collected his lunch from his mother, and hurried off to school. If he happened to arrive late he got punishment with caned stick and same awaited him for failure to perform his exercise adequately.

The Sumerian document gives some idea of the staffing of the school. At the top was the Headmaster, whose Sumerian titles meant literally 'the Expert' or 'the Father of the Tablet House'. Assisting him there was apparently a form-master, as well as specialists in particular subjects, such as Sumerian and mathematics. Their study was "practical." It was rote learning of complex grammar and practice at writing using clay tablets. Historical remain shows that people of Uruk played board games in their leisure time. Students were encouraged with praise while their inadequacies and failures were punished with lashes from a stick or cane.

## A.4 Temples:

As far as religion is concerned Uruk had many different gods and for some key gods there were dedicated temples built by the citizens.

In the Uruk period, our evidence relates mainly to temples and to other apparently religious buildings. Most of it comes from the great precinct of Eanna at Uruk, dedicated to goddess Eanna, and is called Mosaic Temple. The Mosaic temple was decorated with stones with raised platforms to distinguish it from the common building like houses.

The big temple was built of limestone and bitumen on a podium of rammed earth and plastered with lime mortar. The podium itself was built over a woven reed mat called giparu a word which originally referred a reed mat used ritually as a nuptial bed, but took on the meaning as the source of abundance which radiated upward into the structure.

The construction and design of public buildings has much in common with the temple architecture. The building material and construction techniques are in general much the same. There are evidences of two shapes of houses; the first is the rectangular house, built round either an open court or a large room and others have a T-shaped.

## A.5 Residential Houses:

Residential houses for common people were built using mud bricks. People used reed for installing doors to their houses. These residential houses had windows for proper ventilation and sun light. Reed made mats were mostly used in houses for sleeping and sitting. To get access to the house roof, Uruk houses had ramps. People built their homes behind a wall for protection and also kept livestock inside these walls for some part of the day. This wall protected area had also been used for preparing food. Some of these houses also had water reserves in the form of water tanks built from mud-bricks.

## A.6 People of Uruk:

In ancient Mesopotamia, the term family was called a 'house' and a man was expected to build a house. To achieve this goal, he married a woman and they then had children. To give a brief explanation of how ordinary families spend their day based on their roles and responsibilities in the city here we are considering two fisherman families and give an insight into their daily life routines.

Let's consider two fishermen brothers and their wives living in separate houses next to each other. Both families are very close and spend most of their day together. A typical day for such two families starts with waking up on the roof of their house. Sleeping on the roof is due to the very hot climate. Although, most of the buildings in Uruk had ventilation holes the temperatures inside (especially during summer) could become quite unpleasant and most of the citizens would prefer sleeping on the rooftop in the evening, where it would have been much cooler. Each of the houses would also have sleeping mats inside, but these were mostly used for an afternoon nap, when everybody would seek a hideaway from the hot afternoon sun. The wives would wake up first to collect some water from the well, start the fire and prepare breakfast for their husbands. The fishermen wives had a responsibility of preparing the food, making fishing baskets and trading them for other household items on the local market, bringing water from the well, taking care of house work, home and family. The husbands normally started their day by having a morning chat while waiting for the breakfast to be prepared by their wives. These fishermen are two young men and they possess the fishing gear and are capable of catching the fish. The fishermen in Uruk were quite poor, so they had to rely on each other and share their possessions with one another. Our two fishermen brothers jointly owned a fishing boat. One of the brother managed to bring some wood from the mountains and build paddles for the boat, while his younger brother built himself a spear for fishing. After breakfast the fishermen collect their fishing gear and walk towards the city gates. Outside the gates on the river bank they find their boat which they both board and start fishing. One of the fishermen stands in the boat with a spear trying to catch the fish and the other fisherman is rowing. After fishing, the men exit the boat, collect the fishing basket and spear and bring them back to their homes.

Their wives would be waiting for them at home, would light up the fire and prepare dinner for the husbands. After bringing the catch and putting fishing gear back into the house both families would sit next to the fire and eat their meals. After dinner everybody would start climbing onto the roof of their home and would fall asleep there.

## A.7 Agriculture and Irrigation system:

The date palm was ideally suited to the conditions; it flourishes with its roots in stagnant, salty water and, as long as it is kept wet. Pollinates and pruned. The trees not only produce a highly nutritious food which is a staple part of the diet, but the sap provides a useful sweetener and can also be used to make a sort of fermented date wine. Even the stones can be used as fuel while the leaves provide fiber, and the trunk wood. Barley and wheat were the most important cereals, with the amount of wheat declining throughout the third millennium. Another important range of crops were the pulses - lentils, beans, peas - all of which have high protein content, and the fodder plants like the vetches. Sesame and millet as well were summer crops with a good water supply and could be grown as a second crop in the same ground as the main winter crops of cereals.

Evidence for tools by the two of the pictograms found on the Uruk tablet shows the use of ploughs with a seed funnel. In Uruk, hard over fired clay sickles were widely used. Many agricultural tools would have been made of wood, and even of reeds, which were widely used for baskets, booths, doors, and mats so; that all traces of them have vanished. The more elaborate types of equipments, such as ploughs, were presumably owned by only the richer farmers and were pulled by animals like oxen. Smaller men hired them, with the draught animals, from the temples when they were needed. Stock rearing in general was an important element in the economy. Very large flocks of sheep and goats were kept by the temples. Uruk was present on the bank of river Euphrates which helped for irrigation of the land. Other Sources of drinking water were water wells, where mostly women were responsible to carry thewater. Uruk residential houses also had small mud bricked water tanks for the purpose of water storage like animals' drinking water and other similar uses.

One of the biggest differences in the life of ancient Sumerians, that we tried to highlight, compared to the way of life of modern people is the lack of recreation time. The members of the featured fisherman families (especially women) are continuously working. The men can afford to have a morning chat while waiting for the breakfast to be prepared for them, but their day is also filled up with work. After a short chat the fishermen would have a light breakfast, but then would collect their fishing gear and head to the city gates. Outside of the city walls they would find their fishing boat. Their social status is not very high and, therefore, they have to rely on each other constantly and share their possessions with each other. The boat is owned by the older fisherman, while the spear is the property of the younger fisherman. They are also highly dependant on each other as one of them has to paddle the boat and another fisherman has to catch the fish. Their wives are even more interdependent. They cook together, do house work and go to the markets. All their possessions are also shared. In such circumstances an illness of one of them becomes a serious challenge and has a significant impact on the family welfare. Keeping Animals: The citizens of Uruk extensively relied on domestic animals. Stock rearing in general was an important element in the economy of Uruk. Very large flocks of sheep and goats were kept by the temples. But ordinary people also owned goats, sheep, donkey, cows and oxen in small numbers. Animals like goats, sheep were important part of their food. Fishing was another mean of getting meat. Historical facts shows that, to catch the fish people used fishing gears like spear, boat and reed made baskets. Oxen played important role in agriculture and mostly used to level the land before sowing the crops. Similarly donkeys were used for transportation of the goods. Later, donkey carried carts with wooden wheels were serving the transportation needs.

## A.8 Uruk Market:

The city of Uruk had a market area. This market area was comprised of similar rectangular shape buildings as other residential houses in the city. This market area was surrounded by buildings on both left and right sides; where a market street separates them both. This street got significant position in whole market; because sellers had their booths for selling various goods. These booths were made up of reed and on counters of these booths people used to display different products. Major items being sold in market were reed, reed made mats, baskets, clay pottery, and food item like fish, corn and wheat. No money was used at that time and people exchanged their goods with one another.

## A.9 Food:

The Sumerian agriculture in the 3000B.C. suggests a wide use of various cereal grains in Uruk food. People used to grow barely, wheat and among these agricultural products were dates and various other vegetables. A great source of protein was provided with meat of sheep, goat and these animals were also kept as domesticated animals. Fish also supplemented the diet of Sumerians and fishermen used to catch the fish on a boat with a spear. Animals were cooked on an open fire and people used to start fire by striking two stones with each other. Due to hot dry weather inside, people used to spent time on their house roofs. They also used reed made mats to sleep on top of their roofs.

## A.10 Uruk Inventions:

**Cuneiform Writing:**
Writing is undeniably one of humanity's most important inventions. The earliest forms of storing information on objects were numerical inscriptions on clay tablets, used for administration, accounting and trade. The first writing system dates back to around 3000 BC, when the Sumerians developed the first type of script: hundreds of abbreviated pictograms that could be pressed into clay. Each symbol meant the object presented in the picture: each symbol was an ideogram

or word symbol. A writing system of this kind served the purposes that were limited: it was employed to bookkeeping the establishment of regulation and control over the products of agriculture and craftsmanship. The oldest texts listed of livestock and agriculture equipment; a system of numbers was soon developed, a stroke indicating units and a circular impression tens individual symbols for nouns, verbs, and adjectives followed (People of ancient Assyria, Page-9). These symbols were eventually refined and simplified. As round shapes were hard to etch into clay, they were replaced by lines, and depressions were made at the beginning of the line, creating the unique style known to us as cuneiform script. An example clay tablet is shown in figure below:

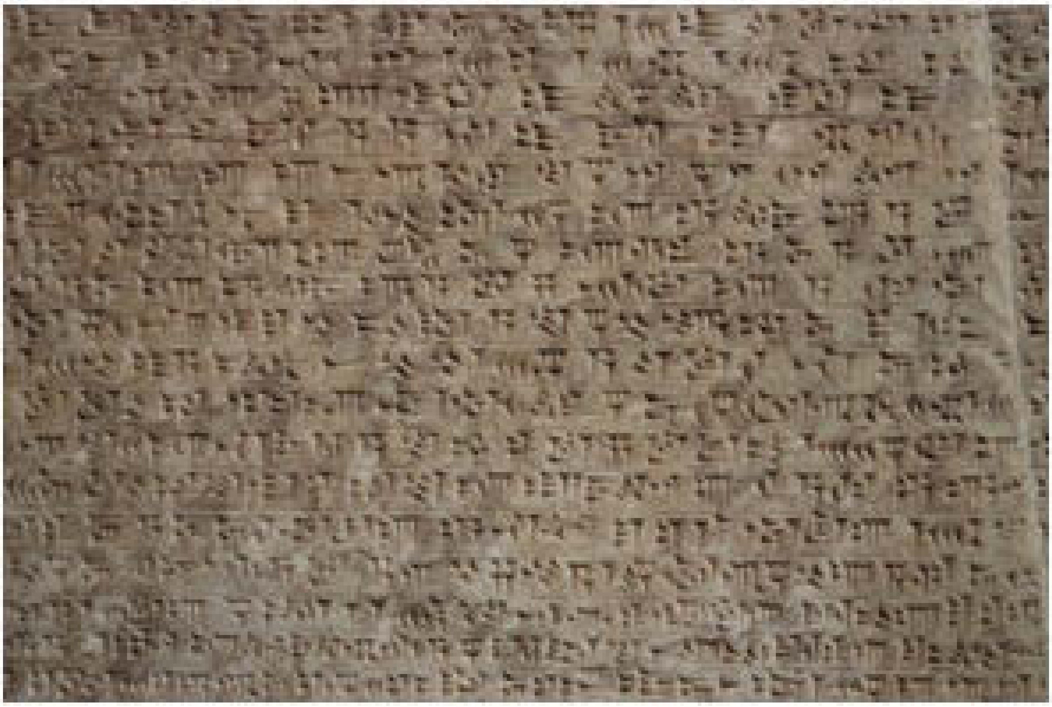


Figure A.3: Cuneiform Writing on A clay Tablet

**Wheel:** The invention of the wheel to assist transportation was made in Uruk, mesopotamia during the third millennium BC. The idea of the wheel is of course much older, and was used first in Mesopotamia for wheel-thrown pottery. When sledges carried heavy loads, log rollers were placed beneath the sledges, eventually evolving into wheeled vehicles, as identified at Uruk by 3000 BC. Ancient wheels of course were used for transportation and also later in war chariots pulled by donkeys. The first wheels started off being made of a solid circle of wood and later spokes were added so they were lighter and much more efficient. The invention of the wheel also created a great increase of trading and food surpluses and also an increase in the production of natural resources.

**Pottery:** The best Uruk period pottery is wheel made but undecorated and unpainted, with a red colored slip or a gray color; the most typical (and far from best) "bevelled rim bowls" about the size and shape of a modern day custard shell. Distinctive forms of pottery were medium sized globular jar with hammer headed or rounded rims, shallow dishes and bowls with inward curving. These were made by clay with the help of a wheel. Use of wheel also allowed the mass production of ceramics and then these pots were sun baked to make them usable.

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http://archaeology.about.com/od/wterms/g/wheel.htm

# APPENDIX B

## Questionnaire (Study II): Teaching History and Culture in 3D Virtual Worlds

**SECTION ONE: DEMOGRAPHICS** The purpose of this survey is to compare the learning ancient history and culture by reading text vs acquiring same knowledge in 3D Virtual World. Please note that your feedback will only be used to study the concept of proposing Believable Embodied Conversational Agents for active learning in the domain of History and Culture. This study does not require any personal data and you would never be identified on any stage of this research. Please try to give to the point response of no more than 250 words. This is the first section of the questionnaire. Here I would quickly take some information related to you. (Tick one box only for all questions)

Q.1 Your Gender

1 Male
2 Female
Q.2 Your Age

1 Less than 20
2 20-24
3 25-34
4 35-44
5 45-54
6 55-64
7 65 and over
Q.3 Are you a native English speaker?
1 Yes
2 No

Q.4 How often do you use Virtual Worlds or Computer games? (Tick one box only)
1 Never
2 Rarely

3 Occasionally
4 Often
5 Very Often
6 Do not know
Q.5 Your Qualifications (Tick one box only)
1 High School
2 Undergrad Studies
3 postgraduate studies
5 Others, namely

Q.6 Your field of study/work activity: (Tick one box only)
1 Exact and life sciences Medicine
2 Computer sciences/ IT
3 Politics Economy, Finances
4 Management, marketing, advertising
5 Humanities
6 Technical studies/ Engineering
7 Any other

**SECTION TWO: Ancient Mesopotamia and Uruk**

Q.1 Do you have any previous knowledge of Ancient Mesopotamia?
1 No
2 Yes (Please give description)

**SECTION THREE: Climate and Buildings**

Q.1 Where did ancient Mesopotamians live?

Q.2 What can you say about the climate/terrain they lived in?

Q.3 What materials were used for creating homes?

Q.4 How would you describe their home?

Q.5 Did they have any non-residential buildings? If so how did they look like?

Q.6 Was there any organized education system present in Uruk? If yes, Please describe.

Q.7 Where did they keep their valuables? Why?

Q.8 How would you describe the Ziggurat of Uruk and its importance to Sumerians?

**SECTION FOUR: People/Food/Animals**

Q.1 What were the major sources of food for people of Uruk?

Q.2 What kind of food preparation procedures did the people of Uruk follow?

Q.3 Were they capable of making fire? If so how did they make fire?

Q.4 Was there any existence of family setup in ancient city of Uruk?

Q.5 What did they wear?

Q.6 Where did they get the water from and how?

Q.7 Where did they sleep?

Q.8 The Daily life of which citizens have you learned about? What was their social status?

Q.9 Do these citizens you learned about had any responsibilities?

Q.10 How did these citizens complete their tasks? What (who) is required for assisting these tasks?

Q.11 Were there any animals kept in the city Which ones?

Q.12 What were Uruk animals used for?

**SECTION Five: Agriculture/ Market place**

Q.1 Which crops were mainly grown in Uruk?

Q.2 Which tools did the people of the Uruk use for agriculture and what procedures did they follow for growing their crops?

Q.3 How would you describe the market space in the city of Uruk?

Q.4 What were the major items traded?

## SECTION SIX: Uruk Inventions

Q.1 Please list down the major inventions of Uruk.

Q.2 How did they keep record of their daily matters like trade, agriculture and accounting?

Q.3 How did they carry their heavy loads and which important invention was introduced?

Q.4 What do you know about the Uruk's pottery and how did they make it? [1]

[1] NOTE: This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 9772 Research.Ethics@uts.edu.au) and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

# APPENDIX C

## Consent Form For User Study

Consent Form: Believable Conversational Agents for Teaching Ancient History and Culture in 3D Virtual Worlds

I ———— agree to participate in the research project Believable Conversational Agents for Teaching Ancient History and Culture in 3D Virtual Worlds being conducted by:

Kiran Ijaz
Email: kijazit.uts.edu.au
Phone: 9514 2039

I understand that the purpose of this study is to investigate the concept of proposing Believable Embodied Conversational Agents for active learning in the domain of History and Culture.

I understand that my participation in this research will involve 15 - 20 minutes of my interaction with the simulation of Believable Conversational Agents followed by filling a questionnaire which should not take more than 10 minutes. I am aware that I can contact Kiran Ijaz(researcher) or Anton Bogdanovych (Supervisor) if I have any concerns about the research. I also understand that I am free to withdraw my participation from this research project at any time I wish, without consequences, and without giving a reason.

I agree that Kiran Ijaz(researcher) has answered all my questions fully and clearly and have helped me during my interaction with the simulation. I agree that the research data gathered from this project may be published in a form that does not identify me in any way. The data collected will only be used in the research thesis, journal and conference publications and this study would be completely anonymous. So I would never be identified at any process of this research later.

———————————— —-/—-/— Signature (participant/guardian)

———————————— —-/—-/— Signature (researcher or delegate)

Contact Details

Email: kijazit.uts.edu.au
Phone: 9514 2039
Or
Anton Bogdanovych
email: antonit.uts.edu.au
Phone: 9514 7932 (Wednesday, Friday)

[1]

[1]NOTE: This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 9772 Research.Ethicsuts.edu.au) and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

# APPENDIX D

## Ethics Letter

23 July 2010 Mr Anton Bogdanovych
Faculty of Engineering and Technology
UNIVERSITY OF TECHNOLOGY, SYDNEY

Dear Anton,
UTS HREC 2010-241 - BOGDANOVYCH, Mr Anton, DEBENHAM, Emeritus Professor John (for IJAZ, Ms Kiran, MA student) - "Believable Conversational Agent for Teaching Ancient History and Culture in 3D Virtual Worlds" Thank you for your response to my email dated 19/07/10. Your response satisfactorily addresses the concerns and questions raised by the Committee, and I am pleased to inform you that ethics clearance is now granted. Your clearance number is UTS HREC REF NO. 2010-241A Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report. I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention. If you have any queries about your ethics clearance, or require any amendments to your research in the future, please do not hesitate to contact the Ethics Secretariat at the Research and Innovation Office, on 02 9514 9772.
Yours sincerely,

Professor Jane Stein-Parbury
Chairperson UTS Human Research Ethics Committee

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