Design of Virtual Tutoring Agents for a Virtual Biology Experiment

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Abstract

Virtual learning environments (VLEs) may possess many advantages over traditional teaching methods in skills training that offer empowerment of constructing the skills by freely exploring a VLE. However, a conflict between the free exploration and ensuring the learning tasks tackled emerges in the learning process. A strategy to balance the conflict is to employ virtual tutoring agents to scaffold the learning tasks. This research has been carried out to investigate the issues of design and utility of a virtual tutoring agent system in a VLE to allow higher education (university based) students to practise immunology laboratory experiments, which simulates a well known immunochemical assay in the Life Sciences area, namely a Radio Immunoassay. This paper discusses the classification of category of the virtual agents in a VLE and focuses on the design of tutoring agents. Three types of the tutoring agents have been selected and implemented in the Radio Immunoassay simulation. The considered points in programming the virtual tutoring agents and their tasks are presented in this paper. A formative evaluation studies have been carried out and discussed to verify the designed virtual tutoring agents are satisfied to the target students' needs.

Keywords

Design of virtual tutoring agent, agent-based virtual learning environments, agent-based virtual environment for biology experiment, agent-based training software in biology, intelligent virtual laboratory, interactive learning software.

Introduction

In Life Sciences education, understanding complex concepts and principles is increasingly crucial. Students' learning success depends upon them comprehending complicated theory and mastering laboratory experimental skills.

To understand complex concepts and principles, students need to be able to study the innate relationships of phenomena and recognize critical points. Laboratory experiments provide the most effective way to simplify and to clarify the comprehension of any complex scientific theory. Unfortunately, there are limitations in real life for students carrying out a laboratory experiment such as time schedule, experimental equipment and using toxic materials.

Virtual Reality (VR) could support the construction of the type of learning environments students need to develop this understanding. VR may have the potential to provide viable learning environments [Psotka, (1995); Winn, (1993)]. VR has been now investigated to create highly advanced learning and skill training environments. It may make important concepts and relationships more salient and memorable, help students build more accurate mental models by engaging them in learning activities. In virtual learning environments, the students become part of a phenomenon and experience it directly. The students play a role in such virtual environments [Camp, (1998)]. The objects in the virtual environments react and move either in response to users' actions or to illustrate motion or their innate behaviour. VR could deepen what the students learn by providing different and complementary insights. VR, as a vehicle for building powerful and compelling simulated environments, allows the students to interact with the virtual world without the usual constraints of the physical world. VR is appealing because it can make for a highly intuitive interface for accessing and organising information.

VR-based applications could provide students with flexible navigation and interaction with the virtual learning environments as in real life. However, a potential dilemma in the promotion of experiential learning emerges. If students are allowed free exploration of these VLEs, how can it be ensured that the target learning objectives are achieved? How can it be ensured that students carry out the necessary activities that will allow the construction of knowledge through their experiences if they are free to carry out some activities and ignore others? Empowerment in the form of free exploration to construct knowledge through interaction with realistic objects and activities should be tempered by the introduction of some form of control (educational strategies) to ensure that the necessary lessons are learned [Cromby, (1996)]. One of the strategies is to employ virtual tutoring agents to scaffold the important activities [Brown, (2002); Rickel, (2000)]. Introducing virtual tutoring agents reduces the flexibility for the students to interact with the VLEs. However, it is necessary to ensure the learning tasks to be tackled.

This project will investigate the design and utility of the tutoring agents in a virtual biology laboratory. The following sections will discuss classification and the types of the tutoring agents embedded in a VLE for biology laboratory exercise. The tutoring agents are analogues of human tutors to provide the students with advice when the needs of help are raised. The formative evaluations of the tutoring agents' system have been carried out with the target users. The purpose of the studies of the formative evaluations is to determine users' requirements and what problems they have experienced in the use of the intelligent software. Based on the feedback of the participants, the intelligent software is improved and assessed in cognitive effectiveness of the VLE by the students.

Classification of Virtual Agents in Three-Dimensional Virtual Environments

Agent-based software introduces a new paradigm for instruction, learning and training in the use of computer aided learning packages. The virtual agents are proposed as a personal butler or assistant [Negroponte, (1997)]. They act autonomously on behalf of themselves or their users, are co-operative in process, convey information to the users, and perform tasks that meet user's goals. In software terms, virtual agents are described as electronic "butlers," performing tasks, such as assisting in learning process [El-khouly, (1999); Baylor, (2002)], and training user's skills [Traum, (2002)]. From the computing viewpoint, these agents are computer programs that simulate a human relationship by doing something that another person could otherwise do for the students [Seiker, (1994)]. The virtual agents in a three-dimensional (3D) virtual environment could be classified into the following categories in terms of their exhibited authentic behaviours [Slator, (1998); (1999)].

Atmosphere agents : an agent that simply lends to the local colour. For example, in an urban simulation there may be a street magician, a street vendor, a street sweeper; in a museum simulation there may be a visitor wandering the exhibits or vendors selling popcorn.

Infrastructure agents : an agent who contributes in some way to the learning process. For example, the agents may be a banker, an employee, and an advertising consultant in an urban simulation. They may be a guide, or an instructor in a museum.

Tutoring agents : an agent that monitors learners' movements, and visits learners to give advice in the form of expert stories and cases, or in some other ways to assist learners. These will represent expertise or past experience of other learners.

Virtual Tutoring Agents in Three-Dimensional Virtual Environments

Virtual agents are built into tutoring systems to respond to the needs of educational and training programmes. The role of the tutoring agents in virtual learning environments emphasizes the interactions and communication between students and these agents as an expert, tutor and assistant [Baylor, (2003a)]. In an agent-based VLE, tutoring agents serve as educators, which introduce concepts and principles, promote an instructional paradigm, and provide help to students. Their ultimate purpose is to communicate with students in order to efficiently fulfil their respective tutoring functions as the educational mission of the system.

Tutoring agents can play several valuable roles in a 3D virtual environment. Since students often fail to recognize that their actions are inappropriate, tutoring agents can intervene with appropriate advice [Rickel, (1997)]. At other times, the students may lack sufficient knowledge to proceed or face an unfamiliar situation. The students could in this case benefit from a tutoring agent that answers the questions or demonstrates a procedure, performance, or a task [Giraffa, (1998)].

To facilitate the assignment of tutoring agents to pedagogical tasks in a learning session, the multiple-agents' concept promotes the idea of designing tutoring agents in learning environments to achieve different pedagogical goals; such as delivering expertise, motivating students, providing procedural tutorials, assessing success and failure within their particular sub-topics, and remedying student performance [Slator, (1998); Baylor, (2003b)].

Design Virtual Tutoring Agents in the Virtual Biology Experiment

Virtual experiment simulation

In a real laboratory, Radio Immunoassay employs molecules labelled with radioactive material (Iodine 125) and permits measurements of extremely small amounts of antigen, antibody, or antigen-antibody complexes. The concentration of such labelled molecules is determined by measuring their radioactivity.

A virtual laboratory has been developed to simulate the procedural tasks of preparing the experiment, mixing labelled antigens with standard and unknown antibodies, vortexing the liquids, centrifuging liquids and separating the supernatant from the liquids [Yu, (2003)]. The user interface of the virtual laboratory is shown in Figure 1. Each of these tasks consists of a series of procedures. The experimental procedures are designed based on the experimental tutorial developed in the Life Sciences Department at the Nottingham Trent University [Billett, 2000]. In real laboratory, some experimental procedures are restricted to be carried out in sequence, called sequential procedures, to ensure the experimental tasks successful and the learning objectives are achieved. Some are not required in sequence, called non-sequential procedures. In the simulated virtual laboratory, the sequential procedures are scaffold by virtual tutoring agents. The non-sequential procedures can be freely carried out, even one can be broken by the other procedures, to offer the students flexibility.

Figure 1. Virtual Laboratory

Types of the tutoring agents embedded in the virtual laboratory

Three types of tutoring agents are created and embedded into the virtual laboratory, which are extended based on previous researcher's work [Slator, (1999)]. The virtual Radio Immunoassay simulation, which constitutes the first part of this research project, provides an exemplar study of the implementation of tutoring agents in such VLE. The three types of tutoring agents in the virtual Radio Immunoassay simulation comprise:

> ***Deductive agents*** which provide assistance to students in the virtual experimental exercises in the course of their deductive reasoning within scientific problem solving required for accomplishment of their goals. The opportunities for the use of deductive agents in the virtual experimental exercises are:
>
> a. *An equipment agent* that detects when a student has failed to acquire the equipment or necessary instruments to achieve their experimental goals. For example, a student selects an incorrect tube to release liquid into.
> b. *An exploration agent* detects when a student has overlooked a goal in their experimental procedures. For example, a student overlooks the addition of a chemical needed in a tube and attempts to go to the next step.
>
> ***Rule-based agents*** provide assistance by:
>
> a. Encoding a set of rules about the domain model that encapsulates the background knowledge of the exercise in the virtual experiment.
> b. Monitoring user's actions and looking for one of these rules to be "broken".
> c. Visiting the users to present expert advice.
>
> ***Case-based agents*** provide assistance to students by presenting them with examples of relevant experience. For example, the case-based agents demonstrate a procedure of a task by playing a video stream or animation.

Agent design

Design of the deductive and rule-based tutoring agents

The deductive and rule-based agents are programmed in the VLE. They monitor, anticipate and recognize the user's actions in the VLE to ensure that the procedures of the virtual exercises are correctly carried out. There is a set of predefined procedure rules. These rules describe the sequential procedures of the virtual experiment. The agents record the status of the 3D objects once the students make an operation on it. Then, the agents compare the actions that the students have carried out with the procedure rules and carry out a check on the status of the 3D objects. If, and only if, the students make a mistake, overlook an object, or break a procedure rule, a tutoring agent presents itself to the students to provide the students with advice. The advice is designed in both text message and sound formats for greater accessibility.

Taking a rule-based tutoring agent as example, the following explanation illustrates the considered points of vortexing liquids in a tube in programming an agent and what the agent does in the VLE:

Aim:	Vortex liquids in a tube.
Procedure rule:	The required liquids, antigens labelled with iodine 125 [I^{125}], unlabelled antibodi antibodies, have been added into the tube in required volume. The tube has beer
Status of the tube:	The status of the tube (recorded in a variable) records the type of liquid that has whether the tube has been capped.
Tasks of the agent:	When the students intend to vortex the liquids in the tube with the vortexing ma • Have the required liquids already been added to the tube? If not, issue appropriate advice. I students proceed. • Has the tube been capped? If not, issue appropriate advice. If yes, keep quite and let the stu
Procedure sequence:	No set sequence is required for vortexing tubes. The tubes can be vortexed in an

A text-based response of the rule-based tutoring agent for vortexing the liquids is shown in Figure 2 when the students make a mistake.

Figure 2. A rule-based tutoring agent

Design of the case-based tutoring agents

The case-based agents are designed to demonstrate the required procedures by playing a video stream when they are explicitly required to do so by the students. It invokes a video player, such as Microsoft Media Player or Real player, and plays the video outside the VLE. The case-based virtual agents are embedded in the Help system and follow the explanation of each procedure. Playing the video stream outside the VLE will not increase the workload of the 3D virtual simulation so that the computer will respond the students' operations quickly and allow the virtual simulations to run smoothly when the video stream is terminated. The strategy of embedding case-based tutoring agents in the help system makes the students think in depth and correct inappropriate actions by themselves first, rather than simply watch the video stream, when a mistake is made. This design strategy makes the students learn the experimental knowledge and skills by making and correcting mistakes.

Evaluation

Evaluation plays a central role in software development to ensure usability and effectiveness of the final product, the two prime indicators of the success of any computer-aided learning tool [Brown, (2001)]. Evaluation is the process by which we gauge the effectiveness, efficiency and usability of intelligent agents.

To develop computer aided learning software, there are many instances when the designer needs answers to questions in order to check that the prototype is really what the users need or want. In this way, evaluation meshes closely with design and improves the learning software by providing feedback. The evaluation process helps to form the software that will be usable as well as useful. For this reason, this kind of evaluation is called formative evaluation [Preece, (1998)].

The formative evaluation exercises are undertaken in collaboration with the target users (students) and the developer. An evaluation study is normally concerned with the activities of user group selection, evaluation methods (including evaluation design, measures, procedures and data collection), results and analysis discussion. The distilled information from evaluation studies is used to improve the software and assess whether the software reaches the users' needs.

In the development of the project, the aim of the formative evaluation studies is to determine users' requirements and what problems they have experienced in the use of the intelligent software. This paper focus on the discussion of the target students' attitude on the virtual tutoring agents, which includes the need for help from the virtual tutoring agents, the preferred types of presentation of the virtual tutoring agents, and the level of detail of the advice provided by the virtual tutoring agents.

Participants

The formative evaluation studies took place in the Life Sciences computer laboratory at the Nottingham Trent University (NTU). Since the intelligent software is developed for a particular user group rather than universal groups, the participants should satisfy certain criteria, such as the knowledge of immunology, and computer skills etc., which are listed in Table 1. Thirty-nine target students had been invited to evaluate the virtual tutoring agents in the VLEs since November 2003 to April 2004. They were students who were currently taking the immunology module as part of an undergraduate degree at the NTU. A criterion of selection of these target students included that they are novices in the use of this 3D virtual laboratory simulation. The profiling of the participants is shown in Table 1.

Table 1. User profiling

User Profiling	**Description**
Age	18 – 19 years old
Sex (male: female)	22:17
Ethnicity	British, Spanish, and Chinese
Physical Abilities/Accessibility Issues	The participants can use the mouse, keyboard and other pointing dev the colours, that is, they are not colour blind, and see words and obje hearing-impaired.
Language	English is used in their immunology module.
Educational background	Undertaking a UK-based University degree in Biology or Biological-r
Extent of expertise	Undergraduate science students with knowledge of biology and immu
Computer skills	The participants are familiar with the use of the mouse, keyboard, m tasks, such as Internet Explorer.
Training they have received on using the 3D virtual environments	The participants are novices in the use of this 3D virtual simulation.

Methods of the evaluation

Design : The participants individually carried out the virtual experimental exercise on a desk-top computer in the computer laboratory. The designer gave them help if it was requested. Participants were asked to volunteer to take part in the study. An interview followed the evaluation.

Measures : A questionnaire survey was used to collect evaluation data. The participants answered the questions after completing the exercise. The questions asked are shown in the form of questionnaire survey in the appendix. The interview offered the students a chance to freely present their opinions about the virtual tutoring agents. The interview and questionnaire survey were used in conjunction as data collection methods to verify the answers to the questions consistent.

Procedure : The formative evaluation study was carried out in five iteration cycles with the participants. The feedback from an evaluation is used to improve the evolutionary prototype. There was no time limitation for completing the virtual exercise. The participants could choose to withdraw from the evaluation study at anytime they wished. Their data, especially personal data, was kept confidential.

Results of the formative evaluation

Results of the questionnaire survey

Table 2. Statistics of the questionnaire survey

Question	**Answers**	**Number of students**	**Percentage**

1. Need help from the agents	Yes	39	100%
	No	0	0
2. Preferred presentation format of the agents	Text message	33	85%
	Voice message	2	5%
	Video	4	10%
	Persona character	0	0
	Other suggestions	0	0
3. When selecting an incorrect object	Display a warning message, but not tell you what is wrong	24	62%
	Display a message and tell you what object should be selected.	11	28%
	Display a warning message and play a video for demonstration	4	10%
	Do nothing	0	0
4. When carrying out a wrong procedure	Display a warning message, but not tell you what is wrong	24	62%
	Display a message and tell you what object should be selected.	11	28%
	Display a warning message and play a video for demonstration	4	10%
	Do nothing	0	0

Results from interview

All of the students agreed that the virtual experiment was an effective way to supplement the module. Embedding virtual agents in the virtual laboratory was a very good idea to support the self-learning process. The virtual reality based intelligent software is a potential way for students to gain the knowledge and experimental experience as they could do in a real laboratory. Some students presented two points about the use of the virtual agents in virtual laboratory.

a. The persona format of the virtual agents does not need to be considered as the students at a university are intelligent. If embedding the persona format of the virtual agents, it annoys the students. The students only need a reminding message either in text or voice format, which are analogues of the human tutors in a laboratory, when they make a mistake.
b. The video-based format of the virtual agents is a good way to demonstrate the procedures when the students carry out the virtual experiment without other people's help. However, for some students, they may prefer thinking the mistake by themselves first rather than watch automatically played video.

Analysis of results and refinement of the virtual experiment

The statistics of the results of the evaluation show the participants' altitudes in terms of the utility of tutoring agents. The results of questionnaire survey show that tutorial agents are necessary for learning software. However, the participants preferred different presentation format of the agents, and different format of advice from the tutoring agents once a mistake occurs, which are consistent with the feedback from interview.

Based on the feedback of the evaluation studies, the virtual tutoring agents are designed in text message format. A voice message is also embedded for great acceptability. Considering some students prefer knowing what mistake has been made, the messages give a clue of the mistake, but not tell the students how to correct the mistake. A help system was created to provide the students with detailed explanation of the experiment, which includes the concepts and principles, and experimental procedures. This help system is displayed in a separate window from the 3D virtual environment when the students make a request. The video-based virtual tutoring agents are embedded at the end of the explanation of each procedure in the help system. The students can easily access them if they need to watch the demonstration. On the other hand, embedding the video in the help system could reduce the workload of the 3D virtual environment, which makes it respond the students' actions fast.

Conclusion

This paper presents the studies of virtual tutoring agents in a 3D VLE, which includes the type of tutoring agents, the design of tutoring agents, the tasks completed by tutoring agents, the formats of advice provided by tutoring agents and the evaluation.

The tutoring agents monitor, anticipate, and recognize the student's actions in the Life Sciences based VLE. They scaffold the sequential procedures in the experimental exercises. A tutoring agent will visit the students when the students reach an impasse, where their progress toward successful completion of exercise is impeded.

The role of the tutoring agents varies in terms of their purposes in the virtual learning environment. Therefore, the tutoring agents are classified into different types. However, all tutoring agents have the same personalised characteristics. They are analogues of human tutors in learning process, which monitor the students' actions and offer advice.

The evaluation studies show that the tutoring agents are necessary for a learning environment. A tutoring agent only performs one specific task. To deal with multi-tasks, the agent system employs multi-agents.

Three types of virtual agents are employed in the VLE. The students preferred different presentation format of the tutoring agents, and different format of advice from the tutoring agents. To make great acceptability of the tutoring agent system, these tutoring agents were designed to present the students with information in varying formats, which can be text messages, sound tracks and video streams.

The feedback from interviews pointed out that the virtual reality based intelligent software was an effective way to supplement the module. The students could gain the knowledge and experimental experience as they did in a real laboratory. However, the effectiveness of the intelligent software in the learning process needs to be investigated in the future. Further work is required to test the effectiveness of the intelligent software in the learning process by carrying out a summative evaluation with a large population of the students.

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Appendix

Questionnaire survey form

Questionnaire survey

1.Do you need the help from the virtual tutoring agents? If yes, please answer the following questions. If not, please submit the questionnaire form.

Yes No

2.What type of presentation format of the virtual tutoring agents do you prefer?

a. Text message
b. Voice message
c. Video
d. Persona character
e. Other suggestions

3.When you select an incorrect object, you would like the virtual tutoring agents to:

a. Display a warning message, but not tell you what is wrong.
b. Display a message and tell you what object should be selected.
c. Display a warning message and display a video for demonstration.
d. Do nothing.

4.When you carry out a wrong procedure, you would like the virtual tutoring agents to:

a. Display a warning message, but not tell you what is wrong.
b. Display a message and tell you the correct procedure.
c. Display a warning message and display a video for demonstration.
d. Do nothing.