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Virtual Observation Lenses for Assessing Online Collaborative Learning Environment

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Abstract. The purpose of this paper is to introduce a new approach for assessing learning outcomes from collaborative work in 3D virtual environments. It represents a novel computational framework that improves recording and observing collaborative activities between students to evaluate learning outcomes. The framework includes a virtual observation model that maps observing learners in classrooms with observing and assessing the students in 3D spaces. This can be accomplished by applying a mechanism that combines natural agents and software agents to support collecting learning evidences from virtual activities and simulate the educators' observation(s). Such a novel framework will solve issues that could develop from evaluating students' performance, interaction, skill and knowledge in collaborative virtual learning environments.

Keywords: E-learning; 3D Virtual Worlds; Assessment; Virtual Observation; Collaborative Learning; Learning Evidence; Software Agents; Natural Agents.

1 Introduction

The power of networks and computers has invented technologies that support learning and connect geographically dispersed learners to enhance learning experiences. Several educational technologies have been widely applied that connect scholars and educators to provide different types of activities and to access learning sessions remotely without requiring physical attendance. By using online environments, organisations could easily educate learners and support collaborative learning without offering physical place or hiring educators.

A great technology that enables virtual collaborative learning is the immersive environment, the 3D virtual worlds (3D VWs). The 3D spaces are increasing in popularity because of many features that distinguish them from other online systems. They connect students in real-time and enhance interactivity, exploration, and engagement between them. Moreover, they facilitate investigation of ideas, situations and places that cannot be reached physically; delivering learning processes; providing

realism of interaction, discussions and activities of even the most complicated topics in simpler conditions with less cost.
Collaborative learning can help students to achieve learning through working with their peers, who support them to enhance their information and skills, resulting in constructing new knowledge and experiences. Learners usually obtain new knowledge while participating in learning sessions, so evaluating learners in a group should not be applied just after the last learning session, but it should also be applied during the learning process. Wells [1] also stated that educators should evaluate the whole learning process when performing collaborative learning activities rather than look at the final artefact as evidence of learning.

However, numerous issues can arise when assessing learning outcomes for a group of students in the 3D environments. Firstly, observing users' behaviour dynamically and collecting evidence of learning are complex tasks in VWs. Secondly, various skills, including communication and negotiation skills, can be gained from collaborative activities, but it is difficult to automatically detect evidence of them in these spaces. Thirdly, labelling and recognizing the evidence of many users in real-time is difficult because several students are contributing at the same time, which makes tracking the evidence much more complex. Therefore, finding an event detection method that can dynamically recognise users' behaviour, collect learning evidence data, and analyse events to measure the learning outcomes, is necessary. Gardner and Elliott [2] indicated that 'learning within technology creates a pedagogical shift that requires teachers to think about measuring outcomes in non-traditional ways'.

The purpose of this paper is to introduce a new approach for assessing learning outcomes from collaborative work in 3D virtual environments. It represents a novel computational framework that improves recording and observing collaborative activities between students to evaluate learning outcomes. The framework includes a virtual observation model that maps observing learners in classrooms with observing and assessing the students in 3D spaces. This can be accomplished by applying a mechanism that combines natural agents and software agents to support collecting learning evidences from virtual activities and simulate the educators' observation(s). Such a novel framework will solve issues that could develop from evaluating students' performance, interaction, skill and knowledge in collaborative virtual learning environments.

2 Related Work

2.1 Identifying Learning Evidence in Virtual Environments

Identifying learning evidence is simple in the multiple choice online test format, but it becomes more problematic in 3D VWs or educational games, because of the large number of observational variables and the complex relationship between these variables and students' performance [3]. Although technological improvements assist in recording data, even for difficult situations, understanding and analysing the composite data that results involves more complex processes.

Certain approaches have been used to assess modelling learners' skills and knowledge in simulation learning spaces. The approaches can be categorised into two groups: 1) knowledge engineering/ cognitive task analysis approach and 2) machine learning/data mining approach. The knowledge engineering approach formulates logical rules to assess and group particular students' behaviours. The rules are also applied to differentiate the level of students' skills such as the study by [4]. In the machine learning/data mining approach, learners' behaviours are recognised by analysing data and extracting learners' performance from the log files that are auto-generated while students are participating. For example, learning evidence has been collected through analysing users' log data by applying cluster analysis algorithms to determine the key feature of students' performance in educational game environments [5].

However, the log files save all the players' responses to the given educational problems which creates enormous amounts of data that provide a serious obstacle for researchers when collecting learning evidence from immersive environments [6]. This makes it very difficult to capture individual students' learning, knowledge, and skills and challenging to identify the actions and performance that represent learning. Moreover, collecting data in simulation or virtual environments without consideration of how the data will be assessed or scored is an ineffective method for creating assessments. Hence, designing the learning environment from the beginning to enable assessment and collecting learning evidence is more preferable [7].

Additional issue with identifying learning evidence is that technologies cannot capture all of the acquired skills. Several skills can be gained from collaborative activities, but it is complicated to automatically detect evidence of them [8]. For example, the quality of the interaction skills between students including teamwork, collaboration, negotiation, and communication are hard to measure with regular assessments. The study [9] proposed techniques that permits assessing learning outcomes (skills, knowledge, and competencies) by using elements such as smart objects and avatars in 3D spaces. However, these techniques lack in measuring the quality of learning in collaborative environments.

Analysing various users' behaviour/data, identifying the meaningful actions, and combining those actions into learning evidence to determine the learning outcomes are very complex processes in such environments. Consequently, discovering techniques that could dynamically recognise learning evidence and analyse events to measure the quality and quantity of learning outcomes is advantageous. Developing such mechanisms will help to identify and gather proof of learning during collaborative activities in immersive worlds and correlate the evidence with learning objectives, to assess the overall outcomes of the learning processes.

According to Thompson and Markauskaite [10], 'educators need to move beyond traditional forms of assessment and search for evidence of learning in the learner interactions with each other and the virtual environment, and artefacts created.' Hence, we have considered another assessment method such as classroom observation which greatly assists educators to evaluate students by collecting evidence about their learning. We have mapped the physical observation to the 3D spaces to provide more insights of what evidence could be collected from students' performance. Section (2.2) gives more explanation of the observation method in learning.

2.2 Observation

2.1.3. 'Teacher observation occurs continually as a natural part of the learning and teaching process and can be used to gather a broad range of information about the students' demonstrations of learning outcomes' [11]. Observation takes place in several settings and with a variety of methods. It can help teachers gather information about the individuals' and groups' behaviours and skills. To distinguish the observation levels in classrooms, Gray [12] introduced conceptual frameworks that follow educational standards to define the basic frames for observing. Because observing classrooms is very complex, he suggests that each teacher should select a specific frame or 'lens' to gain more insight into a specific classroom characteristic. Such 'lenses' are summarised in Table 1.

Table 3. The Observable Signs Pertaining to the Eight-Question Areas [12]

1. The learning climate	• Degree to which students can express their feelings and opinions • Frequency with which student responses are used and extended • Amount of interaction and sharing among learners
2. Classroom management	• Use of preestablished classroom rules • Use of instructional routines • System of incentives and consequences
3. Lesson clarity	• Frequency of examples, illustrations, and demonstrations • Percentage of students who can follow directions given • Use of review and summary
4. Instructional variety	• Use of attention-gaining devices • Changes in voice inflection, body movement, and eye contact • Use of a mix of learning modalities (visual, oral)
5. Teacher's task orientation and content presentation	• Orderliness of transitions • Teacher's preorganization of administrative tasks • Cycles of review, testing, and feedback
6. Students' engagement in the learning process	• Use of exercises and activities to elicit student responses • Monitoring and checking during seatwork • Use of remedial or programmed materials for lower-performing
7. Student success	• Number of correct or partially correct answers • Number of right answers acknowledged or reinforced • Number of delayed corrections vs. immediate corrections
8. Students' higher thought processes and performance outcomes	• Use of teaming, pairing, or other cooperative activities that encourage student problem solving • Display of student products and projects • Opportunities for independent practice and application

Adopting these 'lenses' when observing students can determine what could be evaluated and monitored when assessing students. They can help to observe students learning and to recognise the type of evidence should be collected when measuring the learning outcomes. Furthermore, creating a virtual observation hierarchy model to determine the granularity levels of observing learning activity in collaborative virtual environments can assist designers and developers to identify the learning evidence that can be captured and help to apply it in the virtual environment. Suskie stated that 'the more evidence you collect and consider, the greater confidence you will have in your conclusions about students learning'[13].

3 Proposed Observation Technique in 3D VWs

We propose the Virtual Observation Portal (ObservePortal), which is a 3D virtual environment that can track users' behaviour and capture real-time evidence from collaborative activities. The environment employs real classroom observation lenses and applies each lens to the virtual world. The observation level can be stated in the learning design by the teacher to identify which lens should be activated to evaluate the learners. It determines the levels of granularity for observing learning activity in virtual environments to capture the learning evidence, beginning with general observation to in-depth observation (more details in section 5.4).

To capture the learning events, the platform utilises some techniques from agent systems to track users' actions and predict the learners' acquired skills and knowledge. It has two different types of agents: software agents and natural agents. The software agents track learners and collect different users' clicks and actions, while the natural agents perform peer evaluations of each other to evaluate the quality of performance. These agents are employed to record both implicit and explicit data that will be analysed to determine the learning evidence and students' performance. All agents will work together in real-time to collect the learners' evidence (more details in section 5.3).

3.1 The Learning Environment

The virtual world (ObservePortal) is the environment in which the students will perform the activities. To implement the research prototype, the InterReality Portal will be used, a project developed by a member of the Immersive Learning Lab, Anasol Pena-Rios, at the University of Essex (Figure 1) [14]. It is built upon the Unity [1] platform, a flexible development platform for assembling 2D and 3D collaborative games and environments. The environment was developed using the C# programming language. We chose to apply the prototype within this environment because it supports collaborative programming activities and assists in setting up learning tasks that help students understand the concepts and functionality of embedded systems in smart homes.

[1] https://unity3d.com/unity

Fig. 4. Graphical User Interface (GUI) – InterReality Portal [14]

4 Conceptual Framework

Based upon the literature, observing and measuring online collaborative learning outcomes, both dynamically and on the fly, within 3D virtual worlds is scarce. As a result, we have proposed a Mixed Intelligent Virtual Observation (MIVO) conceptual framework that mixes learning models and computational models for observing and evaluating collaborative learning in 3D VWs. The framework consists of five models: user, learning, observation lenses, mixed agents and presentation (Figure 2). Each model will be discussed in the following section.

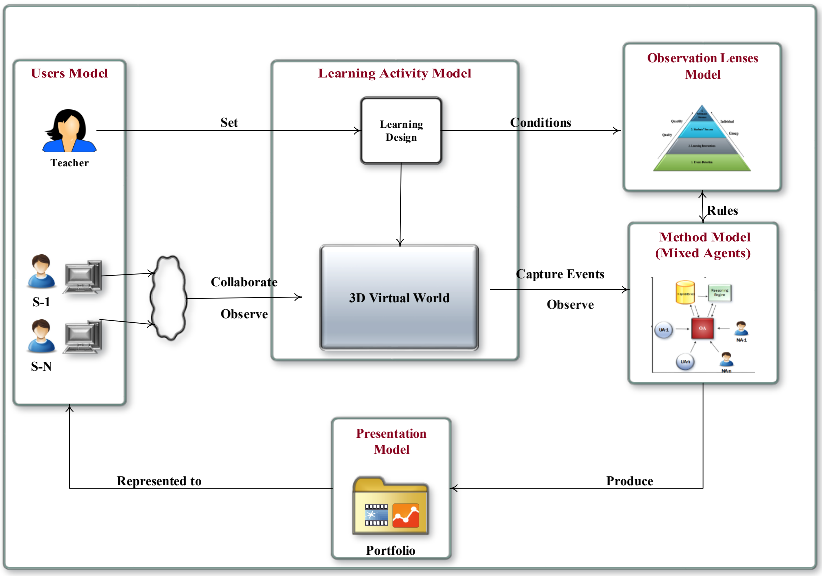

Fig. 5. Mixed **I**ntelligent **V**irtual **O**bservation (MIVO) Conceptual Framework for Collaborative Learning Environment

4.1 Users Model

This model identifies who the users are and their roles within the learning activity. Users will be either learners or teachers, and the specific user interface will be displayed based upon the user's identity and role. For example, instructors have a customisable interface that allows them to design learning activities. Moreover, a teacher can view learners' portfolios to evaluate their performances and review their work. From the learners' viewpoint, the user interface will enable them to interact with the environment and with other students' avatars. All participants will then work together on the simulation learning activities in the 3D environment. They can participate in the activities, evaluate others, obtain learning feedback from the system and view their portfolios.

4.2 Learning Activity Model

This model consists of two parts: the learning design and the environment that contains the collaborative learning practices. The learning design is defined as the learning scenarios that can be shared in the system and that can be planned and adjusted by the teachers. Moreover, the teachers can specify the observation criteria for evaluating the learning outcomes. Also, this model includes the virtual environment that students will participate in.

4.3 Mixed Agents Model (MixAgent)

This model identifies the method of gathering different types of evidence to illustrate individuals' and groups' learning outcomes. We expand the concept of software agents to include natural agents (users). The software agents will be needed to automatically track users' behaviour and collect data from real-time events as users interact with each other and with objects in the virtual world. Two types of software agents are used: user agents and ontology agent. In addition, the natural agents will be combined with them to enhance the capture of evidence. All agents, software and natural agents, will collaborate and work towards one central goal together, to produce evidence that evaluates the quality and quantity of students learning and performance (see Figure 3). In the following section, the agents' capabilities including their particular assessment abilities will be discussed.

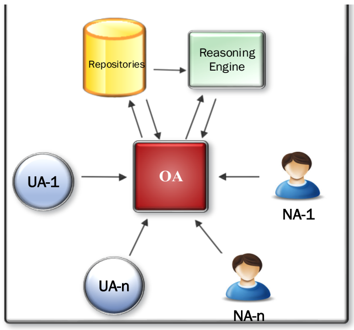

Fig. 6. Mixed Agents Model (MixAgent)

- **User Agents (UA).** These agents will be created once a student is authorised in the environment. There will be an agent for each learner. This agent can trace the user's actions in real time, translate any behaviour into data and send them to the ontology agent. They will monitor users' log data, behaviour and history.
- **Natural Agents (NA).** Peer evaluation could assist in capturing implicit learning evidence that is hard to capture with technology [8], and it would be useful to secure it from people directly to distinguish students' performance. To this end, learners will be considered natural agents. These agents can produce learning evidence by regularly assessing the quality of each other's communication, negotiation, teamwork, and active learning skills. While students are working together, there will be sliding scales scored from 1 to 5 will allow natural agents to act and rate other learners regularly. When the natural agents produce evidence and trigger the system, messages will be sent to the ontology agent. The ontology agent will receive the data and store them in the ontology repository. Employing natural agents will permit capturing the quality of learning outcomes that are too complicated to be identified by technology.
- **Ontology Agent (OA).** This agent is based on a semantic web and ontology approach that models different elements in the VW. Ontologies typically consist of object classes, the relationship between these objects and the properties that the objects have [15]. With ontologies, we can set up all the relationships between objects so that devices can understand the meaning of concepts. They can offer a standardised vocabulary to describe a knowledge domain by developing connected semantics and sets of vocabularies that can be reasoned. Thus, we have proposed this agent which has the ability to receive data from other agents and send them to the repositories. It will act as a communication agent and a bridge between all agents in the learning environment, so the collected data from other agents can be analysed based on logical rules that could assist in retrieving learning evidence. This agent will infer the relationship between the collected data and what it means in term of learning evidence through using a reasoning engine. Moreover, the logical rules will permit reasoning the repositories and parsing more meaning from the data gathered by each agent.

4.4 Observation Lenses Model (OLens Model)

This model determines how we can analyse the data that is captured by the agents. To observe the students in the classrooms, educators should consider numerous criteria, aspects and frames to gain more insight into the students' learning and improve their education. However, not all learning outcomes and skills mentioned can be easily observed and identified in virtual environments. Depending on the observation framework [12], we adopt particular 'lenses' to our model and applied them to the 3D VW to evaluate what could be monitored in these environments. The virtual observation model defines the levels of granularity for observing students and recording evidence of collaborative learning, commencing with high-level to low-level observation (see Figure 4). The observation layers are: events detection, learning interactions, students' success and performance outcomes.

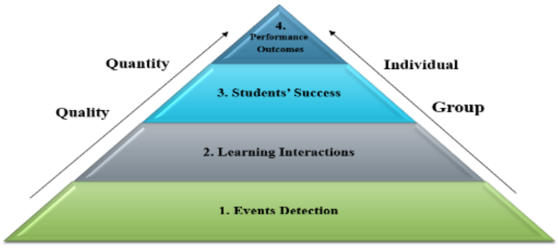

Fig. 4. Observation Lenses Model (OLens Model)

Describing the model lenses and their pedagogical meaning, beginning with the lower level of the hierarchy is Events Detection lens. This simulates an instructor when he/she watches a collaborative activity from high altitude, but without looking deeply into what is happening. In the VW, the automated observer monitors the activity by recognising that a sequence of events is occurring and capturing these events without judging. The second level is Learning Interactions lens, which considers a deeper view of the social and environmental interactions. In our case, the social interactions are between peers, and the environmental interactions are between students and the VW. Evaluating the quality and quantity of collaborations and interactions infers whether the learners have valuable interactions and if they are active learners in their groups. It determines the amount of sharing and interaction among students. The third level is the Students' Success lens. It represents teachers when they are observing the students' success by counting the number of correct answers, the number of right answers reinforced or acknowledged, and the number of delayed corrections. The fourth level is Performance Outcomes, which simulates the observer tracking the students in-depth to identify the skills and knowledge that they have acquired from the learning activities.

These frames help to measure the individual's and the group's performance, and the quality and quantity of each learning outcome. The following sections provide examples of how one can map some of the pedagogical lenses to collect evidence or to create logical rules that can be applied to the VWs.

- **Events Detection Lens.** This level focuses on observing the activity from a high level and collecting different events that demonstrate interactions between students and their surroundings. Examples of the events that can be observed and collected from students and group activities include the following:
  Avatar Actions:
  Avatar Log: <AvatarID, AvatarName, LogInTime, LogOutTime, Date, GroupNo>
  Chat Log: <AvatarID, DialogueTime, DialogueText>
  Touched Object: <AvatarID, ObjectID, ObjectName, TouchedType, Time>
  Rating: <AvatarID, RatedAvatar, RateScore, Time>

  Group Actions:
  Group Log: <GroupID, GroupMembers, StartTime, EndTime, Date>
  Group Dialogue: < GroupID, GroupDialogueText >
  GroupRating: **<**GroupID, GRateScore >

- **Learning Interactions Lens.** In this level, we are extending the teachers' judgements of group interactions in a physical setting to understand the interactions between the group and individuals in the virtual environment. It is possible to infer the quantity and the quality of the learners' interactions by creating rules based upon the teachers' viewpoints. Table 2 gives examples of the rules that can be created in this lens.

Table 4. Examples of the observation rules

	Quantity	**Quality**
Individual	The number of a learner's contributions in using the virtual objects during a period compared with other learners.	The rating scores for a student from other members in a period. 5 = Excellent; 4 = Good; 3 = Average; 2 = Fair; 1 = Poor
Group	The number of the group's contributions in the activities compared with other groups.	The average rating scores for all members in one group.

4.5 Presentation Model

The final model in the framework illustrates how evidence of the learning outcomes will be presented to teachers and learners. From the evidence gathered by agents and applied observation rules, the evaluation model will demonstrate how the performance of individuals and the groups was rated. The observation methods will allow analysing the learning outcomes from the activities and will correlate them to the learners' portfolios. These portfolios can demonstrate students' performances through any type of method, for example, it can include a feedback dashboard displaying when performance was either high or low, to allow teachers to evaluate the group as a whole and as individuals. Another example is that the performance could be reviewed by video snaps that map between time stamps of evidence and video recording to enhance the learning affordances of the immersive environment through visualising and reviewing the learning outcomes.

5 Conclusion and Future Work

In this paper we have introduced and described the Mixed Intelligent Virtual Observation (MIVO) conceptual framework for the collaborative learning environment. It consists of several models: user, learning activity, mixed agents, Observation Lenses (OLens), and presentation. The **MixAgent** and the OLens models play important roles to observe and recognise events that are occurring during the learning activity to evaluate the students learning.

This is a work-in-progress paper and there is much research still needed to be completed. Currently, we are commencing with the technical experimental phases to investigate the appropriate mechanism, based upon the complexity of observing and assessing learning in 3D VWs. The aforementioned collaborative environment, InterReality Portal, is used which allows students, worldwide, to participate in learning activities. In the future, the mixed-agents approach, namely, the combination of the natural agents (users) and software agents will be implemented to provide better results for collecting evidence and evaluating students. Hence, this phase will demonstrate how software agents can be combined with natural agents to improve the collection of learning evidence.

The next phase of the experimental phase will explore how to observe students' activities in the virtual world by applying methods from physical educational settings. The mixed agents approach helps observe and recognise events that are occurring during the learning activity and record them without evaluating the students. To analyse and translate these events, we will examine the frames of the OLens Model to create virtual observing rules that can infer learning outcomes in such environments.

The final experimental phase amalgamates all previous phases and explores the observation system implementation within the design of the collaborative learning activities, constructing learners' portfolios based on the evidence-gathering mechanisms, and analysing this data based upon the observation layers in the model in real-time.

Beside the experimental phases, the evaluation of our work is an essential component which is considered for the future progress. The research framework and models will be evaluated through user-based and expert-based evaluations. We are looking forward to report the results for the experimental and evaluation phases in future events and conferences.

Acknowledgment.

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