

Towards Observing and Assessing Collaborative Learning Activities in Immersive Environments

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Abstract. Immersive environments such as 3-D virtual worlds have shown great potential for learning since they have many features that distinguish them from other learning systems. They support explaining difficult phenomena by visualising objects and their relationships. Additionally, they enable collaborative learning by connecting students in real-time and increase engagement and exploration between them. However, assessing learning outcomes in these environments involves many challenges such as dynamically capturing and analysing the actions of users and translating these actions into learning evidence. This paper focusses on significant aspects of the learning process: observation and assessment. It presents a virtual observation model that maps observing learners in classrooms with observing and assessing students in 3-D virtual environments. In addition, it demonstrates the implementation of the observation model and provides examples of its application. In general, the paper aims to enhance the learning affordances of the 3-D virtual worlds by recording all in-world learning evidence and visualising students' assessments to improve learning.

Keywords: E-learning; Multi-Users Virtual Environments; 3D Virtual Worlds; Assessment; Virtual Observation; Collaborative Learning; Learning Evidence.

1 Introduction

In the 21st century, various educational technologies have been developed to support and enhance collaborative learning such as Multi-Users Virtual Environments (MUVes), also known as 3-D virtual worlds (3-D VWs). Open Wonderland¹, Second Life², Active Worlds³, and Open Simulator⁴ are examples of the platforms that have been recognised to create MUVes. These environments have shown great potential for learning [1] [2] [3], because they have many features that distinguish them from other online learning systems. They support explaining difficult phenomena by visualising

¹ <http://www.openwonderland.org/>

² <http://secondlife.com/>

³ <https://www.activeworlds.com/>

⁴ <http://opensimulator.org/>

objects and their relationships. Additionally, they facilitate exploration and practice-learning activities that cannot easily be done in physical environments [2]. Furthermore, they enable collaborative learning by connecting students in real-time, increasing engagement and analysis between them [4] [5]. Through arranging collaborative learning activities in these environments, students can share their experiences which help to improve knowledge and skills.

Assessing students is a critical aspect when organising learning activities. Usually, learners acquire new information or skills while practicing individual or collaborative activities. Thus, the evaluation of students should be considered from the beginning of the learning process and not just at the end. For example, Wells [6] indicated that educators should assess the whole process when performing group activities rather than assess the final product as learning evidence. However, observing and assessing learning outcomes in the 3-D world could produce some difficulties such as dynamically capturing and analysing the behaviours and actions of users. Additionally, observing evidence about acquiring specific skills such as cognitive skills is challenging. Therefore, an approach is needed to identify learning evidence data, and for analysing the data to assess the learning outcomes of the collaborative activities in any environment. According to Gardner and Elliott [7], 'learning within technology creates a pedagogical shift that requires teachers to think about measuring outcomes in non-traditional ways.' Moreover, virtual environments need more examination to discover their learning potential and to enhance their affordances for teaching and evaluating students [3].

In our previous work [8] [9], we proposed the conceptual models, the virtual observation model (OLens) and the mixed agents model (MixAgent), to support collecting learning data and analysing the data to assess the performance of students. This paper focusses on the work we have done to take existing observational techniques from the real classroom and map them to a MUVE so that they can be used to recognise the learning outcomes from collaborative students. In particular, it represents the continued development of the OLens model and its implementation in a MUVE, as an example of an immersive learning environment. We also demonstrate how this model could be used when evaluating the interaction, performance, knowledge and skill of the learners in collaborative learning environments. The rest of the paper is structured as follows: section 2 (assessments in immersive environments) discusses techniques and previous studies that have assessed the learning of students in virtual worlds. The third section (virtual observation model) introduces the OLens model and the observation layers used within the model. The fourth section (virtual environment) explains the application of the lenses and shows examples of the implementation. Finally, the last section presents the conclusion and the future work.

2 Assessment in Immersive Environments

The assessment of students in general has been defined by Angelo [10] as "an ongoing process aimed at understanding and improving student learning. It involves making expectations explicit and public; setting appropriate criteria and high standards for

learning quality; systematically gathering, analysing and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document, explain and improve performance". Assessment should measure the learning of students based on different aspects such as learner performance, success, knowledge, and skills. On the other hand, observing the essential differences of various categories requires different methods to be applied. For instance, knowledge can properly be assessed by traditional exams, but evaluating skills requires more complex activities and techniques that can demonstrate them. MUVES can achieve this objective through creating complex situations and supporting exploration of phenomena that do not exist in the physical world [2]; which allow the enhancement of skills and competencies. Providing assessments and feedback in the learning process can enhance student learning and improve their performance.

Several approaches have been used to assess students learning in MUVES. Firstly, the traditional school test approach, which involves giving paper tests to students or generating automated questions and multiple choices during or after finishing the learning activity to assess learning. For instance, in Second Life, most educators use an extension of classroom summative tests to provide final assessment [11]. Another example is the quizHUD project [12] in SLOODLE [13] that uses a multiple choice interface to assess students' knowledge. This approach could be useful when the environment is used to give lectures, imitating the physical classroom setting, where the evaluation objective is to assess the student's knowledge. However, traditional school tests should not be applied to measure learning outcomes when the virtual environment offers hands-on or experimental activities to teach students. In these settings, summative tests do not provide a full perspective of the student learning and cannot adapt to the needs of learners, nor provide them with immediate feedback while they are working. MUVES enable significant learning opportunities for distance learners through distributed systems in collaborative and cooperative activities that require new assessment methods to meet today's complex learning requirements. Thompson and Markauskaite [14] stated that '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.'

A second approach that has been applied to assess learning is analysing the actions of students. It is regularly based on the cognitive task analysis method which consists of creating logical rules to track students' behaviours and to distinguish specific levels of the skills of learners [15]. An additional technique to analyse the actions of students is to extract the performances of students from generated log files by applying machine learning or data mining approaches. For instance, Kerr and Chung [16] analysed the log data of users by applying cluster analysis algorithms to define the key feature of the performance of students in educational game environments. In addition, Bernardini and Conati [17] applied cluster methods and class rules on the log data of users to find out the models of learners using successful and unsuccessful strategies within the learning environment. Even though these studies are investigating the behaviour of users, they are limited to studying the relationships between the data and identifying the quality of the learning outcomes from the log files. Moreover, it is more challenging to identify

learning evidence for collaborative learning activities where there are many contributing users. The log files keep all actions of users to problems, and this generates a large amount of data and delivers a serious obstacle for researchers when collecting learning evidence to recognise various learning outcomes [18]. Capturing the data of users without identifying how they are scored is not an effective process for creating assessments. It is more preferable to develop the learning environment from the beginning to gather learning evidence and assess students learning [19].

According to Gobert [20], educators encounter serious issues when assessing learning in immersive environments. The first issue is that there is an absence of theoretical guidance to analyse streams of data generated from the performances of learners. The second issue is the lack of theoretical foundation in literature in the learning assessment and assessment approaches. Conversely, some studies have applied the Evidence-Centred Assessment Design (ECD) framework introduced by Mislevy and Riconscente [21] [18]. ECD is a general framework created to assess students learning in computer-based tests, and it consists of different models: ‘student model’ (what to measure either student skills, knowledge, or abilities), ‘evidence model’ (how to measure), ‘task model’ (where can we measure it). Others have used ECD to assess students in simulation environments to assess learning skills [22]. Shute [23] developed the Stealth assessment based on the ECD which applies an AI approach (Bayesian network) to model the student actions in a learning game and infer the level of problem solving skill. He proved that the inferred learning events closely matched with actual students learning. However, these studies applied the assessment in-game context to assess a specific competence or skill based on the behaviour of a player. On the other hand, there are no standardised assessment models or guidance to observe the learning activity and assess all learning aspects such as student interactions, success, knowledge, and skills. Furthermore, most of these studies focus on assessing individuals, but one of the most important features of MUVES is allowing collaborative activities and sharing knowledge. To measure collaborative learning activity, we need to evaluate the learning of the group as well as the learning of individuals. Nevertheless, there are few studies that present theoretical guidance to assess such activities. Accordingly, this paper continues our previous work on the virtual observation lenses model (OLens), which provides solutions for assessing students, by presenting the mechanisms and aspects that should be considered when assessing collaborative learning activities on immersive environments.

3 Virtual Observation Lenses Model (OLens Model)

The OLens Model [8] defines the frames of observing, capturing, and analysing data to assess collaborative learning activities in immersive environments. The model has been derived from observations in physical classrooms where teachers should observe many aspects of learning to understand the behaviour of students. Thus, we adopted the observation lenses in [24] that focuses on student learning, and modified and applied these lenses to work on 3-D virtual worlds (3-D VWs). The OLens model states the granularity levels for observing the actions of students and clarifies what could be monitored.

Moreover, it defines the learning evidence of collaborative learning, starting with high-level to low-level observation (see Figure 1). The OLens layers are events detection, learning interactions, success of students and performance outcomes.

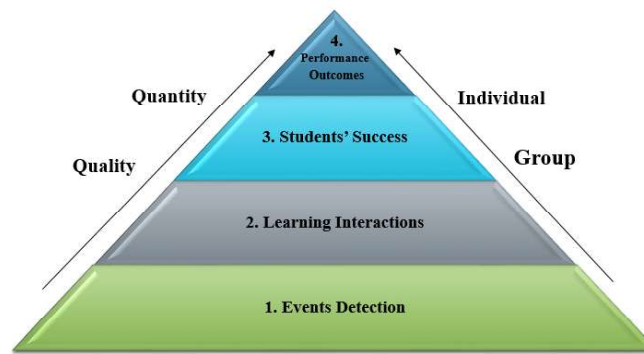


Fig. 1. Observation Lenses Model (OLens Model)

The Events Detection Lens. This lens simulates high-altitude observation, similarly to when a tutor watches a collaborative activity without analysing deeply into what is happening. To apply this in the VW, the system monitors the activity by recording and capturing the sequence of events without assessing learning. This level focuses on collecting all implicit and explicit learning events that are produced by students such as saving the actions and logs of users to support the other lenses that are responsible for analysing these actions to assess learning.

Learning Interactions Lens. This lens reflects a deeper observation of environmental and social interactions. Social interactions relate to interactions between the group members, and environmental interactions involve interactions between users and the VW. Furthermore, this lens focusses on evaluating the quantity as well as the quality of interactions to infer whether the students are active and valuable members in their groups. Examples of factors that measure how many interactions happen are the number of actions of a learner during a period and the number of actions of a group

Students' Success Lens. This level symbolises when educators are observing students' success in the classroom, and extends it to recognise learners' success in VWs. Student's success can be measured by the percentage of the correct responses they achieve to the questions, exercises, or assignments [24].

Performance Outcomes Lens. This level focusses on observing students in-depth to identify the outcomes during the learning activities. In this lens, educators can observe any type of learning outcomes they would like to assess. According to [25], the outcomes of learning involves what a student understands, knows, and is able to do to complete the learning process. They are defined as knowledge, skills and competence. By studying the literature and expert reviews, we can understand the evidence to be collected from learners to measure specific skills and competencies.

The OLens frames support measuring the performances of users and the quantity and quality of each learning outcome. The following section (4) explains the virtual environment that we have used to apply these lenses and gives examples of how these pedagogical lenses can be mapped to assess students' performance in VWs. More details about applying these lenses are presented in section 4.2.

4 Virtual Environment

To make the OLens model come alive in an immersive environment, we present an example of applying the model levels on the Interreality Portal, a 3D virtual environment developed at the University of Essex [26] (See figure 2). The environment is built using Unity3D⁵, a flexible development platform for assembling 2D and 3D collaborative games and environments. We use the Interreality Portal as our learning platform because it supports collaborative learning activities between online students using hands-on activities. The Interreality Portal allows students to collaboratively program different sensors and actuators by creating IF-THEN-ELSE rules in real time. It was designed to teach students the concepts of embedded systems and their functionality in smart homes.



Fig. 2. Graphical User Interface (GUI) – InterReality Portal [26]

4.1 The Learning Scenario

Students were grouped and asked to log on the online virtual environment (a group is formed by two to four students). Each student had their own avatar and they worked collaboratively in given learning tasks to solve numerous problems. These tasks teach them the functionality of embedded systems (sensors and actuators) and how they can create and programme rules using the programming board and icons. Thus, if they create syntactically correct rules, the result is reflected on the virtual smart home (Figure 3).

⁵ <https://unity3d.com/>



Fig. 3. Students collaborating in the virtual environment

To communicate and exchange ideas to accomplish the assigned tasks, learners can use a chat box in the GUI. While participating in the learning activity, the system provides them with the opportunity to rate each other, with the aim of evaluating the quality of their actions and those of their fellow students, using the rating tool (Figure 3). Moreover, the environment tracks the actions of the users and saves all the triggered events in the repository. While the students progress through the different collaborative tasks, the system captures learning evidence and analyses the actions of the users. Then, when the learners finish the assigned tasks, they receive an automated dashboard displaying the final analysis of their individual and group performances, summarising the learning outcomes. In addition, the instructor and each learner can review their work through recorded videos that show their performance compared with the provided assessments.

4.2 Applying the OLens Model

In this section, we provide examples to clarify the methods that apply and map the pedagogical lenses to collect evidence and to create rules and queries that can be implemented on the VW.

Event Detection. This level is where the system starts collecting the actions of students and saving them to the database simulating teachers watching from high view without inferring or assessing students. We have proposed the use of a mixed agents model (MixAgent) [8, 9] which identifies real-time events and captures learning evidence to assess the quality and quantity of the performance of students in virtual worlds. Mix-Agent combines software agents and natural agents (users) to provide better assessments results. Software agents monitor the behaviours and logs of learners, transform actions into data, and then send the data to the repositories. While the natural agents are the students who evaluate their fellow students to capture implicit evidence that is challenging to identify with simple technology [27], students are able to see the quality of the performance of others and evaluate the collaborative learning skills of their peers. Thus, we provided users with a rating tool (Figure 3) to regularly rate their peers and give them scores from 0 to 2 (Negative= 0, Neutral = 1, Positive= 2). These scores are

stored in the repository, and all the data from both agents are used by the OLens model for assessment.

To apply this level and collect evidence from both agents, we created a data repository to save all users actions while working together. Also, we recorded the rating points that the natural agents gave to each other. Examples of the collected data in the VW are as follows:

- User Log: <UserId, UserName, SessionId, IdActivity, ObjectType, ActionType, Service, ServiceInfo, IPAddress, TimeElapsed>
- Session Log: <SessionId, SessionName, StartTime, EndTime >
- Chat Log: <UserId, Room, ChatText, TimeElapsed >
- Programme Log: <UserId, IdActivity, Programme, TrueOrFalse, TimeElapsed>
- Rating Log: < UserId, RatedUserId, Score, TimeElapsed >
- Skills Scores: < UserId, RatedUserId, Skill1_Score, Skill2_Score, Skilln_Score>

Learning Interactions Lens. To implement this level, we build APIs to query the data stored to assess the quantity and the quality of the general contribution of learners in the virtual environment. Table 1 provides examples of the quality and quantity indicators that measure the effectiveness of interactions for individuals and groups which can be applied to this VW.

	Quantity Indicators	Quality Indicator
Individual	<ul style="list-style-type: none"> -The amount of actions in the chat log during a period. -The amount of actions in using the virtual objects during a period. -The amount of actions in creating programmes during a period. 	<ul style="list-style-type: none"> -The average rating scores for a student from other members in a period. Rating scores: Negative= 0, Neutral = 1, Positive= 2
Group	<ul style="list-style-type: none"> -The sum of all the actions of all the members in a group actions in chat log, objects log, and programme log during a period. 	<ul style="list-style-type: none"> -The average rating scores for all members in one group in a period. Rating scores: Negative= 0, Neutral = 1, Positive= 2

Table 1. Interactions Indicators

Student Success Lens. This level extends the decisions of teachers determining the success of students in classrooms to 3D virtual environments. As mentioned, success of students can be measured by counting the percentage of the correct responses the students achieve to questions and tasks [24]. Table 2 gives examples of the indicators that measure the task success in this lens for the group and individuals.

	Quantity Indicator	Quality Indicator
Individual	-The amount of correct/wrong answers during a period. -The amount of completed/ un-completed tasks on time.	-The rating scores from other members about the quality of a student work when doing a task.
Group	-The amount of the group correct/wrong answers during a period. -The number of completed/ un-completed group tasks on time.	-The sum of the rating scores from all members about the quality of the group work when completing a task.

Table 2. Task Success Indicators

Performance Outcomes Lens. This lens is a summative assessment that focuses on evaluating the quantity and quality of the learning outcomes at the end of the learning activity rather than evaluating just the correct answers. Since the activities between students focus more on collaborative learning, it is necessary to assess the learning outcomes based on their collaborative skills. Johnson [28] identified different collaborative skills including communication, maintaining trust, leadership, and creative conflict. However, most of these skills cannot be measured easily by the data collected from the system. They need more feedback from the actions of students with peers and environments. One approach of measuring these students skills is to use a peer evaluation technique to assess the performance outcomes of the learners [29]. Adopting this approach can obtain deeper insights regarding the quality of collaborative skills the students apply on the learning activities. Students were asked to rate the performance of their group members during and after the learning activities. Figure 4 shows a screenshot of the rating scene that includes the collected data from student at the end, and Table 3 gives examples of the learning outcomes indicators to assess students in this lens.

The screenshot shows a web interface titled "Evaluate the Group Members". At the top, there is a text input field labeled "Evaluate the Student". Below this, there are four skill categories, each with a horizontal slider and three markers: "Negative", "Neutral", and "Positive". The categories are: "Communication Skill", "Leadership Skill", "Creative Conflict", and "Maintaining Trust". A blue button labeled "Save Evaluation" is positioned at the bottom right of the interface.

Fig. 4. Final rating screen to evaluate each group member skills

	Quantity Indicator	Quality Indicator
Individual	Summative results at the end of a session: 1-The amount of interactions of a learner from the interactions lens. 2-The amount of a success tasks of a learner from the success lens.	1- The rating scores for the collaborative skills. 2- The average rating scores for a student during the learning activity.
Group	Summative results at the end of a session: 1-The amount of the group actions from the interactions lens. 2-The amount of the group success from success lens.	1- The rating scores of the skills for all the group members 2- The average rating scores for a group from all members.

Table 3. Learning Outcomes Indicators

4.3 Assessment Feedback

After finishing the session, students and teachers can view their work through the dashboard showed in Figure 5, which demonstrates the quantity and quality of groups and individuals' interactions by time. As shown in Table 1, for the quantity of interactions, the system counts the number of users' actions during the learning activity. In addition, to measure the quality of the contribution of a student, the system calculates the rating scores for each student using the feedback from the other members, to determine if the student contributions in the learning task are valuable. Figure 5 is an example of the assessment screen that appears after the learning session finishes. The left section represents the data from automated agents (the quantity of interactions), and the right section represents the data from natural agents (the quality of interactions). Then, the learners can review their work through recorded videos to follow their performance compared with the assessments dashboard, as shown in Figure 6. For example, if the chart shows that the student has low interaction at the beginning, he or she can watch the video to understand this result and know how to increase the performance later.



Fig. 5. Dashboards show a student interactions by time in the learning activity.



Fig. 6. Video recording to review the student performance.

5 Conclusion and Future Work

Real classroom observation and assessment is well documented in the literature. Nevertheless, in immersive environments, observing students and assessing them based on their performance is still in the preliminary phase. Consequently, the paper extends the learning affordances of 3-D VWs, which is the ability to capture all in-world events automatically, and this is very difficult to perform in the real world. Thus, to capture all events, we present the virtual observation model (OLens) which could play important roles to understand the actions of learners during the learning activity and to evaluate their learning in the VWs. The OLens model consists of different levels, including events detection, learning interactions, success of students and performance outcomes lenses. Each lens emphasises evaluating students learning from different aspects. Assessing students is an important phase of the learning process, because it can determine whether the learning objectives have been achieved. Additionally, it can help to understand the performance of learners and provides more awareness about improving the collaborative activities. Moreover, the peer assessment approach that was used provides greater understanding of the value of the contributions of students and give more insights about the collaborations quality.

Also, this paper contributes to enhancing the learning affordances of 3-D VWs by visualising students' assessment to improve learning. It demonstrates the implementation of the model lenses, provides illustrations of the data collected by each lens and gives examples of their applications on the virtual world. In addition, it presents a combination of the final assessment with video recording which can aid learners to recognise their weaknesses and strengths, allowing them to understand how they could improve their performances and enhance their learning. Providing such recorded events and feedback could also support saving them as evidence in students' lifelong learning portfolios.

Finally, this is a work-in-progress model and there is more work still needed to be completed. Currently, we are developing *Student Success* and *Learning Outcomes* lenses. Future work includes the validation of the model through expert-based and user-based evaluations, for which we aim to present our results in forthcoming events.

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