Skill Assessment in Virtual Learning Environments

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***Abstract*— For Virtual Learning Environments (VLEs) to reach their potential as a mainstream educational technology through employing experiential activities, they need assessment rubrics that are easy to execute and measure. This paper presents a study that investigates the use of automatically collected metrics in a 3D VLE along with metrics related to the learning process derived from established assessment criteria for higher order skills such as critical thinking, communication, and collaboration. Our study results provide supporting evidence that learning process metrics collected from a 3D VLE can be used for assessing higher order skills to compliments instructor's understanding of student's skills levels and to provide the necessary support during the learning process.**

Keywords—Virtual Learning Environments, Assessment, Metric

I. INTRODUCTION

With the world becoming a more challenging place to live with the growing population, limited natural resources, and the increasing use of advanced technology, having strong higher order skills such as communication, collaboration, and critical thinking is more and more crucial. Around the globe, educators, recognizing the need for such skills, are forming partnership to identify and support the development of these key skills; mostly known as the 21st Century skills. Examples of these efforts are UNESCO (http://en.unesco.org/themes/education-21st-century) , European Commission Partnership for 21st Century (http://lsl.eun.org/snack24) , Partnership for 21st century (http://www.p21.org), and Canadians for 21st Century Learning (http://c21canada.org).

As part of fostering these key higher order skills, the role of digital technology in education is advised to be refined as well [8]. In today's educational systems, technology is more used as an information consumption tool such as surfing the internet, taking a test or writing essays rather than collaborative knowledge creation tool such as analyzing data, running a simulation or working with people from distinct locations. Instead, digital technology should take a role of an enabler, accelerator of the 21st century skill development [8][12][24].

Researchers suggest that learning strategies used in constructivist theory deserve special position in the 21st century learning [14]. Active learning, learning by doing including role play, scaffolding, and problem-based and collaborative learning are the characteristics of the constructivist learning pedagogy [20][27]. Emerging technologies such as Virtual Learning Environments (VLS's) enable such practices through immersive, procedural, and collaborative simulation that "offer the capability to implement situated learning environments in classroom settings" [1] [7][13][34].

However, like any educational technology, "Computer-Based Learning Environments (CBLEs) are effective to the extent that they can adapt to the needs of individual learners" [5]. Therefore, for VLEs to be effective they should anticipate and adapt to the user needs. Adapting to the individual learners' needs requires observing and assessing learning progress and anticipating those needs [5][36]. Conventional approaches to evaluate knowledge gain are done through pre and posttest assessment via questions and answer method. Due to process-oriented nature of higher order skills (such as critical thinking, communication, and creativity), their assessment requires a different approach that does not rely only on the output but also the process [32][36]. Researchers therefore highlight the importance of computer-based assessment as a help in skill assessment with their capability of capturing rich information while students are going through a learning process [4][35]. Capturing the type, order, and quantity of interactions while student is going through a learning task are considered richer than traditional single answer output-based assessment and provide information on methods and strategies students are using [6] [16][17].

Therefore, it is essential for VLEs to have learning activity assessment methods that are easy for educators to implement and modify and can provide such process-oriented observation of skills and performance. Despite notable suggestions, there is no mature, easy-to-implement performance assessment methodology for 3D VLE's, specifically focusing on higher order skills.

Study presented here looks for evidence that VLE metrics, collected in 3D immersive activities based on learner's interactions with the platform, can be analyzed to get insight in learner's higher order skills and can be used to support assessments based on instructor observation. We argue that this insight provides valuable information regarding the effectiveness of the activity and allows educators to offer necessary support to students during their learning process. The study uses an immersive 3D activity, where learners have the opportunity to demonstrate higher order skills. Learners' actions are recorded and investigated along with VLE captured metrics (such as interactions and movements) for the following study objective:

- Provide supporting evidence that VLE platform metrics can be used to evaluate students higher order skills

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- Report on missing VLE metrics that are needed for skill assessment

In our study, students' skill components are assessed and compared using the following sets of data:

- Instructor observation of participants' activity recording in VLE
- VLE automated basic metrics such as gesture count, trigger activation count
- Manually captured process metrics such as activity count of activity performed suggested by the instruction board, going back to instruction board when task failed
- Students year-end academic grades

Correlation analysis was performed on the following pairs of the above data:

- Instructor's assessment vs. basic metrics
- YearEnd grade vs. basic metrics
- Instructor's assessment vs. process metrics

The main contribution of our work is providing evidence that process-based metrics, such as activity count, are more effective for assessment than basic commonly-used metrics such as gesture counts. Our findings suggest strong relations on three skills (Communication, Engagement, Drawing Conclusion), between the assessments based on learning process metrics and instructor observation. This implies that automatically collecting and analyzing these learning process metrics can support and/or replace instructor assessment.

This investigation is relevant to educators, as it will help them to get insight into students' learning process through VLE statistics, allow them to observe, assess and provide support to students while they are going through immersive activities. It is further relevant to 3D VLE platform designers by offering insight into the student evaluation process and identifying missing metrics that would assist both educators and learners using 3D VLEs as a learning platform.

Summary of the related work by other researchers can be found in the next section. In the following sections, we describe the study design and results, and provide some concluding remarks.

II. RELATED WORKS

Assessing learners' higher order skills within virtual learning environments is not a new concept for scholars. Veenman et al. [33] endorsed the theory that log files captured can be used to get insight into learners' meta cognitive skills. Their study showed strong correlation between calculated skill assessments based on interaction statistics versus external skill assessment. The data captured by platform such as thinking time (no activity between two interactions), scrolling screen, and unique actions performed by students that were scored and used for assessing meta cognitive skills [33]. Veenman study performed in 2D learning tool provides encouraging results to test similar approach in 3D immersive environments.

Due to their spatial nature, multi-user 3D VLE platforms offer more interaction opportunity than single-user 2D platforms used in Veenman study, and foster collaboration and communication. In a study performed at a history course [2], students were asked to use 2D excavation simulation versus 3D excavation simulation, survey showed the effectiveness of 3D simulation. Students found 3D excavation simulation more educationally stimulating than the 2D simulations (Table 1).

Despite these advantages that are well-studied by scholars over the last decade, VLEs are still not employed widely in educational organizations to facilitate skill development. More data supporting learning and training on 3D VLE platforms, particularly with regards to assessment and support, should be provided to help these platforms reach their potential in education.

Questions	Response Value (Mean -Score 1-4)	
	2D	***3D***
I felt I learned something by answering the question	1	3
I found system educationally stimulation	0.8	3.4
Working in group help me to understand the excavation process	0.8	3.8

Table 1 Comparing 2D and 3D Simulation

In terms of assessment methodology, most computer-based learning tools and studies measure learning gains via pretest and posttest conditions in line with the traditional education system [21]. However, researchers have raised concerns about this approach:

- Educators need to interpret events on the new platform before the end of the learning cycle so that they can adequately anticipate students' needs and provide support. Traditionally this is the role performed by human tutors [5].
- These traditional approaches are not adequate for determining students sophisticated skills. To assess and understand the areas for improvement for each student, we need more sophisticated assessment tools to follow student's decision making, thinking and investigation process [10][32].

An immersive interface offers unique potential in non-interruptive, in the background assessment through evidence that can be collected throughout the learning process. As virtual environment evokes wide spectrum of performance, student's engagement, self-efficacy and various sophisticated skills can be assessed [11].

Immersive virtual environments above mentioned potential investigated in the following study. Chrystal Island [29] is an immersive virtual island for students to investigate, collect information, analyze the data and reach conclusion on a biological mystery. Students who exhibit strong self-learning skills, such as self-reflection and critical thinking, can drive their own learning and are often more successful in learning tasks and academic settings. Therefore, it is important to classify students based on their learning skill level and provide the support needed. Study reported by Sabourin, et al. [30], attempts to predicts students' performance through interactions on Chrystal island.

During the learning tasks students are asked about their activity they are involved at the moments and objective of the activity to encourage self-reflection. Students' responses are scored based on the level of reflection. Comparison between pre and post-test knowledge score and self-learning skill level shows that students with higher learning skill gain more knowledge than others. However, this is a self-deceleration type of assessment on students' self-reflection.

Researchers then look at the activities that students used in virtual environment, while the differences in the use were not significant, data shows some trends within successful students, as they perform less experiment but interact more with books and posters, take more notes, and run less experiments.

Shute and her colleagues [32] study and report on 3D game-based stealth assessment using Evidence Centered Assessment design (EDC)[25][31]. According to EDC framework, the first model to build is competency, which determines the competencies that learner will be assessed on. Then it is the evidence model that needs to be built which consists of (a) evidence rules that convert the work products to observable variables, and (b) the statistical model that defines the statistical relationships between the observable and competency variables. Observable variables provide evidence relative to a student's level on these competencies. Once observable values are defined, then it is time to decide how to score them and establish relationship between each observable and the associated level of competencies [32].

Just like competency profile, human phycological profile has different dimensions and traditionally created as a result of self-respond questionnaire. One study of creating psychological profile was carried by Guardiola in immersive virtual environment game setting through user interaction [18]. Working with experts in phycological profiling, researchers categorized and scored each game action per different dimensions in Holland RIESEC model [19]. The study results showed a strong relation between personality profiling based on players scored actions, such as repairing roof or harvesting apples, and their external text-based profiling. This study shows that scoring individual actions can provide insight into the dimensions of the player's physiological profile in an immersive virtual game setting.

Emphasizing the importance of serious games in professional skill development, Loh and Yanyan [21] proposed a metric to measure player's performance resembling the idea behind actionable intelligence [28] . Similar to entertainment game analytics, serious games analytics can be derived from tracing players' gameplay and the visualization of their actions, behaviors, and play-paths within virtual/gaming environments [22][23].

To the best of our knowledge, none of the above VLE performance assessment or profiling methods reached to maturity in a way that classroom teachers can create an immersive activity and easily assign a rubric to assess students' higher order skills. The lack of proper automated assessment tools limits the teachers' ability to use and modify pre-configured immersive environments or create new ones.

New immersive virtual platforms are emerging with sophisticated features. These virtual platforms allow players to import objects from a library, assign information and create simulations on the fly. Therefore, in near future classroom teachers can login to a VLE and create an explorative learning activity without external designer interaction but need proven methodology to set up these 3D activities with proper rubric to evaluate students higher order skills on various components.

We agree with Floryan, et al. [15] in their arguments that we can use wealth of user learner interaction data collected on computerized learning environments to assess students and provide help without requiring large investment or developing complicated assessment methods. The study presented here is a step in that direction.

III. STUDY DESIGN

The study reported here uses an immersive 3D activity to observe students' learning skills. This self-guided VLE activity teaches students the functions of the platform over a path with information and instructions to follow and puzzles to solve to advance at each step. Study objectives are to provide supporting evidence that VLE platform metrics can be used to evaluate students higher order skills, and to report on missing VLE metrics that can be used to for skill assessment

Figure 1. Immersive Learning Activity in Carleton Virtual

Carleton University has been using a 3D VLE, Carleton Virtual, for language learning for over 5 years. Carleton Virtual started on Avaya Engage platform (no longer operational) with a classroom and open area simulation and over the years, more on and off-campus areas were added to support immersive 3D language learning activities as the most commonly used function [3]. The platform currently uses Virbela (http://virbela.com) which similar capabilities as Avaya Engage. The self-learning activity used in this study is a tutorial step for users prior to performing the other course-related activities.

VLE used for this study is built on Avaya Engage platform, which includes features, such as real-time document up-loadable boards and interactive clickable objects. The platform also captures user gestures, interactions, talk-time, and location in a log file for analysis. The 3D immersive self-regulated learning path build on Avaya Engage platform, employs instruction boards to teach students typical features of the VLE platform in use. Instruction boards provides explanation on related features and suggest activities to students to improve their understanding. At the end of each section of the path, there is a related puzzle that students are suggested to solve to advance to next section (Figure 1). However, students are able to advance without solving the puzzle by jumping over a gate if they choose. As the result, students' choices demonstrate some of their learning skills during the activity.

Based on the Canadian Partnership assessment index as guidance on the 21st century competencies [9], the following skills can be observed and assessed through the 3D immersive activity that is selected for this study:

- Communication
- Learning from mistakes
- Engagement
- Drawing conclusions

IV. Experimental Results

A. Data Collection and Analysis

Eight undergraduate students taking English Second Language course joined the study. Participants were from China (4), Middle East (2) and Indonesia/Philippines (2). Their field of study were business, computer science (3), history, architecture, mechanical engineering, biology. During the study, students' VLE activities are self-recorded using school provided screen recording tool to perform the analysis later.

Following activity-based basic metrics collected by VLE platform are extracted from VLE log file for analysis due to their relevance to required tasks:

- Spoke to other (sec)
- Change volume (location) and Unique volumes Visited
- Gestures performed during the activity
- Total triggers used
- Unique features used (calculated through a script)

Learning process metrics were captured manually per each task by watching students' activity recordings. Even though the study activity has 5 different tasks, the following metrics were common and observable in all those tasks:

- Reading instruction board (10sec minimum)
- Performing activity instruction board suggested
- Experimented with any activity
- Opening the door successfully
- Going back to read instruction board when door opening fails
- Advancing by jumping over the gate
- Staying on the course to complete the 3d activity

Yearend academic grade also received and included in the analysis.

B. Study Findings

This study was performed in the context of a course on English as Second Language for international students. There were 10 students in the course and 8 volunteered to participate in the study. The study was approved by the Ethics Committee at Carleton University.

Correlation analysis was performed on the following pairs of the collected data:

- Instructor's assessment vs. basic metrics
- Year-end grade vs. basic metrics
- Instructor's assessment vs. process metrics

Our correlation analysis provides no strong relations between instructor observation-based assessments and VLE-collected basic metrics. The highest and only notable relationship is between year-end academic grade of the students and the number of unique features they used on the platform (Table 2).

The correlation between learning process metrics and observation-based assessments was more positive. The correlation between individual learning process metrics and observation-based assessment provided us with insight with the metrics there were more likely to be useful for assessment. This resulted in selection of some learning process metrics as measure of different skills, as shown in the following formula:

- Communication (Reading instruction board + Performing activity instruction board suggested)
- Engagement (Performing activity instruction board suggested)
- Drawing conclusion (Performing activity instruction board suggested - Cheating by jumping over the gate)
- Learning from mistakes: No strong relations could be identified between two assessments relate to this skill. The Table 2 shows the calculated score for this skill based on learning process metrics using the following formula that gave the best results:(Experimented with any activity + Going back to read instruction board when door opening fails - Cheating by jumping over the gate)

V. Discussion

We performed r correlation matrix analysis with all the metrics we collected, both basic and process metrics with instructor's observation-based skill assessment. Result of this analysis is shown in Table 2. Our study did not provide strong correlation between collected basic metrics versus instructor's skill assessment. Strongest correlation (r=0.64) was found between year-end grade and unique featured used by students during the learning activity. As the objective of the learning activity was learning VLE platform features, this result may be interpreted as academically strong students achieving the lesson objective or naturally tapping on the available resources. More study should be done to identify.

Presented study, however, provided strong evidence that learning process metrics are better indicators in terms of providing insight on student's higher order skills. Correlation values r=.92, r=.90, r=.87 were found between instructor's assessment versus process metric-based calculated assessments for *communication, engagement* and *drawing conclusions* respectively.

Our findings support the theory that, in terms of skill assessment on VLE platforms, collecting process metrics is important. We found that some process-aware metrics should be included in basic VLE metrics, such as time spent looking

	YearEnd Grade	Instructor Assessment: Communication	Instructor Assessment: Engagement	Instructor Assessment: Learning from Mistakes	Instructor Assessment: Drawing Conclusion
SpoketoOthers	0.20	-0.13	-0.14	-0.45	-0.17
Entered New Areas	-0.06	-0.33	-0.49	-o.38	-0.05
Unique Areas Entered	-0.39	-0.13	-0.18	-0.51	0.27
Time Spend	-0.11	0.31	0.14	-0.83	-0.22
Gestured Performed	-0.27	-0.12	-0.36	-0.41	-0.01
Unique Features Used	**0.64**	0.18	0.15	-0.4	0.17
Calculated: Communication	0.18	**0.92**	0.87	0.33	0.78
Calculated: Engagement	0.33	0.70	**0.90**	0.24	0.65
Calculated: Learning from Mistake	0.46	0.30	0.34	0.09	0.35
Calculated: Drawing Conclusion	0.41	0.64	0.70	0.18	**0.87**

Table 2. VLE Metrics vs. YearEnd Grade and Instructor Skill Assessment r Correlation Values

at information boards/objects and also groups of interaction metrics related with process, preferably configurable by instructors, for example time looking at a board plus performing the suggested action or failing to solve problem plus going back to board again to read.

No strong correlation can be identified between *learning from mistake* skill versus metrics nor calculated skills.

It is worth noting that highest correlations for year-end grade were between calculated *learning from mistake skill* (r=.46) and instructor assessed *draw conclusion*s skill (r=.39).

VI. CONCLUSION

Presented study investigated the potential of using 3D VLE metrics to provide insight into student's higher order skills in the context of using 3D immersive activities. This insight is important not only to follow students' progress but also for adapting training activity and making the activity more effective. We observed students in academic setting during the 3D immersive learning activity and compared metric-based calculated skill assessment with assessment based on instructor's observation. Our results suggest strong correlation between learning process metrics versus instructor's skill assessment. Our study adds supporting data on already existing literature that: (1) it is possible to get insight on learner's higher order skills via interaction analysis in VLEs, (2) skill analysis based on learning process metrics provides better insight than assessment based on the VLE basic metrics. We do believe that metric-based skills assessment should complement instructor's assessments but cannot replace them.

Based on our findings, we recommend educators use meaningful interactions to trace learners thinking process while designing 3D learning activities. Human observation assessments are costly. VLE collected metrics may help teachers to provide timely and more frequent feedback to students. We also recommend VLE designers offer an integrated interface to collect and use learning process metrics. Configurable metrics such as number of specific interactions after an identified interaction, such as; performing and experiment b and c after reading information d, suggested as one of the most important configurable metric in skill assessment based on our findings.

Literature suggest student's motivation and self-efficacy play important role in the outcome of computer-based learning activities [26]. In the scope of this paper, we did not analyze the students' survey responses that would give us information on their motivation and self-efficacy. In our next step, we will include this data in our analysis.

In this study, learning activity was on a predefined path. We also like to perform our metric analysis on exploratory immersive activities where students have more freedom in exploring the space.

For the presented study, we limited ourselves to correlation-based analysis. The study was designed as a proof of concept with limited participants (8 participants). Our intention is conduct follow up studies with larger participant groups which provides more significant findings and also allows more comprehensive statistical analyses.

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