Skill Assessment Using Behavior Data in Virtual World

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ABSTRACT
Highly interactive game-like virtual environment has gained increasing spotlight in academic and educational researches. Besides being an efficient and engaging educational tool, virtual environment also collects a lot of behavior data which can be used with Educational Data Mining (EDM) techniques to assess students' learning competencies. In this paper, we propose an assessment system that seamlessly integrates EDM techniques with functionality and affordance of a virtual environment to assess students' learning competency through analyzing their behavioral data and patterns. The virtual environment can record not only students' learning outcome, but also their detailed learning process information, which has the potential to depict the full set of students' learning activity. We also propose a set of metrics which can be used for judging students' Self-Directed Learning skills and how these metrics can be evaluated computationally by capturing students' behavioral data in a virtual environment. The field study, which is conducted in Xinmin Secondary School in Singapore, preliminarily illustrates the effectiveness of our approach.

Keywords
Educational Data Mining; Virtual Environment; Competency Assessment; Self-Directed Learning

1. INTRODUCTION
In the fast changing and increasingly globalized society, students nowadays need to become more conscious, controlled, independent and active in their learning. The new requirements of education urge the creation of new assessment approaches. Besides being an efficient and engaging educational tool, virtual environment also collects a lot of behavior data which can be used with Educational Data Mining (EDM) techniques to assess students' learning competencies. Many researchers have worked in this area [1-3]. The system that we proposed is based on a full-scale 3D virtual environment to assess students' learning competencies. Among all kinds of learning competencies, we focus on Self-Directed Learning (SDL) competency in our research study because it is among the most important learning competencies students need to excel in the knowledge society of the 21st century [4]. SDL skills are important indicators of students' learning competencies as they are the fundamental philosophy behind life-long learning. The proposed system uses Evidence Centered Design (ECD) approach to assess students' SDL competency through analyzing their behavioral data in virtual learning environment. With the Competency Model, Evidence Model, and corresponding Task Model, the system can provide opportunities for students to elicit behavioral indicators of certain SDL skills. These behavioral indicators can be used for assessing the skill levels which cannot be discerned from traditional academic assessment. Moreover, we conducted a pilot study in Xinmin Secondary School Singapore to demonstrate how to evaluate the SDL metrics. The study illustrates the preliminary effectiveness of our approach.

2. MODELING SDL SKILLS
The overall system architecture consists of two main modules: the Virtual Singapura II (VS-II) System and Assessment Automation module. VS-II System is a full-scale 3D virtual world to promote intelligent agent mediated learning. As an open environment, VS-II allows students to explore and learn in a self-directed manner. By recording student's behaviors in the virtual environment, the system provides a convenient and effective setting to elicit students' behavior evidence of their learning skills through the whole learning process.

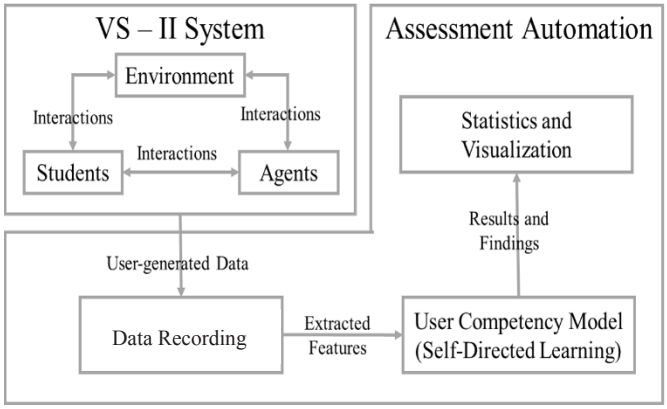

Figure 1. System Architecture for Assessing Students' Learning Competency.

The Assessment Automation module has three sub-modules as shown in Figure 1. The first module – Data Recording meticulously records a wide range of student learning behavior data. There are totally 78 types of events being tracked in the system, and the data collected in the virtual environment consists of three categories: 1) Student learning behavior data, such as locations, timestamps, mouse clicks, etc. 2) Student learning achievement data, such as collected items, fulfilled missions, etc. 3) Student knowledge data, such as correctness of responses, hints required, etc. The second module – User Competency analyzes students' behavioral data through Evidence Centered Design (ECD) approach. Evidence Centered Design (ECD) is the framework for assessment that makes explicit the interrelations among substantive arguments, assessment designs, and operational processes [5]. Similar to the approach Shute has adopted in her study [6], we utilize ECD methodology in our system design to track and interpret students' behavioral data to assess students' SDL competency. The system is designed in a

three-layered model. The three layers are: 1) ***Competency Model*** identifies what should be assessed in terms of skills. The competence of Self-Directed Learning (SDL) is denoted as C_1, where C_1 consists of three aspects of skills $\mathbf{S}^{C_1}$, and $\mathbf{S}^{C_1} = \{S_1, S_2, S_3\}$, where S_1 denotes Ownership of Learning, S_2 denotes Management and Monitoring of Own Learning, and S_3 denotes Extension of Learning. 2) ***Evidence Model*** identifies behaviors that demonstrate the skills defined in 1). The essential student behavioral indicators for SDL are defined as $\mathbf{B}^{S_i} = \{\text{behavioral indicators of } S_i\}$, where $i \in \{1, 2, 3\}$. 3) ***Task Model*** identifies the tasks that would draw out behaviors defined in 2). Let T = {tasks completed by students in the learning environment}, and $\mathrm{T} = \{T_1, T_2, \ldots, T_L\}$**.** Each task T_i is an n-tuple, which consists of an ordered list of learning activities. Let $T_i = (A_1, A_2, \ldots, A_n)$, and $A_i \in \mathbb{A}$ denotes a learning activity. $\mathbb{A}$ is the set of learning activities and each A_i is atomic and cannot be further decomposed into other learning activities.

In our implementation, we focus on the assessment of SDL skills in one of its three aspects, "Management and Monitoring of Own Learning". We illustrated the assessment process by emphasizing one of the skills of SDL competency,S_2, i.e. Management and monitoring of own learning skills. This skill is defined with three behavioral indicators. For each behavioral indicator, we designed several evidence variables to capture a student's performance (as Figure 2). The Last module Statistics and Visualization module visualizes all the results and findings through our user interface.

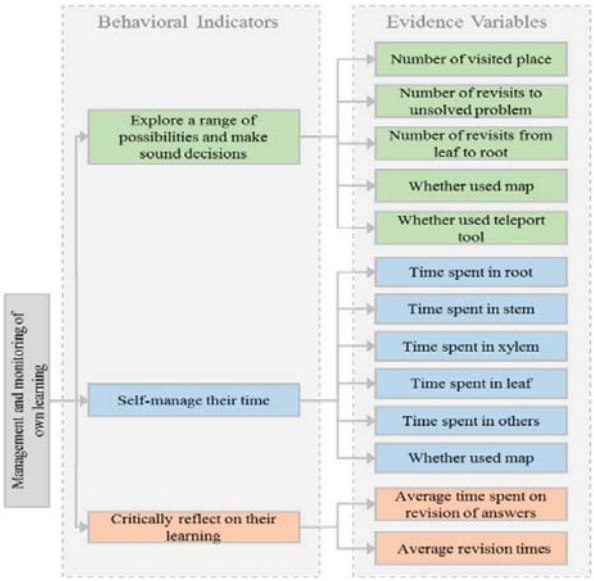

Figure 2. List of Behavioral Indicators and Evidence Variables on Management and Monitoring of Learning.

3. PILOT STUDY AND FINDINGS

The assessment prototype has been deployed in Xinmin secondary school in Singapore. The field study on one side aims to examine whether the whole system is technically workable (data transmission, real time data recording, network setting, client response, etc.), on the other side aims to examine whether the SDL skills can be identified among students with students' real behavioral data. 26 students from Secondary 2 (age 12-13) have participated in our study. In order to get the benchmark, we collected students' SDL skills markings from three of their teachers, and calculated the average scores on each perspective. We also let students fill in a SDL self-report questionnaire.

Significant results have been found. For time management, students who used the virtual map to plan their learning path completed a significantly higher number of learning tasks during the same sessions as compared to those who did not. About 50% of the students in the group with the virtual map completed 4 learning tasks, while for the other group, most students (close to 60% of them) only managed to complete 2 or 3. The average number of learning tasks completed by the group with the map is 3.83, while that of the other group is 2.5. Also, students who more tended to rely on the mobility tools provided in the game (i.e. the teleporting gates, the virtual passport, etc.) tended to limit themselves in terms of self-exploring wide range of possibilities. In contrast, students who were more selective of the tools tend to explore more widely and make better decisions. The correlation coefficient between mobility tool usage and the form teacher's assessment of individual students' exploration skills is -0.5404, indicating a strong negative relationship. These findings support that our system is promising in identifying useful learning behavior metrics, and also has the capability to identify different SDL skills from different behavior patterns.

4. CONCLUSIONS

This paper proposed a virtual environment enabled assessment system for assessing student's SDL skills through personal learning behavior informatics. We provided a set of tools from theoretical models to system implementations to analyze student's behavior data and managed to evaluate the connections between behavioral indicators and student's SDL skills. The proposed three-layered model bridges the gap between definitions of SDL skills and how they can be quantified and evaluated computationally. The seamless integration with VS-II system enables the collection of students' behavioral data in the virtual environment. With the application of educational data mining, the Assessment Automation module analyzes collected behavioral data, consolidates and presents the findings graphically. In the future work, with more and more student data collected, we will gradually refine the benchmarks of student skills and improve the whole assessment process.

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