Improving the Use of Virtual Worlds in Education Through Learning Analytics: A State of Art

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Abstract. The use of Virtual Worlds in Education is becoming an innovative alternative to traditional education. However, these solutions are confronted to several issues such as: lack of indicators to follow up the students' progress, lack of well-defined evaluation parameters, difficulties for evaluating collective and individual contributions, difficulties for keeping students engaged and motivated, a very time-consuming teachers' supervision, and the absence of tutors for guiding the learning process, among others. In this review, we explore and describe academic contributions focused on the application of Learning Analytics to improve Virtual Worlds in Education from three perspectives: Personalized Learning, Adaptive Learning and Educational Intervention. Our results highlight that most of the research focus on support decisions whose nature concerns operational non-real-time issues. Additionally, almost all the contributions focus in solving only a few issues, but none of them offer a holistic framework that could be used by teachers or pedagogical personnel for decision making.

Keywords: Virtual environments · Virtual worlds · Learning analytics
Data mining · Educational platform

1 Introduction

Virtual Worlds, the most common form of Virtual Habitats, is a type of Virtual Environment [1] that has become an innovative alternative to traditional education methods [2]. Over the last decade, their role has grown to the point where most of the universities in the world are reforming their programs for gradually bring these approaches as a lifelong learning instrument [3]. Monitoring the population inside Virtual Worlds or evaluating activity and task designs based on actual user behaviour can provide new insights on large scale implementations [4]. Also the unique features of Virtual Worlds in sensorial learning have promoted the idea of learning ways, anywhere and anytime in immersive and interactive contexts [5, 6].

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Even though the use of Virtual Worlds in education has become almost ubiquitous, it is confronted in practice to several issues such: problems related with knowing what is happening within the virtual world to identify conflictive user behaviours [7–9] or tracking the students' interactions with elements of the virtual world [10, 11], lack of indicators to follow up the progress of the students in the courses [12], lack of implementation of well-defined evaluation parameters [12], difficulties for evaluating the collective and individual contributions while the students handle tasks [13], difficulties for keeping students engaged and motivated [14], a very time-consuming teachers' supervision in the search for signs of doubt, frustration, stress or fatigue from students [15], pedagogical issues that are inherent to conventional learning [16, 17], absence of tutors with experience to guide the learning process [17, 18]. These problems raise the need to pursue the quest of mechanisms to improve the use of Virtual Worlds in education and guarantee the effective fulfilment of learning objectives [19, 20].

In this context, Learning Analytics would contribute to solving some of the issues cited above. Learning Analytics refers to the measurement, collection, analysis and reporting of data about learners, teachers and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs [21]. Applied on learning environments, Learning Analytics enables the analysis of data about teachers and learners that use the environment for identifying behaviour patterns, assess the learning process, improves the overall learning experience and gives the opportunity to use this information to reflect on learning activity of the users [22, 23]. Learning Analytics seeks to exploit educational data to deliver feedback to learners and teachers in the system [24]. In the case of Virtual Worlds used in education, the analysed data can come either from interactions of avatars with other users, the 3D objects of the virtual world, or with the Virtual World itself (e.g. frequency of use, task accomplishment, movement patterns, preferred locations) [7, 25].

Since decisions in education – or in any field – should be informed and based on the right choose of the best available option [26], Learning Analytics would contribute with useful indicators for pedagogical managers to see things from new viewpoints, reduce blind spots, assimilate complex data structures and address issues from 'in-production' courses. Thus, the aim of this study is to explore how Leaning Analytics has been used, up to date, for decision-making intended to address the issues that would impact the fulfilment of learning objectives using Virtual Worlds.

To meet our research objective, we performed an extensive review of literature [27] to study the contributions that link the use of Virtual Worlds in education with Learning Analytics. We performed our review by collecting the articles from the last 10 years, included on Science Direct, the IEEE Xplore library, the ACM Digital Library and the Springer Digital Library.

The rest of the paper is organized as follows. The next section describes the contributions found in our review. In Sect. 3, we present how the contributions deal with the issues cited above in this introduction. The Sect. 3 offers a discussion about the literature found. Finally, in Sect. 4 we offer our conclusions.

2 Using Learning Analytics on Virtual Worlds Used in Education

In this section, we present all the articles found during our review grouped according to three perspectives: Personalized Learning, Adaptive Learning and Educational Intervention [28].

2.1 Personalized Learning

Personalized learning refers to instruction where the Virtual World can be set up to meet the learner needs. The improvement of the learning process is obtained from the analysis of the data of each learner to customize the environment. This customization increases the learners' personal motivation and facilitates the design of strategies for educative coaching [29]. Personalized learning also allows the development of learning schemes in which individual research and experimentation are promoted. It provides a unique, highly focused learning path for each student. Contributions that meet these objectives are presented below.

In their research, [7] propose a framework for the recovery and analysis of data related to educational settings of virtual worlds. For this, the authors implemented a pharmaceutical industrial laboratory named Usalpharma Lab, which is a virtual laboratory in Second Life. The virtual laboratory represents all the installations, equipment and the documentation needed for teaching 'Good Laboratory Practices'. Both, students and teachers are represented as avatars. Teachers guide and evaluate the activities proposed to students during the course, which means that they should be present when the activities are in progress. Every action that occurs into the Virtual World, originated by the user or by any event is saved into a database. The data is exploited later through a framework, which includes the following layers: (1) the 'evidence description layer' that collects the evidence of interactions between the learner and the Virtual World, (2) the 'collector layer', which is responsible for processing the data sent by the description layer, (3) the 'storage layer' that is where the data processed is stored, (4) the 'analysis layer', which analyses data and also maps the information inside a database (several statistical procedures and data mining methods are executed in this layer), and (5) the 'presentation layer', which is responsible for the presentation of information to final users or other applications integrated with this architecture. The main particularity of their approach is that the learner is at the centre of the architecture since their initial interactions are analysed through their five-layer framework, which leads, in turn, to take actions to improve the Virtual World.

In their work, [25] identified and validated learners' behaviour and patterns with the intention to avoid or reduce student defections in virtual courses. They offered insights about the advantages of the structures, contents and interactions on Virtual Worlds when compared with other types of Virtual Environments. After a class, both teachers and students evaluate aspects such acceptance and relevance through surveys. Their responses will lead to execute actions to avoid students' defections and improve the adoption of the Virtual World. The researchers pointed the importance of two aspects of Virtual Worlds used in education for gain learners' acceptance: (1) the versatility on interaction with other users offered by Virtual Worlds (e.g. gestures, text chat, voice chat), and (2) the freedom of movement across an open world (i.e. displacements between virtual islands or virtual lands), which facilitate learners to find places adapted to their preferences.

In their article, [30] report the development of a methodology for studying the behaviour of users with autism through a Virtual World. For collecting data, the authors defined a three-level scheme to analyse reciprocal interaction, which consists of: (1) a first 'interaction mode level' that describes reciprocal interactions (i.e. initiations, responses and continuation of activities and tasks) with focus on the social interactions among participants, (2) a second 'interaction mode level' that considers aspects such as the duration of the activities, or learners' patterns in social activities (i.e. verbalization, text messages or avatar gestures), and (3) a 'context level' that describes learners' engagement and technological supports. The authors personalize the Virtual World based on the data collected from the platform and from the reactions of the faces and gestures captured by a camera.

In [31], the author attempted to apply Learning Analytics methods for studying students with social behaviour disorders. They used a collaborative Virtual World named iSocial. The authors focused on exploring tools that would allow them to gain sense of the data collected from the Virtual World. Then, they focused on answering questions about how participants with social behaviour disorders use their avatars while follow an instruction. Data was collected in two forms: (1) by recording the movements and positions of the avatars, and (2) by filming the movements and gestures of students in the real world, synchronizing them with the actions captured from the Virtual World. The main contribution of this research resides on how the authors used data visualization techniques to understand individual students' behaviour in the Virtual World since each student was considered a special case.

In their work, [32] report their experiences studying a virtual office conceived for teaching aspects about information security. The Virtual World was implemented in Second Life. The aim of the Virtual World was to study the impacts on achievement of learning outcomes though constructivist learning. The authors customized the learning process for two groups of students: a control group and an experimental group. Authors use the experimental group for introducing and testing improvements on the Virtual World and evaluate the results. Later, they analyse which of the changes lead to situations where the students of the experimental group showed better perceived learning achievements that the students of the control group. This trial and error process allows testing learning strategies and uses only those that proved as effective for a student or a group of them.

In [33], authors present a predictive student action model for Virtual Worlds used in education. Using this model, it is possible to predict common behaviours from students by analysing sequences of common mistakes. The authors took data from error logs and clustering it while they observe the time in which errors occur until students achieve the entire practice. Then each defined cluster is represented by an 'automata' that will be used for generating typologies of students. The authors implement their methods on what they called the Student Behaviour Predictor, which has mainly been used to predict the most probable future action based on the last action. This kind of analysis would allow personalizing the learning process based on actions of each student. The model proposed by these authors will help to students to execute actions and fulfil learning objectives using predictive methods.

In [34], the author describes the evolution of computer tools in the transition from e-learning to v-learning. They report the opportunities that the newcomer provides, specialty in public higher education. In his study, the researcher analyses some factors (e.g. motivation) on younger students while they visit a 3D virtual library on Second Life. A description of the main tools focused to adapt the transition from e-learning to v-learning is also offered. The author highlights psychological implications of learner's experience on Virtual Worlds for future studies.

2.2 Adaptive Learning

This approach focuses on automatically adapting learning design, learning process, and methodologies according to the cognitive schemes of students or by the identification of areas where they have difficulties [35]. The customizations come as the result of analysing the data that is captured while students follow a course, just like Personalized Learning. However, even when Personalized Learning and Adaptive Learning look similar, they are not the same. While Personalized Learning refers to customizations by an instructor, Adaptive Learning refers to techniques that allow the monitoring of student ´s progress and the modification of instructions in real time. In our review, we only found a single contribution that analyses and use data in real time.

In [36], authors propose a framework for the use of Virtual Worlds in education focused on the identification of learning flows and the verification of student´s satisfaction through process mining techniques. Their framework has a core based in a Virtual World platform known as OPENET4EVE. The authors propose a feature to model learning processes in Virtual Worlds that can monitor and register the events generated by students and teachers. Then, they use a Process Miner System to study a real flow of information in a course. These adaptations can generate a new structure of the learning process or even a new learning strategy that can be exploited on other case studies.

2.3 Educational Intervention

This approach is a useful instrument to reduce the student failure and promote competency-based learning. The aim is to influence the skills development of a learner to ensure his/her successful training and education [37]. It allows obtaining predictions about the attitude and behaviour that the student would adopt when confronted to a specific content, an evaluation or group works. Once again, we were able to find only one contribution that fits in this category.

In their work, [38] explore the scope of Virtual Worlds and adopt a typology for virtual communities based on the five forces of Michel Porter [39]. For each community, they described five elements: purpose, place, platforms, population, and profit model. The authors selected Second Life as a representative case study for applying two surveys and analysing results. At last, they provide guidelines for the implementations of future Virtual Worlds centred on Education, Social Sciences and Humanities. The authors used the five forces of Porter in order to propose adaptations to Virtual Worlds for providing learners with the skills needed to success on their courses.

3 Solving Issues Concerning the Use of Virtual Worlds Through Learning Analytics

In Table 1, we summarize how each of the contributions described above bring solutions for the most common issues on the use of Virtual Worlds in education.

Table 1. Problems related to the use of Virtual Worlds in Educations

No.	Problem	Personalized learning	Adaptive learning	Educational intervention
1	Identifying conflictive user behaviours	[7, 25, 30–34]	[36]	
2	Track the students' interactions with elements of the Virtual World	[7, 25, 30–34]	[36]	[38]
3	Lack of indicators for following up the progress of the students in the courses	[7, 30]	[36]	
4	Lack of implementation of well-defined evaluation parameters			[38]
5	Difficulties for evaluating the individual and collective contributions while the students handle tasks	[7, 30–34]		
6	Difficulty of keeping students engaged and motivated	[25, 30, 31, 34]		
7	A teachers' very time-consuming supervision in the search for signs of doubt, frustration, stress or fatigue from students	[7, 32]		
8	Pedagogical issues that are inherent to conventional learning	[7, 34]		
9	Absence of virtual tutors for guiding the learning process	[7, 25, 30–32, 34]	[36]	

Concerning Personalized Learning, we can appreciate in Table 1 that most of the contributions offer solutions for: identifying conflictive user behaviours, tracking students' interactions with elements of the Virtual World, evaluating individual and collective contributions while the students handle tasks, keeping students engaged and motivated, and for the absence of virtual tutors for guiding the learning process. These results are not surprising since Learning Analytics has proven to be very useful for dealing with these problems in Virtual Environments. Additionally, the problems listed above are operational in nature and they refer to situations where technological contributions are easier to implement and evaluate. Conversely, more complex problems (i.e.

lack of implementation of well-defined evaluation parameters, teachers' very time-consuming supervision, and pedagogical issues that are inherent to conventional learning) have received less attention. Dealing with such issues demand a higher abstraction level that demands the right construction of indicators for supporting pedagogical decisional process. Nonetheless, some customizations for dealing with these problems have been implemented based on the analysis of data.

Contributions bringing solutions for Adaptive Learning where, by far, fewer than those for Personalized Learning. The unique contribution that uses Learning Analytics deal with several issues: identifying conflictive user behaviours, tracking students' interactions with elements of the Virtual World, following up the progress of the students in the courses, and the absence of virtual tutors for guiding the learning process. Conversely, the problems in where exists absence are: lacking well-defined evaluation parameters, difficulties for evaluating the individual and collective contributions while the students handle tasks, difficulties of keeping students engaged and motivated, teachers' very time-consuming supervision, and pedagogical issues that are inherent to conventional learning. Once again, the attention rest in the champ of operational decisions. However, in this case, it is not surprising since more complex decisions cannot be taken in a real-time fashion.

About Educational Intervention, contributions are also scarce. As it can be appreciated in Table 1, the contribution identified in this category deals with only two issues: track students' interactions with elements of the Virtual World and implementation of well-defined evaluation parameters. This is not surprising since competence-based learning demands complex analysis of data that should respond to the information needs of pedagogical experts.

Regarding the platforms used for implementing the Virtual Worlds, which were later supported by Learning Analytics mechanisms, most of the studies used well-established platforms for hosting virtual worlds (Table 2). Second Life was the most used platform by the contributions retained in our review. Open Wonderland [40, 41] and Open Simulator [36], both distributed under Open Source licences, were also preferred by researchers. The latter two platforms also offer flexibility for implementing monitors that collect data. The remaining contributions developed their own virtual worlds using game development platforms as Unity.

Table 2. Platforms used on retained studies

3DVLE	Contributions using the platform
Second Life	[7, 32, 34, 38]
Open Wonderland	[30, 31]
Open Simulator	[25, 33]
OPENET4EVE	[36]

4 Discussion and Conclusions

Learning Analytics is a powerful tool for improving the use of Virtual Worlds in education. Our review shows that most of the contributions on this field yields on support for

Personalized Learning. That means most of the research were centred on supporting decisions whose nature falls on operational non-real time tasks (e.g. identifying conflictive user behaviours, track the students' interactions with virtual elements, following up the progress of the students, absence of virtual tutors for guiding the learning process). On the other hand, the problems in where exists total or relative absence of treatment were more complex and strategical issues: implementation of well-defined evaluation parameters, evaluation of individual and collective contributions, keep engagement and motivation, reducing supervision time, pedagogical issues that are inherent to conventional learning. Therefore, research opportunities are open in the field of Learning Analytics for supporting decision-making of teachers and pedagogical authorities concerning 'strategical' decisions about contents, pedagogical design, linearity of the learning process, Virtual World design, interfaces, evaluation mechanisms, teamwork, interactions among users, etc.

Surprisingly, few of the contributions can be classified in the camp of Adaptive Learning. A research opportunity rises on the development of models for automatic decisions based on real-time data recovered from Virtual Worlds used in education. An opportunity is also offered for contributions on the field of Educational Intervention, where the identification of relevant indicators for developing competences and reducing student deflection is needed.

Neither of the research reviewed has contributed to the development and application of a framework for dealing with decisions concerning needs of the decision makers of these courses, neither at operational nor strategical level. Instead, cited contributions focus on few aspects of the relationship with decision-making but without following a holistic approach. Even worse, none have even reported the results of asking teachers or pedagogical authorities about their needs in terms of information needs.

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