A systematic literature review of indicators for the understanding of interactions in Virtual Learning Environments

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***Abstract*—Virtual Learning Environments (VLEs) are becoming an innovative e-learning alternative. However, the implementation of these platforms suffers, in practice, of several issues among which the understanding of interactions inside the learning environment is an outstanding challenge for improving student experience. In this systematic literature review, we classify indicators found on academic contributions according to three categories of interactions to which they can contribute: Agent, Frequency and Participation Mode. Our results highlight that most of indicators focus on explicit actions. However, an alternative approach based on the understanding of perceptions and motivations could lead to propose indicators to solve problems for which there is no visible solution. The results presented in this study give a head start for implementing learning analytics solutions that would allow pedagogical managers to improve students' experience on VLEs.**

Keywords— Virtual Environments, Indicators, Learning Analytics, Data Mining, Educational Platform.

I. Introduction

Virtual Learning Environments (VLEs) can be considered as powerful aids to education due to two reasons, the first one by improving communication and interaction between people, and the second one, for providing a powerful tool for controlling educational activities and processes [1]. VLEs can be considered as a tool to potentiate learning competences [2]–[7] based on the understanding of behavioral attitudes related with the interactions teacher-to-student and student-to-student [8].

Although, VLEs can be considered as a potential and innovative tool in education, it is confronted in practice to several issues such as: (1) the need that the learning environment should reflect a real problem and invite the learner to appropriate it [1], (2) the lack of indicators for monitoring the progress of the students in their courses [1], (3) the lack of implementation of well-defined evaluation parameters [1], (4) the difficulty for evaluating the collective and individual contributions while the students handle tasks [9], (5) the problems related with knowing what is happening within the VLE to identify conflictive user behaviors [10]–[12], (6) the need of mechanisms for tracking students' interactions with elements of the virtual world [13], [14], (7) the difficulty for keeping students engaged and motivated [15], (8) a very time-consuming teacher's supervision in the search for signs of doubt, frustration, stress or fatigue from students [15], (9) the existence of pedagogical issues that are inherent to conventional learning [16], [17], and (10) the 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 VLEs in education and guarantee the effective fulfilment of learning objectives [19], [20].

The solution for these problems requires that educators and course administrators make decisions at tactic and operative levels. Since decisions in education – or in any field – should be informed and based on the right choose of the best available option [21], it is important to provide useful indicators for those who manage the virtual courses. The indicators should allow 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 which indicators have been used, up to date, to understand what happens inside educational VLES and how these indicators would allow to make decisions intended to address the issues that impact the fulfilment of learning objectives. Considering that interactions inside VLEs have been recognized as an indicator of the health of the learning experience [1], [13], [14], we grouped the indicators founded according to the agent, frequency and participation mode of the tracked interactions [22], [23].

The rest of this paper is organized as follows. The next section describes the theoretical framework used for this Systematic Literature Review (SLR). Section 3 presents the methodology used. In section 4, we present our results. Finally, in Section 5 we offer a discussion and our conclusions.

II. THEORETICAL FRAMEWORK

We grouped indicators based on the Agent [24]–[26], the Frequency of use [24], [27], and the Participation Mode on the

interactions tracked on VLEs [24], [28], [29]. The description of these categories is presented below.

A. Based on Agent

Moore [25] proposed three types of interactions based on agent: Student-Student, Student-Teacher and Student-Content. An additional fourth type can be found in [26], called StudentSystem [24].

1) Student-Student Interactions

These interactions are focused in the exchanges between the learners in a course [30]. Both synchronous and asynchronous communications are considered [31]. It can include interactions on chats, private messages between students, or public messages in forums [24].

2) Student-Teacher Interactions

They are related with the participation degree of teachers and the extent to which students perceive the accompaniment of the educator in the VLE [24], [32]. Examples of these type of interactions are: synchronous and asynchronous tutoring or message exchanges between teachers and students for answering questions from students about different topics of the course.

3) Student-Content Interactions

These interactions occur when students use digital resources, for example: e-books, documents, videos, 3D videos, audios, or any other learning material that teachers make available [24], [32].

4) Student-System Interactions

Student-System interactions reflect the information exchange between students and the VLE itself via the system interface [24], [26], [32]. It happens, for example, when the student login into the platform or when he/she creates an avatar.

B. Based on Frequency

The second category of indicators concerns the frequency of use of the platform. Herein, five categories are defined [27] depending on the different activities performed in the VLE [24], [32]:

1) Transmission of Content

It refers to the frequency of interactions that occurs when teachers transfer digital content, announcements, or partial and final grades [24], [27].

2) Creating class interactions

They refer to the frequency of exchanges allowing the creation of class interactions and discussions [33].

3) Evaluating students

They refer to the use of tools for evaluating students' achievement of learning goals and objectives, or the effectiveness of educational mechanisms applied in a particular course [27]. Examples of these interactions are: use of tests or drop box tests, questions and answers resources or quizzes, and groups works [34].

4) Evaluations of teachers and courses

It describes features for evaluating teachers and courses and how often these interactions are used [27]. Examples of these interactions include quizzes, course or teaching quality surveys, and satisfaction surveys [24].

5) Computer-based Instruction

They refer to the techniques used in the VLE allowing transmitting self-assessment quizzes, checking prerequisites for access to content, implementing adaptive learning elements [24], and processes for avatars tuition [27], [35], [36].

C. Based on the Participation Mode

This category refers to two types of interactions: active and passive [28], [29].

1) Active

This type of interaction of students is a way of an analogy with spoken communication. It is characterized by the average number of times per week that the students spoke during a course [28]. Examples include asynchronous interactions in a forum or synchronous interactions in chats between students or between teachers and students [24], [29], [32].

2) Passive

It refers to the access and reading of contributions from other users (teachers or other students) but without introducing new elements [29]. It measures the average frequency that students access and presumably read the various messages posted on discussion boards, or the average time that students listened to others during the course [28].

III. METHODOLOGY

The method used in this paper was a SLR [37]–[40]. The main goal was to collect an initial set of relevant primary studies about Learning Analytics and VLEs and provide an initial review of how indicators has been used for tracking interactions and make-decisions intended to address issues that would impact the fulfilment of learning objectives. Our effort was to keep a broad scope in this study to offer a theoretical and empirical basis for future research about indicators in VLEs, open to critique and evaluation, by doing this research as a system, category and course independent as possible.

For collecting the papers of our interest, we used the search string shown in the left side of Table 1. We used that string in the following databases: Science Direct, Institute of Electrical and Electronics Engineers Xplore library, Association for Computing Machinery Digital Library, Springer, and Web of Science. Even though we did not limit our search to a certain period, we only found articles published between 2009 until 2017. Table I depicts the total number of papers obtained from each database.

TABLE I. FOUND STUDIES

Search String	Science Direct	IEEE Xplore	ACM	Springer	WOS	Total
("Virtual Learning Environment") AND ("Learning Analytics")	17	14	6	33	10	80
("Virtual Learning Environment") AND ("Business Intelligence")	10	8	2	5	1	26
("Virtual Environment") AND ("Learning Analytics")	17	7	8	24	2	58
("Virtual Environment") AND ("Business Intelligence")	45	21	18	34	0	118
("Virtual World") AND ("Learning Analytics")	12	20	2	19	0	75
("Virtual World") AND ("Business Intelligence")	49	43	62	42	0	196
Total	150	113	120	157	13	553

From those papers, we eliminated repeated contributions and we retained only those relevant studies whose aim was effectively referring to Learning Analytics in Educational 3D VLEs. After a careful lecture, we codded the retained articles to identify indicators and classify them based on the categories described in Section II. An in-depth analysis of the codded articles was performed in order to identify the indicators that would contribute to addressing the issues detailed in the Section I. The full list of indicators can be provided by request.

IV. RESULTS

A. Coding results

Using the category based on Agent, we present the results related to the indicators shown in Table II. In this category, we notice two different tendencies. On the one hand, the subcategories of interactions "Student-content" and "Studentsystem" are, by far, those with the greatest number of indicators. On the other hand, only a few indicators for "Student-student" and "Student-teacher" were identified. For this, an in deep view of the few indicators identified, revealed a lack of indicators for monitoring collaborative interactions.

TABLE II. NUMBER OF INDICATORS BASED ON AGENT

	Studentstudent	Studentcontent	Studentteacher	Studentsystem
Number of Indicators	14	52	15	63

In the Table III, we present the results about the number of indicators found in the category based on Frequency. We can appreciate that there are three different levels of frequency of use: (1) "Transmission of content" and "Creating class interactions" were both the subcategories with the most of indicators, followed by "Evaluating students". In contrast, "Evaluation of teachers and courses" and "Computer-based instruction" received less attention on the literature revised.

Finally, in Table IV we present the number of indicators of the two sub-categories about interactions based on Participation Mode. We can appreciate that active interactions have four times more indicators that passive interactions.

TABLE III. NUMBER OF INDICATORS BASED ON FREQUENCY

	Transmission of content	Creating class interactions	Evaluating students	Evaluation of teachers and courses	Computer-based instruction
Number of indicators	44	42	29	8	8

TABLE IV. NUMBER OF INDICATORS BASED ON PARTICIPATION MODE

	Active	Passive
Number of indicators	84	24

B. Indicators for solving VLE issues

In our review, we have identified indicators that would help for making decisions for several problems. Bellow, we detailed the problem and some examples of indicators found:

x The learning environment should reflect a real problem and invite the learner to appropriate it. Indicators: objects more used, checkpoints achieved by students per day, checkpoints not achieved by students, evolution of checkpoints achieved by students over the time [10]; number of interactions on activities, number of interactions on resources, and number of interactions on reports [41]. x Lack of indicators for monitoring the progress of the students in their courses. Indicators: average time spent on the VLE, average time spent per session on the VLE [42]; number of words written in the text-chat, number of sentences written in the text-chat, and number of turns taken in the text-chat (a turn is a set of consecutive phrases written by the same player) [43].

x Tracking students' interactions with elements of the virtual world. Indicators: avatar location and rotation, timestamp of the avatar in a special position, interactions with virtual agents, size and location of elements used by students, and telepresence-premises [44].

x Pedagogical issues that are inherent to conventional learning. Indicators: social interactions, interactions on activities [45]; number of books accessed or number of books read [41].

x Lack of implementation of well-defined evaluation parameters. Indicators: checkpoints not achieved by students, checkpoints achieved by students per day,

evolution of checkpoints achieved by students over the time [10].

x Problems related to knowing what is happening within the VLE to identify conflictive user behaviors. Indicators: number of minutes on conversations, number of students and teachers with conversations, number of conversations per each visit, number of minutes per conversation [46]. x Absence of tutors with experience to guide the learning process. Indicators: perception of usefulness of the tool or improving the course content/instruction, perception of value of the tool's Graphical User Interface [47].

Finally, we did not find adapted indicators for the following problems:

x Learning environment should stimulate and at the same time challenge the learner's reasoning.

x Difficulties for evaluating the collective and individual contributions while the students handle tasks.

x A very time-consuming teacher's supervision in the search for signs of doubt, frustration, stress or fatigue from students.

V. CONCLUSIONS

Several indicators can be adapted in a learning analytics solution to serve as a useful tool to solve the problems identified on VLEs. The results of this review can be used as a point of start for the analysis, design, development and implementation of learning analytics on educational VLEs.

Here, we determined a lack of attention in evaluation of teachers and courses which means that we should take attention to conceive indicators for evaluation of quality of teachers and courses. Automatic evaluation indicators can be implemented taking as a point to start the relationship with teachers.

A need has been identified concerning the indicators which allow to follow the collaborative interactions between studentstudent and student-teacher through student's and teacher's avatars.

Indicators tend to offer solutions for explicit actions. However, an alternative approach, based on the understanding of perceptions and motivations could lead to propose indicators for problems such as: developing VLEs that stimulate and at the same time challenge the learner's reasoning or even the identification of signs of doubt, frustration, stress or fatigue from students.

Finally, the development of mechanisms to measure collective and individual contributions while the students handle tasks on VLEs is also a clue for future research.

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