

# Learning analytics as a tool for academic monitoring of virtual students of University Technological Institutes

**Las analíticas de aprendizaje como herramientas de monitoreo académico de estudiantes virtuales de Institutos Tecnológicos Universitarios**

**Learning analytics como ferramenta de acompanhamento académico de alunos virtuais em Institutos Tecnológicos Universitários**

**Milton Rafael Maridueña Arroyave\***  
**Patricia Alexandra Núñez Panta\*\***  
**Luz Marina Bejarano Ospina\*\*\***

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## Abstract

This article presents four categories of learning analytics tools: dashboards, specific tools, ad hoc tools, and learning analytics frameworks. It also describes the features of several tools within each of these categories: (1) Moodle Dashboard and Moodle's default reporting tool; (2) the Interactions tool and the Teamwork Assessment Tool; (3) SNAPP, GraphFES, and Moodle Engagement Analytics; and (4) VeLA and GISMO. The study focuses on how these tools can be used to analyze courses by collecting actual data from a course that extensively used forums, wikis, web resources, videos, quizzes, and assignments. The subsequent discussion highlights how these different tools complement each other and suggests the incorporation of basic dashboards into learning platforms and the adoption of external frameworks for learning analytics.

**Keywords:** Learning analytics - User interaction - Tools - Learning Analytics

## Resumen

Este artículo presenta cuatro categorías de herramientas de análisis del aprendizaje: paneles de control, herramientas específicas, herramientas ad hoc y marcos de análisis del aprendizaje. Además, describe las características de varias herramientas dentro de cada una de estas categorías: (1) Moodle Dashboard y la herramienta de informes predeterminada de Moodle; (2) la herramienta de Interacciones y la Herramienta de Evaluación del Trabajo en Equipo; (3) SNAPP, GraphFES y Moodle Engagement Analytics; y (4) VeLA

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\* PhD., Instituto Tecnológico Superior "Espíritu Santo", Universidad de Guayaquil [milton.maridueña@ug.edu.ec](mailto:milton.maridueña@ug.edu.ec), [mrmaridueña@tes.edu.ec](mailto:mrmaridueña@tes.edu.ec), <https://orcid.org/0000-0002-8876-1896>

\* MSc. Instituto Tecnológico Superior "Espíritu Santo", [pnunez@tes.edu.ec](mailto:pnunez@tes.edu.ec), <https://orcid.org/0000-0003-3870-8517>

\* MSc., Universidad de Guayaquil, [luz.bejarano@ug.edu.ec](mailto:luz.bejarano@ug.edu.ec), <https://orcid.org/0000-0002-8494-0571>

y GISMO. El estudio se centra en cómo estas herramientas pueden utilizarse para analizar cursos mediante la recopilación de datos reales de un curso que utilizó extensamente foros, wikis, recursos web, videos, cuestionarios y tareas. La discusión posterior destaca cómo estas diferentes herramientas se complementan entre sí y sugiere la incorporación de paneles básicos en las plataformas de aprendizaje y la adopción de marcos externos para el análisis del aprendizaje.

**Palabras clave:** Analíticas de aprendizaje – Interacción de usuarios - Herramientas

### **Resumo**

Este artigo apresenta quatro categorias de ferramentas de análise da aprendizagem: painéis de controlo, ferramentas específicas, ferramentas ad hoc e quadros de análise da aprendizagem. Descreve as características de várias ferramentas dentro de cada uma destas categorias: (1) o Painel de Controlo do Moodle e a ferramenta de relatório predefinida do Moodle; (2) a ferramenta Interações e a Ferramenta de Avaliação do Trabalho em Equipa; (3) SNAPP, GraphFES e Moodle Engagement Analytics; e (4) VeLA e GISMO. O estudo centra-se na forma como estas ferramentas podem ser utilizadas para analisar cursos, recolhendo dados reais de um curso que utilizou extensivamente fóruns, wikis, recursos Web, vídeos, questionários e trabalhos. A discussão subsequente destaca a forma como estas diferentes ferramentas se complementam e sugere a incorporação de painéis básicos nas plataformas de aprendizagem e a adoção de quadros externos para a análise da aprendizagem.

**Palavras-chave:** Análise da aprendizagem - Interação dos utilizadores - Ferramentas - Análise da aprendizagem

### **INTRODUCTION**

The integration of Information and Communication Technologies (ICT) in educational processes offers a novel way of educating in both face-to-face and distance learning environments. An outstanding example of this aspect is the use of platforms for virtual learning environments, such as Learning Management Systems (LMS). These LMSs provide support for both fully online and *blended learning*. In online and blended learning, due to the absence of direct physical interaction, instructors and course coordinators require tools that allow them to track student progress. LMSs collect large amounts of information about student interactions, but this information is often stored in LMS databases in the form of raw data,

making the extraction and processing of relevant information often a complex process (Macfadyen & Dawson, 2012)..

The records stored in learning management systems (LMS) contain a large amount of data related to interactions between students and teachers, as well as access to resources, virtual activities and functions of the system itself. This data can provide information on how and when students complete their assignments, participate in the course, among other aspects. However, extracting meaningful data and converting this information into actionable knowledge represents a challenge. New educational disciplines, such as educational data mining, academic analytics or learning analytics, offer diverse but converging approaches, methodologies, techniques and tools aimed at simplifying this transformation process.

Educational data mining encompasses a variety of techniques that focus on obtaining educational data through the use of statistical machine learning algorithms and data mining, with the purpose of conducting analysis and addressing research questions in the educational field (Romero & Ventura, 2010) . On the other hand, academic analytics is approached differently, emphasizing the analysis of institutional data related to students, and, therefore, it is more oriented toward decision making related to institutional policies (Goldstein & Katz, 2005); (Goldstein P. , 2005). Finally, the central goal of learning analytics is to "measure, collect, analyze and generate reports on data about students and their contexts, in order to understand and optimize the learning process and the environments in which it takes place." (Fergusson, 2012).

From the above it is clear that, despite certain distinctions among the three disciplines, they all share the common goal of understanding teaching and learning for the purpose of making informed educational decisions aimed at improving the learning process (Agudo-Peregrina & Iglesias-Pradas, 2014)..

Today, a wide variety of tools are available that simplify educational data collection and analysis for the purpose of learning analytics. A general way to categorize these tools would be as follows. (Hernandez-Garcia & Conde, 2014).:

- Dashboards, both those of general use that are compatible with various platforms and those specific to each platform, are intended to provide visual and summarized information about the activity on the platform by various actors in the learning process, mainly students and teachers.

- *Ad hoc* tools, designed and developed on a customized basis, are aimed at monitoring and analyzing highly specific information, adapted to particular situations and contexts.
- Learning Analytics tools focus on the analysis of specific aspects and seek to provide detailed information, often with specialized representations. They are often versatile and work on multiple platforms.
- Learning analytics frameworks and tools aim to standardize learning ontologies and implement them in various systems. In addition, they seek to explore learner behaviors in different educational contexts and provide customizable visual representations of information to the user.

Given the wide range of applications of learning analytics, the main purpose of this research is to describe some of them and to apply them by comparing their results using a common data set of courses delivered in a learning management system (LMS) such as Moodle. This comparison will highlight the usefulness, advantages and disadvantages of the various approaches and perspectives, as well as how they can complement each other. Therefore, the study is divided into two well-defined parts: first, the various learning analytics tools that will be analyzed will be presented, and then the empirical part will address the results, including a comparison of the tools following the analysis of data sets from previously taught courses. Finally, the study will conclude by drawing conclusions about the results obtained by applying the various tools.

### **Analysis of learning analytics tools**

This research covers both cross-platform tools and LMS (Learning Management System) specific tools. Different versions of Moodle are required to test the different tools, as not all analytical tools are available for all versions of Moodle.

Most of these tools analyze user interaction from the LMS log data. This means that most tools extract and transform data from the `mdl_log` database table. Until version 2.7, each developer could potentially add their logs to this table from an application, leading to log formats that might not be "standard".

This problem was solved by defining a new logging system in Moodle 2.7. The new logging system collects more detailed information about user interaction than the previous system and, more importantly, provides a standard API for writing and reading logs, as well as improving system performance.

Both registration systems can coexist in Moodle installations with version numbers 2.7 and higher. However, taking advantage of the capabilities of the new registration system requires an adaptation of the different tools, and some of them have not yet been upgraded to compatible versions. Therefore, the comparison presented in this study involves the use of different versions of Moodle; it should be noted that the main objective of this research is to compare tools for learning analytics, not to address issues related to how logs are stored in Moodle. The following sections describe and analyze the different tools, according to the categorization shown in the Introduction of the paper:

### **General Purpose Control Panels**

Dashboards provide information about student or teacher activity on the platform and present it in an aggregated and visually enriched form, mainly in the form of tables and graphs with varying degrees of interactivity. Dashboards can be applied to different platforms (Sánchez-de-Castro & Delgado-Kloos, 2012). (Alier & Casany, 2014) or to a specific one (Dimitrova, 2007). These tools focus mainly on describing the activity performed in an LMS using very specific metrics, they show some relevant indicators at a glance, but generally do not provide additional information on how those metrics relate to each other. The main dashboard application for Moodle is the Moodle Dashboard. There are other dashboards for Moodle, such as LearnGLASS or GoogleAnalytics, but these require customization and mapping of user accounts to external systems and/or direct coding into the Moodle source code.

The Moodle Control Panel is provided as a block and allows users to display graphically or literally the result of any query made in Moodle. When used in standard course formats, the block gives access to an additional page showing the data generated for the specified query. There are different options for displaying the information obtained from queries: tables (line charts, tabular tables and tree views), graphs (line charts, bar charts, pie charts and doughnut charts), geospatial charts and maps, and timelines. The Moodle Dashboard can display the generated data directly, but can also be combined with other blocks to form a complex and highly customizable dashboard. It has powerful data filtering capabilities, as well as functionality to automatically generate data exports (Dashboard block, 2015). The Moodle Dashboard is compatible up to Moodle version 2.5.

In addition to the Moodle Dashboard, the default Moodle reporting tool can also be considered as a control panel. This Moodle reporting

tool facilitates the analysis of information about user interactions on the platform in different contexts, such as site, course or activity. The reports provide data on user comments, course activity (most active courses, courses with the most enrolled users, highest participation), LMS event logs (information about user interaction in the LMS) and real-time logs (interactions occurring at a specific time), as well as graphs and statistics on user activity and viewing/publishing actions. It is also possible to apply additional filters to this information. At the course and activity level, it is also possible to collect data on course and activity completion, time spent completing an activity, and grading information.

### **Ad Hoc Tools for Learning Analytics**

Ad hoc tools are designed for the purpose of monitoring or analyzing very specific information and addressing a particular need in a specific context, with a set of defined constraints and conditions. The main limitation of these solutions is that they generally lack flexibility and scalability. In this section, two of these tools are described: (1) Interactions, a Moodle add-on that groups types of interactions for subsequent analysis, and (2) a web service that facilitates individual student assessment in teamwork contexts.

Interactions is an add-in that is compatible with Moodle versions 1.9 and 2.0 to 2.3. It is installed as a reporting block that adds functionality to the default reporting tool, with separate access permissions. In essence, Interactions adds a library that extends this functionality, including filtering capabilities, by creating an MS Excel spreadsheet with two distinct worksheets. The first worksheet is an exact replica of the log reporting tool's MS Excel file. The second worksheet processes each record and assigns it to a category within three different classifications (by agent, by frequency of use, and by mode of participation). Moodle and eLearning experts were involved in defining the correspondence between actions and categories. The final result shows the total number of interactions for each category for each user on the platform. Since the results are already in Excel format, it is easy to generate graphs from the output. In addition, the format allows for seamless integration with statistical analysis tools such as SPSS. It is relevant to note that the assignment of each record to a specific category (a record can belong to one and only one category for each classification group, but can be present in all groups) is coded in the processing library, which implies that any modification in those assignments requires modifying the add-in code.

The other tool is an ad hoc web service designed to assess student performance in teamwork contexts. Based on the work of Fidalgo-Blanco et al. (Garcia & Sein, 2013), the web service proposes an approach to validate data on interactions as indicators of individual performance in teamwork contexts, based on the comprehensive training model of Teamwork Competence Training (CTMTC) (Fidalgo, 2014). The CTMTC establishes how to collect evidence from three sources: forums, cloud file storage services and wikis. The system extracts student interactions, which allows individual students to be evaluated and conflicts to be detected. The tool uses Moodle's web services layer (Pozo, 2011) and extracts data from Moodle logs, focusing on posts and forum threads. It works in Moodle versions from 2.1 to 2.6 (its use in Moodle 2.7 or later versions would require adaptation to the new registration system). The tool allows selecting a forum within the course and then displaying data on student interactions with peers, and has three different display modes: forum-based, team-based and thread-based. The tool provides information on the total number of posts in the forum/team/thread, as well as the number of people registered (the total number of team members), the average participation of each student, the list of teams and the complete list of students with their respective numbers of posts, dates of creation of the first and last thread, list of threads (with the date of creation) and team members and degree of participation. In addition, action rules can be established based on thresholds defined according to the number of messages (Conde, 2020).

### **Learning Analytics Tools for Problem Specific Analysis**

This category covers learning analytics tools that focus on specific data and offer a very particular type of representation. These applications have very specific functionalities and therefore may or may not meet institutional and personal needs. Examples of tools that can be used on different platforms in this category are LEMO, SNAPP, StepUp!, while LMS-specific tools include Moodle Engagement Analytics, Moodle Learning Analytics Enriched Rubric or GraphFES.

Our analysis focus will be on two specific tools for social network analysis: SNAPP (available on multiple platforms) and SNAPP (available on multiple platforms). (Heathcote, 2021) and GraphFES (unique to Moodle), both designed to identify students who are not actively participating and to provide information about social interactions in the classroom. In addition, Moodle Engagement

Analytics will be evaluated. (Engagement Analytics Plugin, 2015) a Moodle block designed to provide information on students at risk.

GraphFES (Graph Forum Extraction Service) is a web service that connects to Moodle logs, both old and new standard ones, and extracts information from all the message boards in a specific course. Then, all the information collected by GraphFES is processed to create three different types of graphs: (1) a graph that shows all the messages aggregated by all users and how they are related to each other (i.e., a map of all posts and how they are connected and organized in threads); (2) a graph that connects all users in the course according to who has read the content posted by others and how many times they have done so; (3) a graph similar to the previous one, but in this case, the relationships between users in the course are based on who responds to whom. Once GraphFES has built the social network graph, it delivers it as a .gefx file that can be opened in Gephi. The main idea behind GraphFES is that social network analysis is most effectively done outside of the learning platform, using specialized social network analysis tools such as Gephi. Some advantages and applications of Gephi in analyzing higher education courses from a social learning analytics perspective can be found in. (Hernandez, 2014) (Gonzalez, 2020).

SNAPP (Social Networks Adapting Pedagogical Practice) (Heathcote, 2021) works as a bookmark that extracts information from message boards in Sakai, Blackboard, Moodle, and Desire2Learn, and then builds the resulting social network in a Java application. There are two versions of SNAPP (v.1.5 and v.2.1), and their functionalities are similar. SNAPP is structured in tabs, the first three of which are interactive. The first tab displays the social network graph from interactions and allows the user to manipulate the graph by filtering, applying different layouts to the social graph and selecting individual nodes; in SNAPP, the nodes represent participants on the message board. SNAPP v.2.1 also displays a timeline of messages posted on the forum. A second tab displays the values of the number of posts per user in v.1.5 and the main parameters of the social network (degree, internal and external degree, eigenvector betweenness and centrality, and network density) in v.2.1. Finally, the third tab allows exporting the graph in GraphML and VNA formats in v.1.5, or writing annotations in v.2.1 (export capabilities are included in the first tab in v.2.1, with the ability to export to .gefx format).

Engagement Analytics is a Moodle extension that is presented as a block and has the function of collecting and displaying information

through indicators on student progress. As the name suggests, this block provides users with insight into a student's level of engagement, which refers to the activities that influence students' success in an online course. The block provides real-time information on how students interact with resources and uses a set of indicators and a risk alert algorithm. This information can be valuable for teachers to identify at-risk students and make decisions about when to intervene to prevent student failure. The indicators included in Engagement Analytics relate to student assessment, forum participation and login frequency, and it is possible to assign different weights to each indicator to describe and model the risk of failure in a personalized way. The indicators are composed of several elements, and the weights of the elements can also be adjusted. This extension is compatible with Moodle from version 2.2 to version 2.7 and allows expansion of the predefined indicators.

### **Learning analysis frameworks and tools**

The fourth category of tools encompasses applications and frameworks that can be used in various platforms or environments to investigate different aspects of learning through various visual representations. Examples of such tools include SAM, VeLa or GISMO (this review focuses on the latter two).

VeLa (Visual eLearning Analytics) is a framework that uses web services to extract information from Learning Management System (LMS) records. VeLa provides various representations of the information and presents it interactively. For example, users have the ability to filter, search or dynamically modify the representation of information. VeLa offers four distinct functionalities: (1) a spiral-shaped semantic timeline that facilitates tracking user activity on the platform during specific periods; (2) an interactive semantic tag cloud that allows users to analyze the most relevant terms and concepts used in a course; (3) a social graph that displays user interactions; and (4) a tool to compare and establish relationships between data stored in the LMS and user activity. VeLa is based on visual analytics techniques.

GISMO is an interactive, graphical monitoring tool that provides visualization of student activities in online courses. GISMO is a plug-in available for Moodle versions 1.9.X and 2.X that allows teachers to examine various information about students, such as course attendance, reading materials, or assignment submission. GISMO provides comprehensive visualizations that give an overview of the entire class, not just a specific student or a particular resource. GISMO offers seven different visualizations: access summary,

course access, resource access, assignment summary, quiz summary, resource access summary, resource access timeline per student, and resource access per student.

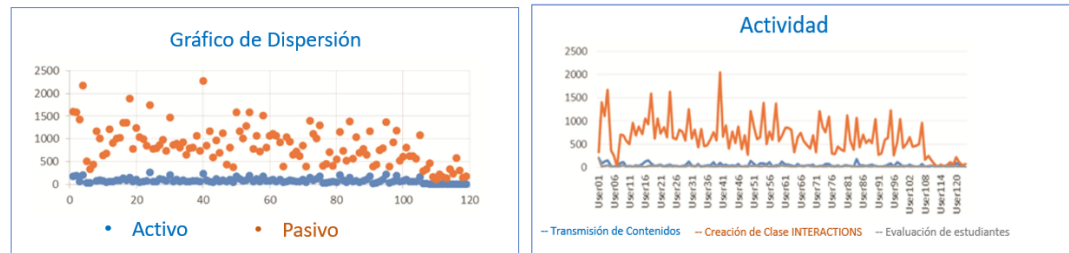
## **MATERIALS AND METHODS**

To evaluate the performance of the different tools, this study uses data from 119 students of an Object Oriented Programming course in the Software Development Technology Career of the Guayaquil Institute, Ecuador (Teaching Period 2021- 2022). The course methodology aims to encourage teamwork among students. The intensive use of forums, wikis, web resources, videos, quizzes and assignments in the course makes it a suitable test bed for all the tools detailed in the introduction section of the paper. The main results of the application of these tools are detailed below:

- Moodle Dashboard. The latest version of the tool works correctly for Moodle 2.5. It has been tested on a Moodle 2.6 and no results are obtained from a simple query. With debug mode enabled, it is also possible to see an error, but no information is displayed. It is possible that the tool is not adapted to Moodle versions higher than 2.5.
- Moodle's default reporting tool displays over 122,640 log records (111,644 are view actions, 9,398 are actions to add resources, and 821 are update actions). Detailed but raw information about each action is displayed in a table, and it is possible to export the results to a spreadsheet.
- Interactions. The plugin does not work correctly in Moodle versions 2.3 onwards. However, since it only processes data from the Moodle registration table, it was possible to import the data directly through MySQL import and process the data in Moodle 2.1. The result is a spreadsheet, where it is up to the teacher or course administrator to create graphs from the data to display information (see Figure 1 as an example) and detect abnormal levels of different types of activity. The data can also be analyzed with statistical packages such as SPSS.

**Figure 1**

Charts created in MS Excel using interaction data.



Source: Prepared by the authors

The teamwork assessment tool requires the activation of Moodle web services. The tool provides a list of links to the course forums. After selecting them, it is possible to see the participation in each forum, in a group and individual participation. From this information, it is possible, for example, to know that the groups working in the mornings (there is a specific forum for them) have posted 4974 messages with an average of 81.54 per user, and also who is the person with the most messages (192 messages in this case). When inspecting a single group (group M9 in this case), the tool reports 990 messages, 6 users, 183 short messages (less than 140 characters) and 807 long messages, 141.43 messages per user, and how participation is distributed among students (in this case, between 13% and 19%) (Figure 2). Additional filtering by thread is also possible.

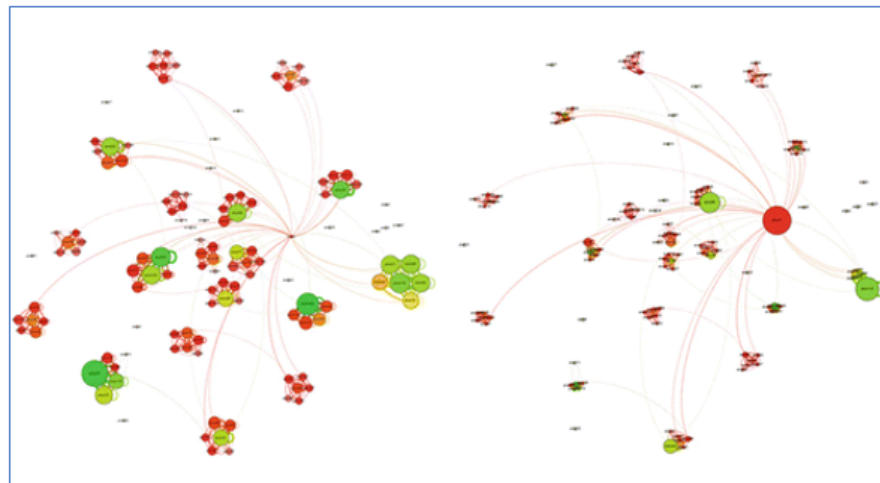
**Figure 2.** Teamwork evaluation tool showing information on student participation in a forum.



Source: Prepared by the authors

GraphFES provides an interface that requires login credentials, platform URL and course ID as input data. Once the web service is active and the necessary permissions have been granted in Moodle, GraphFES comprehensively collects all information related to Moodle forum activity from the platform's data log table via the web service. It then creates two lists containing nodes representing messages and users, as well as the connections between them that indicate who has participated in the conversations and who has replied to whom. The result of this process is presented in the form of three .gefx files, which can be opened and analyzed in the Gephi tool. For more detailed information on how to conduct social learning analytics using Gephi, reference can be found in. (Hernandez, 2014). Figure 3 provides a visual representation of the three social graphs generated by GraphFES, covering the totality of users and messages in the course, without applying filters or using specific node attributes.

**Figure 3.** Social graphs of messages posted (9241) and messages read and responses among users (124, including teachers).

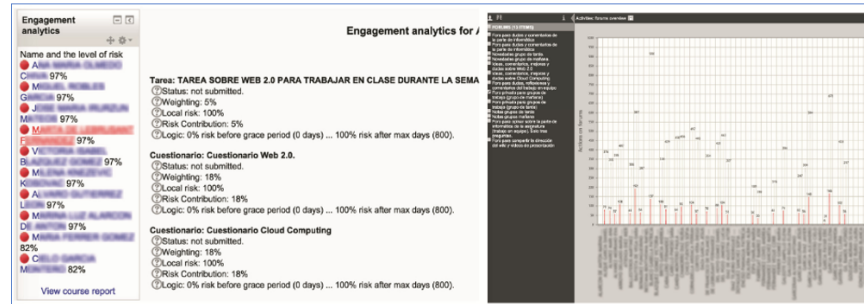


Source: Prepared by the authors

Version 2.1 of the SNAPP application does not work correctly in any version of Moodle and requires setting security exceptions in the Java runtime environment because it connects to an external source to perform parsing. To build the social graph, the application loads all the threads in a forum and processes the HTML content. The problem seems to lie in the construction of the social graph, and no participants are identified. Version 1.5 also does not yield any results for a message board, but allows to analyze individual threads. Unfortunately, it only works in earlier versions of Moodle (2.1), where it was not possible to restore course data.

Moodle Engagement Analytics aims to detect at-risk students. The configuration for this study assigned equal relevance (weight) to logins, forum participation and assignments. Figure 4a shows the results of the analysis (at-risk students are shown in red on the left side). The tool detected 18 at-risk students (probability of failure greater than 65%). Clicking on the student's name displays a report explaining why this person is considered at risk (Figure 4a, right side).

**Figure 4.** Participation block showing at-risk students and the report of a specific student (left, 4a) and the report of actions in a specific forum in GISMO (right, 4b).



Source: Prepared by the authors

VeLA uses Moodle log data to show how message board threads were used, highlighting their primary use in query resolution, teamwork tasks, and news. In addition, it provides visual representations of user interactions with peers and resources using force graphs. This tool offers an integrated experience by allowing filters and selections to be applied to all views simultaneously.

GISMO offers different visual representations of user interactions. The example below shows the number of overall actions in the forums. Students' reading and writing actions are clearly distinguished, and it is very easy to compare who has the most reading actions (979) or who has posted the most messages (259). GISMO can also show students' actions in a specific forum (as shown in Figure 4b) and in other activities and resources.

## RESULTS

From the analysis of the tools, it is possible to observe their strengths and limitations. However, it is also important to note that the choice of tool will depend largely on the needs of the users. For example, Moodle's default reporting tool offers a wealth of information and filtering capabilities, but the information it provides consists of raw data, so it offers very detailed information but is not able to provide meaningful aggregate information about courses. As an example, the tool cannot answer a simple question such as "How many students have not yet started a course?", or more complex questions about the progress of students in a course.

From a theoretical point of view, Moodle Dashboard could provide answers to these questions, including data visualizations (despite its

lack of interactivity). However, this study was unable to test Moodle Dashboard due to its extremely difficult configuration process and limited compatibility with the latest versions of Moodle. In addition, Moodle Dashboard lacks flexibility for custom queries and reports, making it necessary to use ad hoc tools for particular purposes.

This study has investigated two of these ad hoc tools. Interactions numerically represents user interactions in a spreadsheet, allowing customization of graphs and facilitating statistical analysis, and the teamwork assessment tool has a web interface and focuses on the analysis and evaluation of student participation in discussion forums. Both tools solve very specific problems; however, their specificity makes it difficult to apply them in other contexts or platforms.

The study also described tools designed to address specific problems: two tools for social learning analysis (three, if the social graph included in VeLA is considered) and a tool for tracking student progress and detecting at-risk students. The main difference between the first two tools is that SNAPP includes a basic social network analysis module within the platform, although it could not be tested with the study data due to performance problems, while GraphFES allows a complete and more detailed analysis using an external program. In terms of tracking students and detecting at-risk students, Moodle Engagement Analytics is based on predefined indicators and facilitates real-time monitoring of a course, allowing teachers to take action when the system detects at-risk students; a major drawback is that, despite allowing customization of indicator weights, the indicators are not intuitive and adding new indicators requires additional coding.

Learning analytics frameworks aim to overcome the limitations of the above-mentioned types of tools, and they integrate data, different functionalities and visualizations, as well as interactive data manipulation into a single system. Obviously, learning analytics frameworks are not as well suited to specific tasks due to their general purpose design. In some ways, these frameworks could be considered a kind of advanced dashboard that integrates information, but can also provide very detailed information about courses and students.

## CONCLUSIONS

A qualitative analysis of the different tools included in the study shows that there is a need to add learning analytics capabilities to LMS such as Moodle within the same platform.

For simplicity and compatibility, some basic dashboard and alert system would be adequate for this task without the need for

additional user training. However, it is demonstrated in this study how different tools complement each other by adding new functionalities and that a more insightful analysis of educational data requires integration, complex visualizations and interactivity, for which learning analytics frameworks are suitable tools.

A focus on the development, flexibility and stability of the LMS web services layer would be critical to facilitate the implementation of these frameworks. In addition, a by-product of a consistent web services layer is the ability to utilize multiple existing external specific programs for analysis (as illustrated by GraphFES and Gephi) that can provide a deeper level of analysis than some basic LMS add-ons.

Finally, it is felt that the use of complex learning analytics frameworks is not geared towards students or teachers (whose needs should be covered by basic dashboards). To reach their full potential, the frameworks should also integrate institutional and academic data, and be managed and operated by experts with a learning platform analyst role. Analysts would then act as "learning consultants" for the different agents in the learning process (course coordinators, teachers, students).

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