Exploring Software Engineering Subjects by Using Visual Learning Analytics Techniques

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Abstract— **The application of the Information and Communication Technologies to teaching and learning processes is linked to the development of new tools and services that can help students and teachers. Learning platforms are a clear example of this. They are very popular tools in eLearning contexts and provide different kinds of learning applications and services. In addition, these environments also register most of the interactions between the learning process stakeholders and the system. This information could potentially be used to make decisions but usually it is stored as raw data, which is very difficult to understand. This work presents a system that employs visual learning analytic techniques to facilitate the exploitation of that information. The system presented includes several tools that make possible to explore issues such as: when interaction is carried out, which contents are the most important for users, how they interact with others, etc. The system was tested in the context of a software engineering subject, taking into account the stored logs of five academic years. From this analysis it is possible to see how visual analytics can help decision-making and in this context how it helps to improve educational processes.**

Index Terms— **Visual analytics, Learning Analytics, Decision Making, Learning Management Systems**

I. INTRODUCTION

THE emergence of Information and Communication Technologies (ICTs), especially with the popularization of the Internet, personal computers and mobile devices, has made an important impact on different areas. The application of ICTs in educational contexts is an example of this. The different stakeholders of the teaching and learning processes have a wide set of technological tools that can be used to enhance learning –for instance, Learning Management Systems (LMSs). These systems, quite widespread both in industry and academic contexts [1], are very useful tools for learners and teachers. They are focused on course delivery and provide teachers with tools that not only support but also extend the traditional concept of the classroom and facilitate managerial tasks [2]. LMSs also support student learning by providing the spaces in which they may perform their academic activities, complement their lectures and, to a greater or lesser extent, collaborate with other students and teachers. What is more interesting for this research is that LMSs can easily gather information about the interaction of students with their peers, with their teachers, with the system, with the course contents, etc. This information could remain hidden in other learning modalities such as in face-to-face learning.

It is necessary to exploit this information to extract useful knowledge for people in charge of education programs, so they can make decisions in order to improve student learning. However, this is not an easy task because most of this information is stored as raw data. This means a huge quantity of complex information that should be analyzed to obtain real meaning from it. In order to better understand the problem we can consider the example of a Software Engineering subject of the Computer Science Degree of the University of Salamanca. It has around 50000 records per year, so it is very difficult to extract useful knowledge from such data. However, with these records it is possible to explore if the subject is progressing as expected, how students are interacting with their peers and teachers, if teachers are participating or not in forums, which concepts are the most discussed in forums, if the amount of interaction is linked to better grades, etc. In order to gather such information it is necessary to present all the stored information in a comprehensive way, so the people in charge of a learning activity can identify the most relevant aspects and make decisions accordingly. Learning Analytics (LA), Academic Analytics (AA) or Educational Data Mining (EDM) can be used to do this.

Higher education institutions (HEIs) are organized according to a hierarchical structure; a typical organization can be: University> Faculty> Department> Course> University Campus. These structures and the different actors of the HEIs are in need

of Analytics systems with different scales and granularities. Ferreira and Andrade summarize the use of Analytics at the macro and micro scales, emphasizing the complementary relationship between them [3].

According to Buckingham Shum and Ferguson, the earliest mention of the term Learning Analytics dates back to 2000 [4]. But that mention was marginal and, in the beginning, Learning Analytics was a derivation of the principles of Business Intelligence and Data Mining used in Enterprise Information Systems applied to the educational field, in a very theoretical and prospective way [5]. However, with the advent and worldwide expansion of LMSs, the emergence of Personal Learning Environments (PLEs) and Massive Online Courses (MOOCs) more quantity of information is stored [6-8].

Given this context, there are several definitions of Learning Analytics and not all authors agree on them. A possible one was proposed by Ferguson: "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs [9]".

Other possible trend to apply is Academic Analytics. It was defined by Goldstein and Katz [10] as the application of business intelligence tools to learning. Academic Analytics aims to go beyond the information report to facilitate decision-making. These decisions are mainly focused on the institution and the organization while Learning Analytics is more focused on making decisions related to students, teachers and the learning process itself [11].

Educational Data Mining is another analytic possibility to take into account. It is a field that exploits statistical, machine-learning, and data-mining algorithms over the different types of educational data. Its main objective is to analyze these types of data in order to resolve educational research issues [12]. Learning Analytics also shares many attributes with Educational Data Mining [13]. Thus, whether Educational Data Mining is a subset of Learning Analytics or a different discipline with some points in common is for many still an open debate [5].

Despite the differences between Learning Analytics, Educational Analytics and Academic Analytics, they have a common objective that is the improvement and better understanding of teaching and learning processes. In order to achieve this, it is necessary to facilitate common ways to visualize and exploit the results of the analysis. In this case the idea is to explore logs stored in LMSs in order to make decisions to improve learning and teaching of a subject. This improvement can take place while the subjects are being developed or once they have finished. In order to do so, analyzed information should be represented in a way that facilitates making decisions [14] and in this sense Visual Analytics has an important role.

This term was coined by Thomas and Cook [15] as "the science of analytical reasoning facilitated by interactive visual interfaces". It "combines automated analysis techniques with interactive visualizations to create an effective understanding, reasoning and decision making process, based on very large and complex data sets" [16].

The present work describes how the Software Engineering records are exploited from the University of Salamanca LMS, but in a way that not only facilitates visualizing the information, but also interacting with it. That is, teachers can filter, search, or change dynamically the representation of the information and personalize the grouping of activities represented.

In order to carry out such analysis several tools could be applied. Attending to their purpose they can be classified into:

- General-purpose dashboards that can be applied to different platforms [17, 18], or to a specific one [19, 20]. They usually provide information about students or teachers activity in the platform as information presented in tables and enhanced with some bar charts or pie charts. The main problem of these solutions is that they are focused on the description of the activity carried out in the LMS, using very specific metrics and not providing relationships between the pieces of information.
- Ad-hoc defined tools. These tools are defined to track or analyze very specific information and for a specific context. The problem of these solutions is that they are neither flexible nor scalable. Examples of these tools are [21-25].
- Learning Analytics tools to analyze specific issues. These tools can be applied to different platforms and are usually focused on specific information with a specific type of representation. The main drawback of these approaches is that the analysis they carry out may or may not meet the necessities of an institution. Some examples can be LEMO [26], SNAPP [27], StepUp![28], etc.
- Learning Analytics framework or tools. They can be applied to several platforms or contexts and explore different issues through different visual representations. Tools such as SAM [29-31] or VeLa [32] can be included in this group.

Regarding the specific tools that can be applied to Moodle, which is the LMS used by University of Salamanca, some examples are: VeLA, previously described; GISMO Moodle, a dashboard that gathers log information and shows some graphical representations [33]. Muños-Organero analyzes the effects of motivational states on student performance in an eLearning scenario and measures the correlation between the student interaction patterns with the e-learning system and his or her level of motivation. The number and type of student interactions in the system are used to establish this correlation. However, in order to provide further details, student interactions are divided into three groups: studying the contents of the course, participating in e-learning activities such as forums, and updating the student profile by uploading a photograph of the student and providing personal data [20]. Moodle Dashboard [34], another tool with several ways to represent log information; Moodog, which visualizes metrics of activity logs in Moodle using bar charts [35]; SNAPP, a social interaction learning analytics tool that can be applied to several LMSs [27]; Google Analytics plugin [18]; iWrite, which allows researchers and instructors to learn more about the students' writing activities, particularly about features of individual and group writing activities that correlate with quality outcomes. The evaluation provides data collected in general classroom activities and writing assignments (individual and

collaborative), using mainstream tools yet allowing for new intelligent support tools to be integrated [36]; etc.

This paper addresses the problem of representing subject-related information by using VeLA. It is a Visual eLearning Analytics system [37] that includes four main functionalities: 1) A Semantic Spiral Timeline that facilitates tracking the activity during specific periods of time and permitting the discovery of activity patterns; 2) A Semantic Tagcloud that allows the teacher to find the most important words in forums, platform and content filtered by different parameters, enabling to read the temporal evolution of these through the TagCloud representation of each; 3) A social graph that allows distinguishing the interactions among the students and teachers in different subjects and representing some automatic LA metrics [20, 21], whose results can be interpreted through the graph; and 4) A tool to compare and establish relationships among the data stored in the LMS and the activities the users carry out.

The reason to use this system is that VeLA goes beyond other LA tools because: 1) VeLA is a LA framework supported by visual analytics techniques. Compared to other initiatives, especially dashboards, that only present information in tables and some bar charts or pie charts [38], VeLA allows interaction with the dataset and presents linked views of the data. For instance, the user can select a specific period of time in the spiral view; immediately the changes made will affect both the tagcloud and the social graph views (see section 4); and 2) VeLA can be applied to several learning platforms because it uses web services to interact with the LMS, so it is possible to easily adapt it to other platforms.

The VeLA system has been used to analyze the logs of the subject Software Engineering during five years, and it is possible to extract knowledge from them that facilitates making decisions.

The paper is structured as follows. Section 2 describes the theoretical model that supports the visual analytics tools. Section 3 shows the tools integrated in the visual analytics system. Section 4 presents a case study with the information of a Software Engineering subject. Finally, in Section 5, some conclusions are posed.

II. THE VISUALIZATION MODEL

This work tries to define tools and processes that make easier the analysis of learning evidences. In this way it would be possible to make decisions that help to improve students' learning and that can be applied to subjects such as Software Engineering.

The present section describes some of the research works that supported the visual analytics model, the process to articulate this model and the main issues that it should take into account to be applied to eLearning courses.

A. The theoretical model

The aim of a visual analytics system is to facilitate the exploitation of information stored in educational contexts to improve learning processes. To do so visual analytics should join the advantages of different analytics trends such as LA, AA or EDM.

The application of Visual Analytics to education provides highly interactive tools that show data from different perspectives. These tools facilitate both the exploration of the information and the confirmation of hypotheses about educational issues.

In this case the visualization model to be used tries to embrace the challenges of Ferguson [39] and takes into account previous research related to the above mentioned analytics trends such as: Chatti et al. [40] LA reference model; Clow LA cycle theory [41]; Keim [16] visual data exploration and some issues and constraints from Greller and Draschsler critical dimensions model [42].

Therefore the main contribution of this model is the combination of automatic analytics and exploratory techniques to facilitate information understanding as well as the interaction with that information.

The model is articulated through a process based on the work of Ben Shneiderman [43] and extended by Daniel Keim, et al. [44]. The idea is to facilitate interactive visualizations with which the users can explore the information to extract abstract models from sets of data too big or too complex to be easily analyzed. The process can be understood as an iterative sequence of stages that take into account different stakeholders such as students, teachers, people in charge of institutions and other staff. These stages are:

- Requirements analysis. During this stage it is necessary to establish what information to consider, how it is recorded, what the constraints of this analysis (if any) are, what the expected results are, etc.
- Data Model. During this stage is defined what data should be considered and how it is described.
- Representation Model. This stage involves two states: visualization and the definition of analytic models. Visualization provides the users with a way to represent and interact with the information while the definition of analytic models is related to what techniques are used to analyze the data and which parameters can be manipulated in the representations. Both states are related, since analytic models can be modified depending on the kind of representation, and the way in which information is analyzed can change how data and interaction are presented.
- Knowledge Management and Process Feedback. After the representation of the information it is possible to obtain data about learning processes and the analytic system. This information can be used to improve the visual analysis process and in future iterations and/or in similar situations.

B. *Visual analytics system for eLearning*

With the model described in the previous section it is necessary to consider the most important factors that can be analyzed in educational contexts.

As, for this work, LMSs and online courses are studied, the visual analytics system should take into account the following issues: 1) eLearning processes may not be restricted to specific periods of time; 2) the duration of courses and subjects can depend on the context where they are carried out (a degree subject is different from a specialization course related to an institution); 3) eLearning courses have some aspects to take specially into account, such as the interaction of teachers and students during the courses, the quality of their participation, etc.

Given this context the Visual Analytics system should consider how interaction evolves over time; what contents are relevant for students and which ones are not; who are the most active users in forums; what is the relationship between participation and students' performance; etc.

These issues are addressed by the Visual Analytics System through the development of four tools that facilitate the analysis of courses, subjects and campus over time; the analysis of content by using a semantic tagcloud; the analysis of interaction through social network representation; and the analysis of frequency of different category of interactions.

The next section describes how the visual analytics system is implemented and its main functionalities.

III. THE VIRTUAL eLEARNING ANALYTICS SYSTEM

In order to apply the visual analytics model it is necessary to develop a set of tools. With this aim in mind, the VeLA system was developed.

The VeLA system is a Java visualization framework that includes 4 tools to explore different perspectives of the data stored in the LMS. These perspectives can be used separately or combined. For instance, if a period of time is selected in one of the tools the rest also show data according to that selection.

The current development of VeLA works for Moodle. There are different reasons for using Moodle in this context. Besides the fact that Moodle is one of the most popular LMSs all over the world it is also: 1) open source; 2) developed and supported by an international community with more than 57,000,000 members [45]; 3) a system with more than 85,000 installed servers in which there are more than 76 million students; 4) translated to more than 75 languages [46, 47]; 5) highly successful in different institutions [48]; and 6) it includes a web service layer that opens it to allow integrating third-party tools and information exploitation [49].

This last issue is very important in this case, because it facilitates the access to learners' and teachers' activity stored in the LMS [50]. The use of web services to access the LMS makes the VeLA system independent of the programming language in which the LMS is implemented, as well as independent of a specific version of the selected LMS. VeLA can be used with Moodle but also with other LMSs with just a change in the set of web services used to access the information. Most of the LMSs include a web service layer [51], so this guarantees the portability of VeLA.

Starting with the general view, the representation of the campus, university or course depends on the data restored or obtained. This general view is depicted with the parallel-coordinates technique. Therefore it is necessary to define what we are interested in, in this case the courses of Software Engineering (Fig. 1). With the information gathered from the LMS it is possible to show different visualizations that support decision-making processes.
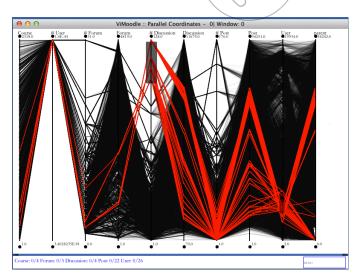

Fig. 1 Global view on parallel-coordinates technique. There are multi-lines over the vertical axes. Each line represents a course. The position of the crossing point with the vertical axes means a course characteristic, for example the number of posts, number of students registered, etc.
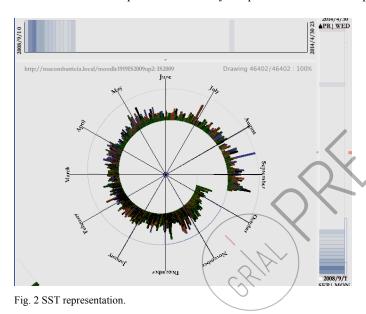
A. Spiral Timeline

One of the issues that the VeLA model should satisfy is to represent how the activity of learners and teachers evolves over time. The system should consider different contexts, users, periods of time, etc.

In order to do so a Semantic Spiral Timeline (SST) is used [52]. The SST provides compact representation of the overall use of the LMS. The information view can be adapted to the user's requirements, so he/she can explore all the available temporal data, going from the overview to the detail of a given person or activity within a period of time. The SST includes a visual technique to balance the detail and context in data visualization, known as semantic zooming or multi-scale interfaces. It changes the type and meaning of information displayed by the object [53].

The visualization has three panels (Fig. 2) with different data views. The main representation is the spiral timeline, which, in its simplest form, is merely a sequence of color-coded events. These are ordered clockwise with the oldest data at the center of the spiral and the outermost data depicting the most recent event. The remaining two panels provide additional views of the data shown in the spiral. In the top view the temporal data is drawn in a linear representation, showing the current data on focus. Finally, on the right hand side, you find the data overview (i.e. the context), which also includes a slider for selecting the period in focus. The tool also includes the possibility to configure the parameters of the representation making selections, defining periods of time, etc.

The views presented by these three panels are inter-linked. This means that, since all the views are different ways of conveying the same information, when the user interacts with one of them and changes the representation, the other views are also changed depending on the action originally performed by the user and on how that action affects the shared dataset [54]. With these tools it is possible to find cyclic patterns in a selected period of time using the spiral.

Fig. 2 SST representation.

B. Semantic Tagcloud

Another functionality that VeLA provides is a semantic analysis of contents published by students and teachers. To do so a Semantic Tagcloud (STC) was developed [55].

A tag-cloud usually has a particular purpose: to present a visual overview of a collection of texts. It presents a certain number of most-often used tags in a defined area of the user interface. A tag's popularity is expressed by its font size (relative to the other tags) and is therefore easily recognized [56]. Tagclouds are also navigation interfaces as the tags are usually hyperlinks leading to a collection of items they are associated with.

Fig. 3 Semantic Tagcloud representing the words for a Software Engineering subject.

In this case the tagcloud facilitates the representation of students' and teachers' contributions in forums (Fig. 3). It uses different sizes for words depending on the frequency and facilitating the navigation through posts, forums, threads, for a person, a course or a defined selection.

Fig. 4 Representation of a tag in the tag-cloud.

In addition, the tagcloud is also representing the evolution of the tags over time. Tagclouds can evolve as the associated data source changes. This desire to study trends and understand how text content or topics evolve over time has been the purpose of other visualizations such as the commonly-used line graphs and bar charts [57]. The STC represents a wave graph and bar graph per each tag in order to show how it evolves over time. This is shown in Fig. 4, the bar-graph (as curves in the background of the word), the wave-graph (as lines that grow up from the bottom of the word) and representation of the tag. For these there are different colors that can be assigned to them depending on the type of activity (if the tag is created, read or updated). In these graphs the x-axis encodes time and the y-axis encodes the significance of the word clouds.

Fig. 4 provides an overview of a tag with its three components: the bar graph, wave graph representation and the tag. The size of the font represents how meaningful the word is in the forum activity of the VLE. The curves shown in Fig. 4 present the significance of the word, which is depicted on background, extracted from a stream of forum posts. The thin lines that grow up from the bottom of the word to the top are the representation of the bar graph.

In addition to these functionalities, the tagcloud tool included in VeLA provides a physical and a semantic zoom. A physical zoom changes the size and visible detail of objects, while a semantic zoom changes the type and meaning of the information displayed by the object [58]. When the users use the semantic zoom, depending on the context, the tool selects for analysis the forum-posts related to the word zoomed. For example, if the user makes double click on a course, forum or discussion, the tool uses for this analysis all forum posts from that course or discussion or forum. In case the user makes semantic zoom on a word, the tool takes all forum posts that have the specific word selected to do the reconstruction of the temporal tag-cloud.

Furthermore the users can choose what they want to see. They can show or hide every element of the representation on the visualization. With this tool it is possible to analyze if the forums are used properly or not, which the most discussed terms are, when they have been discussed, etc.

C. Social Networks Graph (SNG)

In LMSs interactions between students and teachers and their use of resources represent the participation in the platform. This participation can be assessed [59] and can be related to other indicators such as grades.

Although the users of these LMSs have constructed massive graph structures of social connectivity, these connections are not properly represented. The LMS merely shows the network connections of single individuals as a list. Articulated connections between students and teachers in these systems are not clear. Higher-level community patterns can be even harder to discern. This has problematic implications for the members' ability to explore their online community and gauge both the scale and the individuals to which their self-reported personal information is exposed [60].

The SNG is used to represent the map of the relationships with the links, and the frequency of activities of the students and teachers with the size of icons, in the same graph. On the graph, entities such as Person, Course, discussion, posts and resources (coded as shown in Fig. 5) are shown as nodes and how they interact are represented as links between them.

Graph element position is based on a physics simulation of interacting forces; by default, nodes repel each other, edges act as springs, and drag forces (similar to air resistance) are applied. This force between nodes depends on the weight of the elements, which depends on the number of relations that each of them has and its edge size depends on the element degree and its hierarchy depth. Node size is directly proportional to node degree (number of connections with another node). Also the social graph can be transformed depending on the distance –bacon number, "Degrees of Separation", DOS [61]– between the selected node and the others. The filter of separation number can be customized.
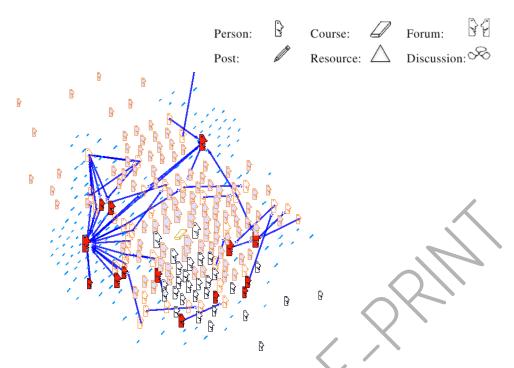

Fig. 5 SGN and legend.

The different nodes can be hidden or be colored (individually or by groups) in order to distinguish or consider only some type of interactions. For instance, teachers can be represented with a color, students with another, etc. Moreover, the SNG includes textual searching tools.

Furthermore, the SNG makes possible to detect the frequency in the interaction of students in the forum and with the resources of a course, something that several studies relate to students' performance [59, 62]; therefore it can help to predict and make the best decision on the right moment.

D. Parallel-coordinates representation

An important issue in the analysis of the interaction in learning platforms is the relationships between indicators. This can be done by using tools that facilitate the comparison between users' activity considering dimensions such as time, the forum, the role of the user, etc. In order to understand how different issues are related VeLA includes a specific tool. It is an interactive multidimensional visualization that uses a parallel-coordinates technique [63].

This technique has been commonly used to show multivalued data. Dimensions are represented in vertical parallel axes and the data are represented as lines that connect these axes. In this case the dimensions (factors to compare) are represented as the horizontal axis, and the polygonal lines that connect them are the students and in some case the courses, depending on the level of the analysis. For instance, some dimensions to consider how the participation is related to the grades could be the logs of the users, type of interaction, role of the user, action he/she carries out, module affecting the specific user and grade (Fig. 6). And, in the case of the course, it can be the number of posts and the replies written on them, the metric that we can use to know how active the course is, or the number of discussions (Fig. 1).

With this kind of representation it is possible to see the kind of activities that affect the grades, if the moment in which they are carried out is important, etc. In addition, the tool facilitates the interaction with the representation by tagging spaces with more interaction (more lines), establishing groups of users to analyze (coloring their activities) and facilitating the definition of groups of activities.

IV. CASE STUDY

In order to check how these visual analytics tools can be used and the information they gather about students, teachers and their interaction, a case study has been carried out. It has been applied to a Software Engineering subject of the University of

Salamanca. This section describes the subject and the outcomes obtained from the application of the tool.

A. Software Engineering Subject

Software Engineering is a discipline extremely important in the curriculum of the future computer science engineers. It comprises 60 hours (45 theoretical hours and 15 lab hours) and is focused on the following topics: Lifecycle and process requirement elicitation and documentation; Analysis and design methods and notation; and Modularity, software architecture, and software reuse principles.

During the practical part of the subject, students have to develop a small project, at the analysis and design levels, which they must do in groups of three members and which they have to present at the end of the semester. Additionally, 10 hours of the time assigned to practice are reserved for organizing two-hour problem-solving workshops. Each workshop is devoted to a concrete modeling technique, and the students have the opportunity to discuss the solution to a given problem, so that they can learn from the mistakes and the corrections made during the workshop.

The Software Engineering subject is supported by the Moodle LMS of the University of Salamanca. The subject uses Moodle as a resource repository and a place to facilitate students' interaction.
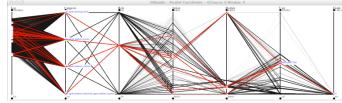

Fig. 6 Parallel-coordinates representation to show how the activities carried out by a specific set of students affect the grades.

The information gathered by this LMS is exploited in order to discover necessities of the users, behavior patterns of the students, new ways to improve the subject and so on.

The case study explores Software Engineering subject logs from 2008 to 2013, that is, five academic years. Each academic year has associated an average of 43,000 logs and 160 students. This means around 21,500 log entries and 800 students to be analyzed for the five years period. In all these courses the subject has been developed in the first semester of the academic year (September to February).

B. Results of the application of VeLA

In order to extract useful data from which people in charge of Software Engineering can make decisions, the different tools included into VeLA were applied. With these tools it is possible to attend to issues such as: 1) When interaction happens and how it can affect teaching and learning; 2) How the tools provided by the LMS are used; 3) The understanding of the concepts taught in face-to-face classes; 4) The participation of the students and teachers in the subject; 5) The level of interaction of students with the resources and the impact it has on students' grades; and 6) How different activities, resources and user actions are related between them and to students' final grades.

1) When interaction happens

In order to check when interaction happens the SST was used. It allows checking when users access the platform and what the most critical moments are for them. Theoretically, the increase should be focused on October, November and a part of December, which are the busiest months and when workshops take place. Data analysis results can be seen in Fig. 7. It shows that periods of increased activity correspond to the months of classroom teaching, with particularly representative peaks around workshops dates. This makes sense since the students have to use the platform for their solution proposals delivery and because these exercises will be commented in the forums later. In addition, it is possible to see an initial peak that represents the start of the course when the students begin to access the contents published in the platform. During this period it can be interesting to introduce a greater presence of teachers. Likewise, it would also be interesting to increase students' participation during periods of low activity.

Moreover, with this tool teachers can know when during the week the accesses to resources and activities are more intensive (Fig. 8). In this case study the most relevant days to students were Monday, Tuesday and Wednesday; teachers can use that information in order to introduce new resources in the subject when students usually read it.
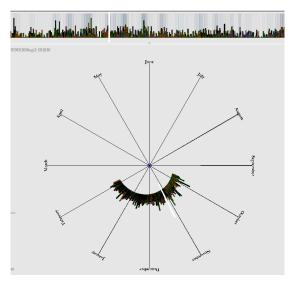
Fig. 7 Spiral Timeline to represent the activity of the first 4 months of the subject.
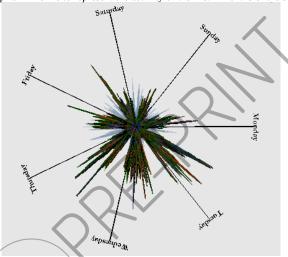

Fig. 8 Activity during the rest of the days of the week.

2) How tools were used

Regarding issues 2 and 3 (understanding of concepts and use of tools) the STC was used. It helps the people in charge of the course to analyze the interaction and content published during the course. In this case study have been used 5 academic years with an average of 18 forums, 123 discussion threads, 242 posts and 32,105 forum accesses per academic course. This means an average of 3,512 different tags per year. An example of the STC application for an academic year is shown in Fig. 3.

Some of the terms shown are repeated throughout the five academic courses. Taking into account the different pieces of recorded information it is possible to assert that forums are used for:

- Publishing information. The forum is used to inform students about events related to the subject, such as: announcements, schedule changes, dissertation defense, list of assignment submissions and so on. The following words must be highlighted in this sense: *Noticia, Aviso, Defensa, Convoca, Examen, Hora*, etc. (in English: News, Notice, Defense, Summons, Review, Time, respectively).
- Modelling Discussions. The forums are used to discuss issues and tools related to Software Engineering, tags such as: *Discusión, Entidad, Relación, Datos, Diagrama, Atributo, Modelo*, *SET*, etc. (in English: Discussion, Entity, Relation, Data, Diagram, Attribute, Model, SET (that is the acronym of a used CASE tool), respectively). Besides, here some issues of the workshop statement must be considered, such as: Id, Gestión, Sistema, etc. (in English: Identification, Management, System, respectively).
- Doubts Resolution. This is a very common use of the forum. Some tags related to this are: *semana, problema, prácticas, duda, forma, despacho, entrega, solución*, etc. (in English: week, problems, practices, doubt, form, Web, Office, Delivery Solution, respectively).

3) Understanding of concepts

In addition to the application of this tool it is possible to know if several students have doubts about a concept because they discuss it. In the Software Engineering subject there are some concepts that are more difficult than others to understand by the

students. These concepts are usually among the most discussed in the forums, and therefore those with larger words in the STC. With this information the teacher can know which concepts should be enhanced. For instance, during 2 of the years explored the UML Association Class was a much discussed term, so this concept was reinforced during face-to-face classes.

4) Participation of students

The analysis of the participation is very important in this kind of subject. During the course a higher participation can be rewarded with a higher grade; however, if students' interaction is low, their grade will not be penalized.

This means that it is important to see if there are students that are participating more in forums and accessing more resources. To do so the SNG is very useful. For instance, Fig. 9 shows the most active users (the biggest ones in the figure) and the most important forums (the nearest to the users cloud and the biggest ones represented) and the posts most frequently read and resources most used (also the biggest in the figure). Furthermore, the user of the SNG can hide and show connections between items. In this case it would be interesting to see the interaction between users in Fig. 5.

5) Interaction with resources

Another interesting functionality that the SNG provides is to know the students who most use the published resources. It can be depicted the influence of a resource through selecting, dragging to a corner of the screen and those users with any interaction with it will move toward the resource: the nearer a user is to the resource, the higher an interaction he/she has with it. Following this idea and using the context menu the option "discussion & resources relationship" can be selected, which groups all the discussions and resources as close as possible with an invisible force line. This derives in the distribution of the students depending on their activity level, which is directly related to their performance (Fig. 10).
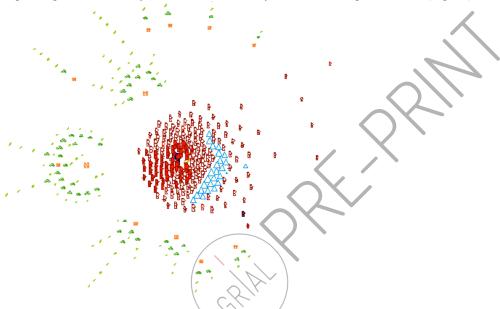

Fig. 9 Social Graph with the distribution of resources users, forums and posts.

Fig. 10 Representation of users interaction with resources.

It would be possible to color the students taking into account their grades, but this has no sense for the Software Engineering subject, because grades are not included in Moodle. Nevertheless, the space distribution of the students on Fig. 10 shows the most active students depending on the distance of the grouped resources and discussion, therefore the best students too. To know if the interaction with resources can be related to higher grades it was necessary to manually select each student, get his/her data and check their grade also manually in the gradebook. With this strategy it was possible to see that 72.8% of the students with a higher interaction also have better grades. To achieve this conclusion, 20 of the students who were nearer the most relevant resources in the social graph were considered. If their grade was between 7-10/10 the relationship was confirmed. The percentage for this relationship in each academic year is shown in Table 1.

6) Relationship between students interactions, resources and activities

In order to check these results, and specially to facilitate the estimation of relationships between different dimensions, parallel coordinates can be applied.

TABLE I.   PERCENTAGE OF STUDENTS WITH HIGH GRADES AND HIGH INTERACTION WITH RESOURCES

Ac. Year	08/09	09/10	10/11	11/12	12/13
Percentage	72%	67%	78%	65%	82%

However, in this case one dimension cannot be used, namely grades. This is because (as commented above) the Software Engineering subject does not use the Moodle gradebook to manage students' grades, so they are not in the LMS and cannot be compared. Fig. 6 shows that all lines converge in the same point at the bottom of the last column. This is because such column represents grades and the students' grades have not been introduced in the platform, so their default grade for a course is 0. In case that grades were stored in the LMS this tool could help the course coordinator to detect how participation impacts on grades, what interactions are the most common, which of them influences more, etc.

V. CONCLUSIONS

The application of technology to fields such as Education gives teachers and learners a wide set of possible tools to use, and also gathers information about how learning and teaching processes are carried out. However, the access to and exploitation of this information in order to make decisions that improve learners' results is not an easy task. VeLA has been designed to make this possible. VeLA integrates several analytics techniques that have been tested in different contexts. It provides a set of tools and a visualization and interaction model that can help learners and teachers.

For this specific work it was tested in a Software Engineering subject. It allows analyzing issues related to frequency of students' interactions, understanding of concepts, use of tools and relationship between interactions, tools and resources.

From the analysis of interaction frequency, carried out by using the STT, it was possible to know what the most active periods in the LMS are. With this information it was possible to introduce new staff when students' interaction was very high, and also introduce new contents and tools to increase their participation when the interaction was low. Specifically for Software Engineering we have tried in present editions of the subject to introduce new discussions in forums so the participation was higher. However, this also implies more work from lecturers.

With the STC it was possible to see with which aim the forums were used, and also to analyze the discussions of the concepts of the subject. With this information, it is feasible to: 1) avoid improper use of forums; and 2) to promote the discussion of concepts, or support with contents existing discussions in order help learners to understand the more difficult issues of a subject. For instance, in the Software Engineering subject we have found out difficulties with concepts such as association classes, aggregation and composition. With this information, during face-to-face classes, the concepts have been clarified and new resources were added for future editions of the subject.

Another important issue that VeLA can address is the analysis of the participation and the interaction of learners and teachers in the LMS. It is possible to analyze the level of participation of teachers and learners and the impact it has on grades. The SNG shows this with a force graph. Taking this into account it is possible to define strategies in order to improve learners' and teachers' participation. In addition, these tools make also possible to see who is interacting with whom and/or what resources are more accessed. With such information teachers can see how the collaboration between peers can impact on learners' grades and which are the resources with which learners have a higher interaction. The researchers have seen during the case study that interaction is related to better grades, but also this tool has helped us to know which students were interacting less. With that information the teachers talked to these students to understand their problems and try to help them. Of the 10 students surveyed the last year, 6 passed the subject.

Moreover, VeLA facilitates the comparison between different dimensions of the interaction in the LMS. For instance, it would be possible to know if the students that carry out some activity and read some contents obtain at the end of the subject a better grade. This is done by using the parallel-coordinates tool. With it, teachers can promote those activities that improve student grades or remove/change those that are linked to students' lower grades. In this case this tool –although it has been applied– was not very useful because, as commented above, grades were not included in the platform.

Although VeLA is a very complete visual analytics system, it would be desirable to combine it with other learning analytic tools. For instance it would be possible to use in the system additional LA techniques, such as the inclusion of categories of interaction as those defined by Agudo-Peregrina et al. [21]. By using these categories it is possible to detect what types of interaction are more frequent and promote those that can improve learning [64-65].

Beyond the case study presented the system has been tested with other courses (online courses, blended), courses from different areas (for instance, an Object-Oriented Programming subject) and it allows to extract useful information for teachers. These experts are essential in order to obtain real knowledge and make proper decisions that can help to improve learning.

Although VeLA is a system being currently applied in several courses and subjects of different universities, it is not finished

yet. The system can be enriched: 1) by applying it to other contexts, looking for possible drawbacks and additional requirements; 2) by defining new representation models; 3) by defining visualization models that take into account color-blinded people and 4) by improving the system to be more efficient (currently, when it has to analyze a huge quantity of records to analyze it can be slow). It is also necessary to explore which data are really useful, how we can analyze them properly and whether this really helps us to improve students' results, as Ferguson discussed.

As a final conclusion we can say that Visual Analytics is a technique that can help to better understand what is happening in a subject and therefore make decisions that help students to succeed.

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