

# Interactive Visualization Tools to Improve Learning and Teaching in Online Learning Environments

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## ABSTRACT

This paper presents two interactive visualization tools for learning management systems (LMS) in order to improve learning and teaching in online courses. The first tool was developed at the Intelligent Information Systems Laboratory (IISLab) at the Tampere University of Technology (TUT). The tool is used to analyse students' activity from automatically recorded user log data and to build interactive visualizations. They provide valuable insights into the learning process and participation of students in a course offered to teachers and students. The second tool was developed at the Unitelma Sapienza University. It extends navigation and search functionalities in the discussion forum of an LMS with a topic-driven paradigm. The tool analyses forum content and automatically identifies discussion topics. It then enhances the original forum with a topic-driven navigation structure and an interactive search graph. Both tools have been developed as plug-ins for the Moodle LMS, but their analysis processes and techniques can be adopted into any LMS.

**Keywords:** e-learning, learning analytics, information retrieval, data mining, information visualization, visualization tools.

## INTRODUCTION

As online learning spreads and becomes pervasive, the need for tools that monitor students' participation in online courses and measure knowledge and skills development has greatly increased. Most learning management systems (LMS) and Web-based solutions that are adopted to offer online courses are able to record rich amounts of information about students' activity, such as communication, collaboration, and participation in online courses. Many LMSs also offer reports and even simple graphs about each student's (elementary) actions. However, these reports are poor indicators of students' activity and participation if they are considered singly (Soller,

2001). Exploiting the log data of LMSs in order to understand the activity in an e-learning environment, how to improve student learning processes, and how to support the process of teaching requires tools and strategies that help to select the right information in a timely fashion and present it at the right location in a correct, clear and effective way (Tufte, 2001; Tervakari et al., 2014).

To achieve this goal, at IISLab<sup>1</sup> was developed a visual analytics instrument called the TUT LA tool. The implementation of the tool was for TUT Circle<sup>2</sup>, an e-learning environment that is built using the Drupal<sup>3</sup> content management system (Silius et al., 2011; Tervakari et al., 2013). In this paper, we present the basic principles of an extended version of this tool, which was re-implemented as a plug-in for the widely adopted Moodle<sup>4</sup> LMS.

Discussion forums are one of the main means of asynchronous communication used in e-learning environments. They are available in all LMSs. Forums are used in online courses to facilitate the learning and teaching processes, such as supporting student-to-teacher interaction, student collaboration, group work and cooperative learning. Discussions held in a forum within a certain period are a potentially useful source of information for any student that subsequently accesses the forum online. However, the success of a forum as an information source and means of communication is determined by the richness of its content. Moreover, its content (discussions and messages) can be navigated and searched. While the first property depends on user participation and use of the medium, the second depends on the navigation structure and the search features provided by the forum.

To support the discovery and retrieval of relevant information in discussion forums in the e-learning environment of distance-learning through the Unitelma Sapienza University, we defined a data analysis process that exploits information retrieval techniques. It employs topic models (Blei, 2011) and formal concept analysis (Ganter and Wille, 1999) to identify the topics discussed in a given forum and to provide topic-driven searches and navigation (Cerulo and Distante, 2013)(Distante et al., 2014).

In this paper, we briefly describe these processes and describe the implementations of the plug-ins for the Moodle LMS. They provide interactive visualizations that help both students and teachers find the information they need and monitor students' learning and actions in the learning environment.

## RELATED WORK

Recently, on-line education systems have become widespread tools adopted by both historical and newly founded educational institutions. E-learning and e-teaching are new contexts for education through which large amounts of information are generated and available to users worldwide. A large portion of the available information takes the form of free text without the structure required for automated knowledge retrieval.

Learning analytics provides valuable support for teachers and students to understand learning habits and to obtain rich information about learning and teaching processes. Learning analytics is

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<sup>1</sup> <http://www.tut.fi/en/about-tut/departments/mathematics/research/iislab/index.htm> (last accessed on 1 October 2014).

<sup>2</sup> TUT Circle is a social media-enhanced learning environment developed by the IISLab of the Tampere University of Technology. TUT Circle promotes students' networking, collaboration and communications in small groups by allowing them to send private messages, chat, create, contribute to and comment on content, exchange opinions, share resources and create communities for different needs. Students can also control the visibility of their information and allow access to the information either for the members of their small group or for all students. [www.tut.fi/piiri](http://www.tut.fi/piiri)

<sup>3</sup> [www.drupal.org](http://www.drupal.org)

<sup>4</sup> [www.moodle.org](http://www.moodle.org)

commonly used to measure, collect, analyse and report user data about learners in order to understand and optimize learning, learning environments and teaching (Siemens and Long, 2011). For example, Carr (2012) reported that a great number of open online courses monitor every user's action, such as pausing a video, increasing feedback speed, responding to quiz questions, revising assignments and participating in forums. The data are then used to analyse student behaviour and test how people learn. Hence, the teacher can tailor the learning environment to fit each student's learning style and needs.

The lack of quality in collected tracking data represents a major challenge to ensure its effective utilization. Moreover, large amounts of data can be difficult to analyze, interpret and understand because processing data requires complex cognitive processes. However, if the data are packed and presented in a correct, clear and effective manner, users can process an incredible amount. When the data presented are complex to perceive and process, adequate visual presentations are mandatory (Berg, 2012). Appropriate visualizations can help to process information, such as by increasing memory and the number of available processing resources, reducing the number of searches for information, enhancing the recognition of patterns, enabling perceptual inference operations and using perceptual attention mechanisms for monitoring (Ware, 2012). A good visualization helps the users understand the data, confirms what the users already know, and provides insights into the data. However, to be understood, the context of the data used should be familiar and interesting to the users.

Historically, data mining has been used to extract knowledge from free text (Baeza-Yates and Ribeiro-Neto, 1999). Knowledge extractions from e-learning systems, particularly from user generated data, was introduced in (Castro, Vellido, Nebot and Mugica, 2007b; Hanna, 2004). Tang and McCalla (2005) investigated patterns of system usage in teachers and students' learning behaviour. Data clustering was suggested to promote group-based collaborative learning and to diagnose students incrementally (Castro et al., 2007a).

Information retrieval techniques consider that texts are represented by a vector of terms that are usually weighted by their occurrence in documents. The availability of different media (e.g., image, video, audio etc.) has recently demanded more sophisticated information retrieval techniques that are capable of treating new kinds of information (Goodrum, 2000; Foote, 1999; Beel et al., 2009). E-learning forums are usually represented as text. Hence, traditional information retrieval techniques are usually adopted to search for relevant information. Association-rules mining has been widely adopted in e-learning, specifically in recommendation systems (Za'iane, 2002; Yang et al., 2010), learning material organization (Tsai et al., 2001), student learning assessments (Romero et al., 2005), course adaptation to the student's behaviour (Hogo, 2010) and evaluation of educational Websites (dos Santos Machado and Becker, 2003). The development of cooperative learning and knowledge sharing inside student groups predominates in recent research trends (Jakobson et al., 2012). In particular, Web technologies take advantage of the opportunities raised by mixing the social and the semantic Web (Ghename et al., 2012). Dicheva and Dichev (2006) investigated concept maps and their use of navigation in educational contexts. They propose a framework and a set of tools for the development of ontology-aware repositories of learning materials. The idea is similar to our topic-driven navigation structure. In our approach, topics are extracted from free text semi-automatically by leveraging information retrieval techniques which are then validated by the user, whereas concepts have to be manually defined by the authors of the learning materials (Dicheva and Dichev, 2006).

## **THE PROPOSED INTERACTIVE VISUALIZATION TOOLS**

words are by default linked with the AND operator, and the system retrieves a list of all posts containing the keywords used in the search.

The second approach was used the TDForum Moodle plug-in. While performing the tasks, we collected the number of items inspected and the time needed to achieve the information search goal. In the Moodle full-text search, the number of inspected items was computed by counting the number of posts examined before finding the expected posts. In the topic-driven navigation approach, the number of inspected items was the sum of two quantities: the number of links followed to reach the closest topic in the Discussion Topics View of the TDForum plug-in and the number of posts examined before finding the correct posts.

The findings showed that in general the number of items inspected using the full-text search was on average higher than the number of items inspected using TDForum. Moreover, the time necessary to obtain the correct answer was on average less in the TDForum. The reason is that in the full-text search more time was spent in choosing the correct search keywords. These results confirmed that the TDForum tool facilitates and improves information searches in the discussion forums on a Moodle platform.

## **CONCLUSIONS AND FURTHER RESEARCH**

The interactive learning data visualizations provided by the TUT LA tool can offer concrete and practical support for students in their learning activities in online courses. They can help students to monitor and evaluate their performance processes and learning outcomes in order to make strategic adjustments to improve, which could bring real benefits to students. Especially on massive open online courses (MOOCs) that require students to be responsible for their learning, self-regulation and other learning skills.

Teachers of online courses can also benefit from visualizations in many ways. For example, the visual analytic tools, such as the TUT LA tool, could help teachers to make decisions regarding pedagogical strategies, instructional guidance, actions and interventions that may be used to support student participation and activity. In order to support teachers in obtaining increased practical value by using the visual analytics tool, the controls used to specify data and manipulate views need further development. Visual analytics could also be used to retrieve valuable information about how students use the course platform, how they study subtopics and how they use learning materials and other resources, such as how much time students spend in watching a video or reading a chapter of the learning material, in which order students study the learning materials offered, and which parts of the assignments students have completed. This kind of information can help teachers to evaluate students' learning performance and monitor their progress during courses. In MOOCs with thousands of students, the TUT LA tool could offer valuable practical support for teachers, such as identifying students at risk of failing or dropping out. The information can also be used to identify topics that students skip and learning materials that they do not use, which may help the teacher to improve the instructional design of the course

Effective search and navigation capabilities associated with discussion forums in online courses are decisive in making forums a useful information source for students, as well as an additional means of communication. Moreover, according to earlier research, students prefer tools and information that can provide them with practical support in analysing and examining textual information, such as messages on discussion forums, in order to discover new information (Silius et al., 2013; Tervakari et al. 2014).

In this paper, we presented two tools for use with Moodle LMS: a tool for learning analytics and a tool for enhancing content searches and navigation in a forum. Both tools were designed to support students and teachers in e-learning environments.

IISLab at TUT in Finland, Unitelma Sapienza University in Italy, and the University of La Plata in Argentina have started a collaborative research that aims to extend and evaluate the usefulness of their visual analytics tools and forum enhancement approach by means of a set of controlled experiments replicated in different classrooms. We expect the measured advantages to be twofold: i) information is retrieved in less time, and ii) contents stored in on-line forums are managed and tracked in a more effective manner.

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