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Applying Learning Analytics in Problem-Based Learning Engineering Semester Projects

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INTRODUCTION

Learning Analytics (LA) aims to improve the learning process by analysing learning data, and communicating the results of this analysis to both educators and learners. LA has been employed in a few cases for improving Problem Based Learning (PBL) courses but the literature has yet to discuss how PBL project work could benefit by LA. This paper presents a novel approach for enhancing PBL with LA in order to produce a new educational paradigm (PBL_LA). This paper presents a trial that took place in an engineering study in order to draw evidence-based conclusions on the PBL_LA approach. The trial run during one semester and aimed at introducing LA in PBL semester projects. For this trial, we adapted a set of software tools for supporting PBL_LA to Moodle, which is a Learning Management System (LMS), and its analytics tools. In this paper, we present this adaptation and some preliminary results of the trial. Finally, we discuss the potential of the PBL_LA approach for improving learning and teaching in this kind of engineering PBL projects.

1 BACKGROUND

1.1 The PBL pedagogy

PBL is a student-centred pedagogy in which students learn through the experience of problem solving [1]. The goals of PBL are to help the students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation [2]. PBL represents also a paradigm shift from traditional classroom/lecture teaching. The role of the instructor in PBL (known as the tutor) is to facilitate learning by supporting, guiding, and monitoring the learning process. Finally, PBL may support group work. Working in groups, students identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. This procedure enhances content knowledge, while simultaneously fosters the development of communication, problem-solving, critical thinking, collaboration, and self-directed learning skills. PBL was first introduced in the medical school program at McMaster University in Hamilton, Ontario, Canada in the late 1960s [1]. Since then, various universities and other educational institutes have adopted PBL as a model of teaching and learning. From such local adaptations, various PBL models have arisen. In Aalborg University (AAU), Denmark, all university programs have been based on PBL, also referred to as “the PBL - Aalborg model” [3]. When establishing the AAU in 1974, a redeveloped approach to the traditional PBL had already emerged, and the ideals in this involved providing students with an active, participative role, and high degree of engagement in the creation of knowledge, both in lectures and as part of group-based project work. The PBL - Aalborg Model has become both nationally and internationally recognized and a trademark for Aalborg University.

1.2 Application of LA in PBL

LA has the goal of studying and analysing acquired learner data from virtual learning environments with the aim of improving the teaching and learning process. A significant amount of work has already been done in enhancing the PBL methodology by employing LA. Oliveira and Santos in their study [4] established a virtual teaching and learning environment, called PBLMaestro, which has been designed to support the workflow of the xPBL methodology, which implements PBL in Computer Science education. In order to track student progress, PBLMaestro used the Authentic Assessment model [5] in order to evaluate the performance of students in different stages of the PBL approach (problem formulation, problem analysis, implementation, etc). Moreover, this environment used a LA module that allowed the storage and use of learning data, which was generated when students interacted with the modules of PBLMaestro. This module provided teachers real-time data on individual student performance and behaviour, and group collaboration, so teachers could intervene in order to help students during the course. The results of this study showed that by combining the Authentic Assessment model and LA, it was possible to determine and focus on the concepts that students had more difficulty with and identify the groups that performed better in the management process, and in meeting the course requirements. Finally, PBLMaestro provided an individual look on student engagement, participation and dedication in the group. Luckin et al. [6] developed a framework for project-based learning, which is a methodology that combines PBL with collaborative problem solving. This framework was designed for learning, where technology is used either to support learning or to apply LA for capturing learning data collected from project based learning scenarios. They suggested a flexible approach to the analysis of such machine-generated data, where the collected data was combined with data collated by human observers and analysed using the framework. Luckin et al. proposed this kind of data analysis because they claimed that there would always be aspects of PBL activities that take place away from any current technology. They aimed at testing the framework empirically with project-based data and considering what appropriate LA requirements might be extracted.

Tempelaar et al. [7] proposed a dispositional LA infrastructure that combines learning dispositions data with Learning Management System (LMS) student engagement/activity data, and data extracted from computer assisted formative assessments. Their study run in an introductory mathematics and statistics module combining face-to-face PBL sessions with e-tutorials, and investigated the predictive power of learning dispositions, outcomes of continuous formative assessments, and other LMS generated data in modelling student performance and their potential to generate informative feedback. The results of this study showed that computer assisted formative assessments were the best predictor for detecting underperforming students and academic performance, while basic LMS data did not substantially predict learning.

Fidalgo – Bianco et al. [8] studied the use of LA to accurately measure and access teamwork. Their study correlated final individual grades of team members with three categories of interactions in a private forum used to organise and carry out the different teamwork phases, namely based on the agent (student–student, student–teacher, student–contents), the frequency of use (most used, moderately used and rarely used) and the form of participation (active or passive). The exploration of these indicators contributed to the assessment of the individual development within the teamwork context. The results indicated that there was a direct relation between these interactions and final grading corresponding to individual assessment of teamwork activities by teachers. Additionally, the information provided by the

LA system and timely information extraction allowed for corrective measures, and making decisions to improve the learning process of teamwork.

In this paper, we propose a pedagogical approach based on a framework (PBL_LA) that supports PBL by using Learning Analytics (LA) to exploit the data generated during learning. In the next session, we describe the various layers of the PBL_LA framework.

2 THE PBL_LA FRAMEWORK

In order to design the PBL_LA framework, the PBL - Aalborg model and its steps were examined in detail, as well as the main topics of research interest regarding LA. During this study, we identified the concepts to be included in the framework that are the subjects that should be taken into consideration during the design, delivery and assessment of data-driven PBL-based courses. The framework is comprised of three layers.

The Pedagogical Layer consists of all the PBL steps of the PBL - Aalborg model, i.e. group forming, problem formulation, task formulation etc. Within these steps, the PBL_LA approach will study the activities realized by the learners in order to successfully execute each step (e.g. brainstorming, literature search, voting etc.) as well as the evidence that show the level of performance for each student.

The Data Layer consists of all the different data that is usually generated during learning. This data can be derived from students' interactions within different e-learning tools (e.g. forum, assignment etc.), within other types of tools (e.g. task recording, meeting minutes etc.), from teachers' interactions (e.g. grading, assessments, posts etc.) and from the tools used (e.g. login sessions, times spent, content access etc.).

The Analytics Layer consists of the LA methods and tools available for gathering, processing, analysing and interpreting data into meaningful information. These LA methods generate insightful visualizations for both teachers and learners so that they can make sense of the analytics results (e.g. engagement analysis, social network analysis, clustering etc.).

This framework aims to improve the learning experience for both teachers and learners. Teachers will be able to monitor and scaffold students in each step of PBL by making sense of their interactions and progress, while students will receive guidance and encouragement to participate more actively when needed, and thus gradually improve their performance. In order to draw evidence-based conclusions on the PBL_LA framework, we piloted it in PBL semester projects at the Media Technology program of Aalborg University. In the next section, we introduce this program and present how this framework was applied for its students.

3 PBL_LA IN ENGINEERING SEMESTER PROJECTS

3.1 PBL semester projects at Media Technology

Over the past years, engineering education has been challenged to embed creativity and innovation into undergraduate and postgraduate programs, in order to produce graduates who can easily adapt to the needs of a rapidly changing world [9]. Moreover, a number of engineering programs have arisen that transcend the division between technical, scientific and artistic disciplines. The Media Technology (MT) education at Aalborg University, Denmark is such a "creative" engineering study. The MT program links many areas within film and media science, animation, sound design, computer science and psychology to meet the growing need to understand new applications, and to design and develop technology that takes center stage in our lives [10]. Thus, MT is an education that focuses on research and development,

which combines technology and creativity and looks at the technology behind areas such as advanced computer graphics, games, electronic music, animations, and interactive art, to name a few. During the span of the education, MT students are given a strong technical foundation, both in theory and in practice. According to the PBL – Aalborg Model, the MT program curriculum is mapped onto semesters, where students spend approximately 50% of their time on course work (3 courses) and the other 50% on a semester project, where students collaborate in groups. The semester courses support project work, which follows the PBL approach. Each semester is governed by a fixed theme, which is selected to serve as the context, where the courses and the semester project address the learning objectives. Each group of students is assigned a supervisor, who guides the students during the project, and makes sure they are progressing according to the goals of the semester.

3.2 Methods

The PBL_LA framework has been applied to gather, process, analyze, and interpret learning data during the second semester project at the bachelor MT program. The theme of this semester is “Human-Computer Interaction”, so during the semester project the students should foster key competences in designing, developing and evaluating an artefact, such as a desktop or a mobile application, using a user-centered approach. While pursuing this aim, they are able to apply knowledge and skills in mathematics, programming and interaction design. The trial is currently taking place during the spring semester 2018, where 94 MT students are divided in 14 groups. Moodle serves as an LMS for supporting and monitoring student progress during the semester project. We have employed various Moodle activities, in order to implement the PBL_LA framework.

Four forum activities are used for communication between supervisors and student groups, and within groups. Two of them are accessible by all students and supervisors: one is meant to support an open discussion on the semester project in general, and the other is dedicated to announcements from the supervisors (students could not post in this forum). There is also a group-based forum, where students can communicate only with students belonging to their group, and lastly a forum, which students of the same group can use in order to communicate with their supervisor (aimed to replace email communication between groups and supervisors, which could not provide any learning data for LA purposes).

A wiki activity is introduced in order for groups to keep notes of their progress. The groups are required to update this wiki (called “status report”) with the status of the project and an agenda, before each meeting with their supervisor. The wiki structure allows for keeping previous versions of the status report, so at the end of the semester the groups will have an overview of the project progress.

A checklist activity is employed to create a simple Gantt chart containing the main tasks of the project and a few fixed deadlines. The students are able to modify this checklist by adding new tasks and/or new deadlines, if necessary. The task list is meant to facilitate project management for students, and to provide supervisors with an overview of the progress of all groups.

Finally, a feedback activity is used for individual student feedback on collaboration within their groups, communication with their supervisor, and possible issues. Students are required to submit their feedback before each semester group meeting (meetings that take place three times during the semester, where teachers and representatives from each group meet in order

to discuss the overall progress of the semester). Answers to this feedback activity are submitted anonymously, in order to encourage students to report issues.

4 PRELIMINARY RESULTS

During this trial, learning data is gathered and analysed using the standard functionality of Moodle. Moodle keeps log data, and provides action reports for all users enrolled in a specific course. Main actions include the viewing, editing and posting of content. This kind of data is gathered as students use the platform in order to shape an understanding of their overall engagement with the LMS. In order to draw conclusions on their engagement to the semester project, data coming from the aforementioned activities are thoroughly examined using either quantitative or qualitative data analysis. Quantitative data is extracted from the forum and the wiki activities (number of posts and views), and from student access of resources (Table 1). The forum dedicated to a general discussion on the project, and the one meant to support communication among the members of a group has not provided so far any valuable data, since students use normally other platforms to perform these tasks (mainly Facebook), and therefore hardly use them. The discussions in the forum, which is dedicated to the communication between supervisors and their groups, the wiki, and the feedback activities are also analyzed qualitatively in order to identify the topics brought up during the semester both by students and supervisors. For this qualitative analysis, an inductive approach is applied, where consensus on findings is sought among three researchers in order to ensure a deep reflexive analysis, and to strengthen the validity of the findings. The goal of this analysis is to create a list of the various topics raised and their frequency during the semester for each group (internally, and during communication with the supervisor), and then correlate the data in the list with the other type of data gathered on the platform.

Table 1. Number of view and posts in various Moodle activities per student in a randomly selected group (S1: Student 1, S2: Student 2, etc)

ActionActivity/Student	S1	S2	S3	S4	S5	S6	S7	Group Total
Status Report(View)	1	3	45	0	4	36	12	101
Status Report(Post)	0	0	2	0	0	9	0	11
Status Report(Total)	1	3	47	0	4	45	12	112
Discussion with Supervisor (View)	13	5	85	6	6	62	13	190
Discussion with Supervisor (Post)	1	0	4	0	0	2	0	7
Discussion with Supervisor (Total)	14	5	89	6	6	64	13	197
Anouncements(View)	0	0	10	0	2	0	4	16
Open Discussions(View)	0	0	2	0	1	1	0	4
Open Discussions(Post)	0	0	1	0	0	0	0	1
Open Discussions(Total)	0	0	3	0	1	1	0	5
Group Forum(View)	0	0	0	0	0	0	0	0
Group Forum(Post)	0	0	0	0	0	0	0	0
Group Forum(Total)	0	0	0	0	0	0	0	0
P2_Overview(View)	1	5	15	0	0	3	0	24
P2_Project Description(View)	4	2	11	0	0	2	0	19
P2_themes(View)	5	7	7	0	0	3	2	24
P2_report Structure(View)	0	7	4	0	0	2	2	15
P2_Sketchbook(View)	0	2	0	0	0	0	0	2
P2_AV_production	1	2	0	0	0	0	0	3
Groups, Supervisors and Themes(View)	0	0	7	0	0	1	2	10

LA are also applied by using two added plugins (tools) in Moodle, namely GISMO and Heatmap. GISMO is a graphical interactive monitoring tool that provides visualization of students' activities in online courses to instructors. With GISMO, instructors can examine various aspects of distance students, such as the attendance to courses, reading of materials, submission of assignments etc. (Fig. 1). The Heatmap tool overlays a heatmap onto a course

to highlight activities with more or less activity in order to help teachers gain insight on the use of the various elements of their courses.

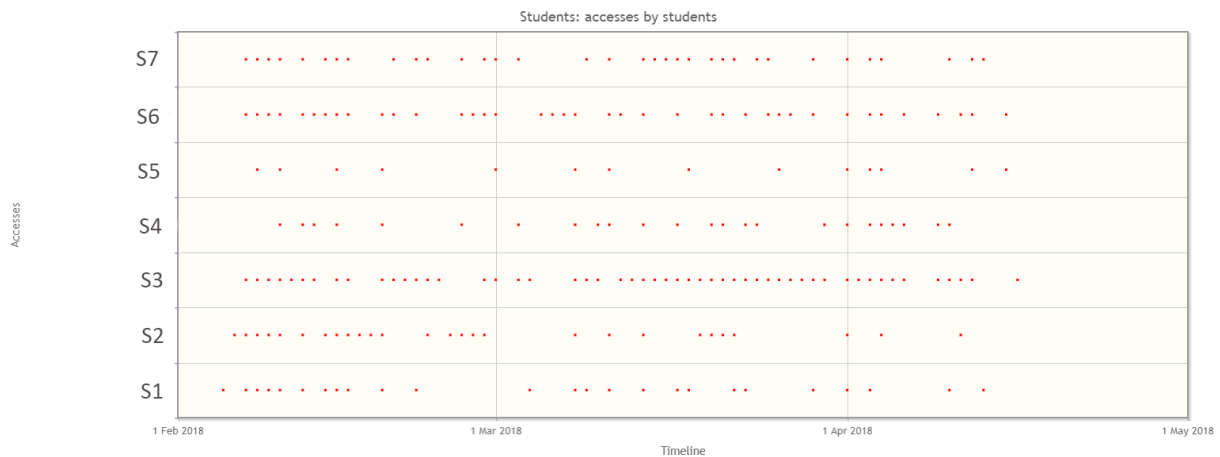


Fig. 1. Learning data as acquired from GISMO around the mid-period of the trial

5 DISCUSSION

This paper presents a trial carried out in PBL engineering semester projects. PBL shifts the focus from understanding common knowledge to developing new knowledge through "learning by doing" activities, and accommodates active participation of students. However, there is a need for this very promising model to exploit novel opportunities and technologies, such as LA, that will unleash new benefits and capabilities. During this trial, we are able to gather learning data on engagement and performance both on individual and group level. So far, students' learning progress during these projects was only analysed and evaluated by the group supervisor. By employing LA, we are able to gain an overview on how students and groups are evolving during the semester. Moreover, by analysing forum discussions, we are able to identify topics discussed between groups and their supervisors, to analyse supervisor engagement, and to keep track of issues that come up during the semester. After the end of the semester, we aim at correlating the data gathered in Moodle with examination results. We believe that the PBL_LA approach will help teachers/supervisors, students, and study coordinators to draw overall conclusions on how semester projects progressed for the first time.

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