Enhancing Moodle to Support Problem Based Learning

The *Nucleo* experience

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Abstract— **Problem-Based Learning (PBL) is an educational paradigm that promotes the development of highly valuable soft skills. PBL can be combined with other approaches, such as collaborative learning, to enhance students' team skills. *Nucleo* is a blended learning approach where students work in self-regulated teams. *Nucleo* combines Problem-Based Learning, collaborative learning, role-play game dynamics and a fantasy metaphor. In this paper we describe how the *Moodle* Learning Management System is being used to support the development of *Nucleo* learning scenarios in courses with a total of more than 300 students. The approach is implemented by combining built-in tools of the LMS and specific plug-ins. Plug-ins provide support for Vermunt's ILS (used to build the teams), for assigning roles in the teams or managing groups, among others. Although this work is focused on the *Moodle* platform, the paradigm can be repurposed and applied to different environments.**

Keywords: Problem-Based Learning, Nucleo, Moodle, Collaborative learning

I. Introduction

Virtual Learning Environments (VLE) in general and Learning Management Systems (LMS) in particular are following the path of modern Internet applications, as the social and communication habits of learners and teachers change. Social networks, Multi-User Virtual Environments (MUVEs), online games and free software collaborative tools such as *Google Apps* have opened the door to new possibilities in collaborative learning.

But it is not just a matter of the possibilities that recent advances in technology enable. Educational paradigms are also changing, as learning is not just about acquiring technical knowledge anymore. Work is increasingly becoming a team-integrated activity, and less of an activity that one can carry out alone.

As society demands professionals with complex skills, learning has to cope with the new needs. Therefore the educational system must ensure students acquire abilities like working in teams, organization of team-work, dealing with conflicts, communication of ideas and concepts, and leadership.

This leads to a change in traditional class dynamics where collaborative learning paradigms are becoming more and more prominent both in face to face and in online learning. Among these paradigms Problem Based Learning (PBL) has been in the educational arena for many years [1] with proven results in terms of developing situated learning and soft skills [2].

Modern LMS offer a wide range of possibilities that enable the integration of PBL and other collaborative paradigms in class dynamics. Class or group forums, chat-rooms, *wikis*, databases or glossaries are a few examples of the tools that the teacher may use to support collaborative pedagogical approaches in most popular LMS (e.g. *Moodle*, *Sakai*, *Blackboard*, etc.).

Nevertheless, since common LMS have not been designed to support PBL explicitly, it is useful to have some additional functionality for managing a PBL approach. Some examples of these functionalities are: automatic group formation, group evaluation and assessment of the methodology in terms of soft skills acquisition.

Nucleo is a blended learning approach that combines game dynamics with a PBL underlying strategy and with adaptation to student's learning styles [3][4]. It is conceived to change students' attitude to a more active role and to help them to acquire soft skills. It uses *Moodle*, a popular LMS, extended through plug-ins that facilitates managing the specific work-flow involved in our modified PBL approach. Both the learning strategy and the *Moodle* plug-ins are being tested in several courses at the *Complutense University of Madrid* (UCM).

This paper is structured as follows: in section II we describe the pedagogical basis of our approach *Nucleo*. We describe the implementation of *Nucleo* in *Moodle* in two sections: in III we focus on the built-in tools that are used and in IV we describe the plug-ins developed. In section V we present the cases of study that are being conducted in several university courses and finally in section VI we present the main conclusions of this study.

II. Pedagogical basis of the approach

According to Barrows & Tamblyn [1], Problem-Based Learning (PBL) can be explained as "the learning that results

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from the process of working towards the understanding or resolution of a problem." In most cases, PBL is performed in small groups, fostering discussion and collaborative discovery, as the groups need to collaborate in order to work-out the solution for a specific problem or set of problems.

Educational literature has shown the benefits of using PBL and other approaches that promote active collaborative learning to improve students' thinking skills [5]. Furthermore, collaborative learning also provides opportunities for developing social and communication skills, acquiring positive attitudes towards co-members and course material, and building social relationships and group cohesion [6].

However, the collaborative nature of PBL is frequently an issue. It is often difficult to arrange the schedules of all the members of a team to participate in work sessions. The possibility of meeting remotely can allow more effective PBL initiatives. In this sense, *Moodle* and other Learning Management Systems with collaborative tools can help.

Group cooperation and cohesiveness are key factors in the success of PBL strategies. Therefore simply providing students with some remote communication tools does not guarantee the emergence of the social interactions that lead to effective collaboration [7].

The underlying learning strategy of *Nucleo* is an enhanced PBL approach oriented towards reaching two basic educational objectives by improving group cohesion:

- *To induce a change in students' attitude towards a more active role*. *Nucleo* makes use of a game metaphor and a role-game dynamic that gives the students the main role in their own learning process [8], resulting in an increased motivation [9].
- *To help students improve and practice soft skills during the learning process*. *Nucleo* uses an adaptation model based on Vermunt's framework for learning styles (Inventory for Learning Styles - ILS) [10] in order to form effective semi-autonomous teams in which students are grouped considering their compatibility in terms of their learning strategies. Besides, the approach pursues to improve group coordination by distributing the work according to functional roles that are also assigned to the students depending on their classification in the ILS.

A. Motivation, Narrative, and Role-Playing Games

Several authors such as [11] consider that the "Net Generation" of students belongs to a new digital media culture that behaves very differently compared to their teachers and parents. For instance, students now are used to multimedia content connected by hyperlinks where knowledge is freely explored and discovered, and find the traditional teacher-centered courses quite unattractive, preferring collaborative learning with peers. Although there have been important advances to make teaching strategies more interactive and appealing to them [11], this evolution does not seem to completely fulfill the needs of knowledge disclosure for these students.

Considering these observations, the potential integration of game dynamics in education has drawn significant attention, especially for PBL approaches. In this regard Role-Playing Games (RPG) are suitable genres for Problem-Based Learning [12].

In *Nucleo* students must collaborate in small groups to solve complex, ill-structured, real world problems. The difference is that in *Nucleo* the real world is a fantastic one. Problems are embedded in a game narrative, and solving them is part of the game. Instead of trying to disguise the educational aspect inside the game, as it is commonly done in game based learning approaches, we have turned the whole learning setting into a game, on the idea that playing and solving problems share many features.

The baseline metaphor leads the students to a fantasy world in which they play the role of warriors trained to face a threat against their civilization. Students are organized in auto-regulated teams of 3 or 4 students where each individual is assigned a role with specific functions and responsibilities. The adaptation model establishes how the roles are assigned.

Groups of students face "assignments" that simulate real danger situations. The final goal is to be awarded with the title of "Paladins" (social recognition), warriors that fight for the survival of the civilization. During these assignments students compete both individually and across teams.

Assignments represent the practical cases of the underlying PBL approach. They are set in the domain of knowledge and are presented embedded in the narrative of the baseline metaphor.

B. Adaptation to Learning Styles

Vermunt's model [10]is a classification of students according to their learning strategies more than a categorization of learning styles, as it is commonly understood. This view matches with our idea of reaching auto-regulated teams, as it can provide criteria for grouping together students with complementary learning strategies.

Vermunt classifies students into four types depending on the attitudes they adopt in five different areas of learning by means of its ILS. These four learning styles are: meaning-directed (MD), application-directed (AD), reproduction-directed (RD), and undirected (U). This approach helps to distinguish the students who need more intensive guidance through the learning process from those who are more capable of guiding their own learning experience. Those students who are able to self-regulate their learning processes usually present MD and AD patterns, and they would benefit from a more open teaching strategy. Students who would need stronger teacher control and guidance commonly correspond to the RD and U patterns.

The team formation algorithm assigns at least one MD or one AD student per group. The Captain of the crew (assigned to MD or AD profiles) is in charge of project planning and progress monitoring. The Knowledge Integrator –KI- (assigned to RD profiles) is in charge of controlling and supervising that all team members acquire the required knowledge. The member Responsible for Communication –RC- (assigned to U profiles) is in charge of managing communication between team and tutor.

III. Implementation of *Nucleo* in Moodle Using Built-in Tools

The *Nucleo* approach is being used in different programming courses in the UCM since 2007. Following the pedagogical rationale described in the previous section, the learning strategy follows the cycle depicted in the figure bellow (Figure 1):

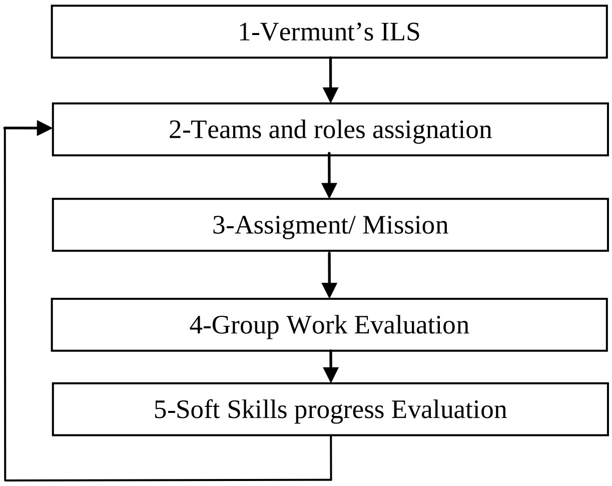

Figure 1. Learning strategy cycle

The learning cycle starts with the fulfillment of the ILS by all students in the class (phase 1). Based on the results obtained in this test, the teams and the roles are assigned (phase 2). Once this process has been completed, the teacher gives the assignment (phase 3) that needs to be solved according to the following steps (see Figure 2):

3.1. Identify the nature of the problem (mission). Brain storming.

2.2. Identify the concepts needed to be acquired to solve the problem.

3.3. Identify the targets and the schedule. Assign tasks and elaborate a preliminar planning.

3.4. Preliminar design of the program. Identify the modules and interfaces in the program. Design the main algorithms.

3.5. Code implementation.

3.6. Debug and testing.

3.7. Results and code delivery

Once the groups turn in the code that solves the assignment, the process is completed by the fulfillment of evaluation questionnaires by both students and teachers (phases 4 and 5). The results in the evaluations are used to correct and enrich the student profile for the next team formation and role assignation process.

Different collaborative tools provided by Moodle are used throughout the third step, which is the work involved in the completion of the mission (see Figure 2):

- Private Group Forums (PGF). Through the entire process different group forums are active, every one devoted to a single step in order to improve the classification of the posts into different subjects.
- Private Group Chat (PGC). One chat room (common to all steps) is active throughout the process.

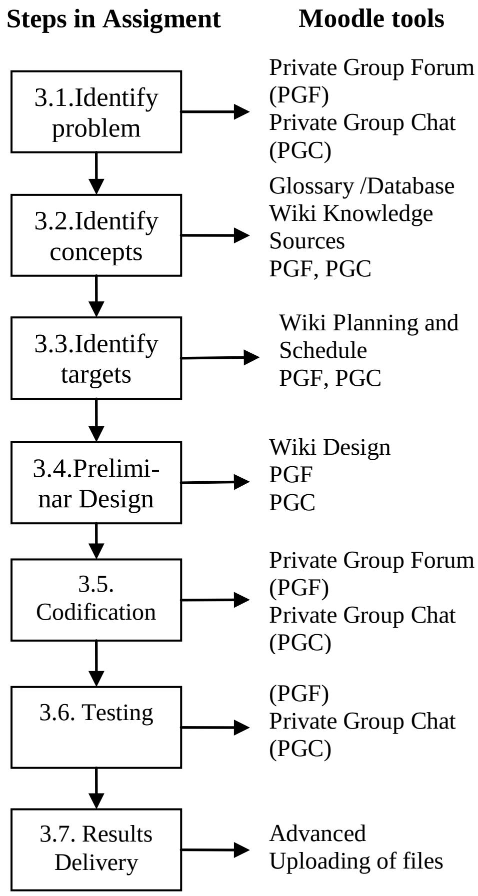

Figure 2. *Moodle*'s collaborative tools used in each stage of a mission

- Wiki Knowledge Sources, Glossary and Database. In this private group tools the team members are asked to collect all the concepts needed to solve the problem and the sources used to acquire them. The knowledge integrator is responsible of keeping the *wiki* updated.
- Wiki Planning and Schedule. In this *wiki*, the team will fulfill the planning, schedule and task distribution for the assignment. The captain is responsible of keeping it updated.
- Wiki Design. Team members design the program using this *wiki*.
- The utility "Advanced Uploading of Files" is used to deliver the final results of the assignment.

Even though the workflow involved in phase 3 (steps for completing and assignment) can be managed through *Moodle* standard tools, the environment does not provide any tools for the rest of the phases depicted in figure 1 (e.g. Vermunt's ILS realization and evaluation, Teams and Roles assignation, Group Evaluation and Soft Skills Progress Evaluation).

In the next section we describe the plug-ins developed for these purposes are explained in detail.

Figure 3. Moodle's activity view (in Spanish) were the *Nucleo* plug-ins are the activities starting with prefix "AVC_"

IV. ENHANCEMENT OF *NUCLEO* BY DEVELOPING PLUG-INS

Nucleo plug-ins are available to the teacher in the main *Moodle* view. These plug-ins appear as activities (Figure 3), easing the introduction of the *Nucleo* paradigm for users already familiar with the LMS.

A. *Vermunt ILS*

The completion and evaluation of the Vermunt ILS is managed through one plug-in. This plug-in performs the evaluation of the student to identify the Vermunt's ILS. This evaluation is done through a 100-item questionnaire.

The results of the Vermunt evaluation are used to determine each student MD-U score, and thus identify the potential leaders for the different groups. Information acquired through this plug-in is used by the Group Manager and the Role Manager.

B. *Group and Role Managers*

Two plug-ins are used for Group and Role Management. The Group Management plug-in allows for the automatic generation of student groups based on their MD-U levels. Besides, this plug-in uses past performance when available to improve the resulting groups.

The Role Management plug-in uses information about individual students to assign one of the 3 roles in each group. This assignation is based on the results of the Vermunt test to achieve optimal results.

It must be noted that these plug-ins must be used in sequential order. First, the teacher creates the groups with the Group Manager plug-in. Later the teacher assigns the roles within the group with the Role Management plug-in.

C. *Evaluation of Soft Skills progress*

This set of 5 plug-ins were developed in order to evaluate the students' progress in five different soft skills competencies: commitment, innovation capability, leadership, communication and ability to develop teamwork.

- *Weighting of competencies*. The individual mark is calculated by weighting the group score with the progress in the five competencies and the results achieved in the practice. This module lets the teacher decide the weight (i.e. percentage) of each individual variable in the individual score (Figure 4).

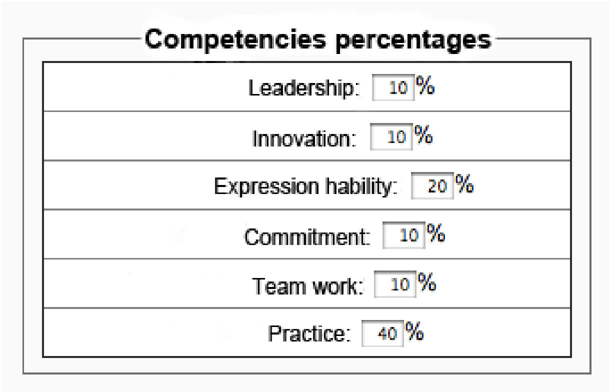

Figure 4. The competence weighting plug-in allows the teacher to assign weights or percentages to five different competencies and the results of the practice.

- *Auto-evaluation test.* This is a 25-item questionnaire for the students to perform a self-evaluation of their progress. There are questions concerning four of the three competencies (commitment, teamwork and leadership).
- *Peer-to-peer evaluation test.* Teammates have to co-evaluate each other's in terms of four of the five competencies: commitment, innovation, leadership and ability to develop teamwork.
- *Teacher evaluation*. Teachers have to evaluate the progress of their students through a 35-item questionnaire that intends to measure the 5 competencies analyzed.

Group 1

Name:	M.L:	Mission 1:			
		G.N:	L:	I.S:	G.S:
Maria Gonzalez	**52**	**Group 1**	**106**	**5.99**	**4**
Juan Diaz	**50**	**Group 1**	**89**	**5.82**	**4**

M.L: Main Leadership | G.N: Group Name | L: Leadership | I.S: Individual Score | G.S: Group Score

Group 2

Name:	M.L:	Mission 1:			
		G.N:	L:	I.S:	G.S:
Pepe Lopez	**41**	**Group 2**	**57**	**5.88**	**9**
Lucia Diaz	**69**	**Group 2**	**96**	**7.58**	**9**

M.L: Main Leadership | G.N: Group Name | L: Leadership | I.S: Individual Score | G.S: Group Score

Figure 5. Summary view of the results. This summary is provided at the end of the results plug-in to provide an overall view of the results of each group and each individual student (the students in this screenshot are not real).

- *Results*. This module completes the calculation with some automatic variables collected through student system interaction. These variables are linked to the commitment (numbers of posts responded, number of entries in group *wikis*), communication (number of different words used in posts and *wikis*, number of orthographical mistakes), innovation (number of threads initiated in forums) and leadership abilities (also number of threads initiated in forums, number of entries in the *wiki* planning utility). The results are later presented in a summary table so the teacher has an overall view of the progress of each group and individual student (Figure 5).

V. Description of Case Studies and Preliminar Results

The *Nucleo* strategy has been applied to several programming courses. The results of the case studies conducted from 2007 to 2009 have been described in other papers [3][4][9][13]. The strategy had proven to be successful in terms of enhancing students' motivation [9] and in terms of facilitating the practice of soft skills and teamwork [4]. Also the team formation strategy based on Vermunt's model was validated and found to be satisfactory [13]

During this academic year (2010-2011) the evaluation has been extended to other faculties in the UCM and other educational domains: two courses in the physics faculty, one in the economics faculty, one in the politics and sociology faculty and 13 in the educational faculty. More than 300 students and 16 teachers are currently taking part in the experiment.

The current set of case studies are focused on the following objectives:

- Get more data on how the *Nucleo* approach affects motivation.
- Improve the grouping algorithm. In our previous experiments we used a genetic algorithm based on Vermunt's model for grouping students. Even though according to the students' perception, the team formation was successful in 70% of the cases, this ratio should be improved [13]. Current experiments are oriented to varying the grouping algorithm for the first iteration in order to get better results.
- Take data about students' improvement in terms of soft skills acquisition. Even though previous experiments demonstrated that the interaction among students rose significantly, the system did not provide ways of measuring student's soft skills acquisition.
- Get information on how the automatic variables collected by student/system interaction can indicate soft skills progression and reduce the need for explicit evaluation instruments and questionnaires.

VI. Conclusions

Problem-Based Learning and Collaborative learning paradigms are gaining importance as the labor market increasingly demands professionals that are able to develop team-integrated work. These paradigms have been proven to provide benefits in the learning of many of the soft skills required.

Although most Learning Management Systems provide collaborative tools that enable the workflow involved in Problem Based Learning, they still lack specific modules to manage important phases in the process. However, modern LMS also allow the possibility for independent creation of plug-ins to extend the provided functionalities.

In this paper we have described the need for these modules and presented *Nucleo*, our solution developed as plug-ins for *Moodle*. We have developed several plug-ins to cope with team formation, role assignation and evaluation of soft skills progress. These plug-ins allow users familiar with the LMS to easily apply the PBL paradigm to their courses.

During the current academic course these plug-ins are being tested in several courses at the *Complutense University of Madrid*. More than 300 students and 16 teachers are currently using our system, allowing them to apply the latest advances in PBL in real learning scenarios.

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