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Towards designing cognitively-enriched project-oriented courses within a blended problem-based learning context

Abstract: Traditional education seems to gradually and moderately make way for self-directed and student-centred learning strategies that will efficiently enable students to reach their full potentials and will sufficiently prepare them for their upcoming professional careers. Problem-Based Learning (PBL) is such a strategy, since it enables active participation by shifting the focus from the delivery of knowledge to its creation by the students, in their endeavour to implement problem-based projects. PBL is more commonly used in project–oriented courses, where students have to not only build but also apply new knowledge in real world contexts and therefore familiarize themselves with work conditions. Online technologies, such as cognitive tools, are able to harmonize this shift by visualizing some of the more demanding steps of PBL as well as facilitating collaboration and knowledge building. The aim of this paper is to investigate the incorporation of cognitive technologies in project–oriented courses, using a Blended PBL strategy. To this end, we implement our findings in a Project Management postgraduate course. Based on the gathered results, we propose a framework that can guide the design of project-oriented courses and we argue that its adaptation can exploit the identified strengths and avoid the weaknesses and lead to successful and immersive learning processes.

***Keywords**: Problem-Based Learning - Blended Learning - Cognitive tools – Project-oriented courses – Course design*

Introduction

Learning from problems is an instinctual human impulse that accompanies us in our everyday life. We spend significant effort to solve issues and accumulate relevant knowledge to resolve them accordingly and habitually (Barrows and Tamblyn 1980). Thus, in theory, transferring this process to educational contexts should not be difficult. That is not the case though; learning through solving problems appears to face significant challenges, mostly regarding the mentality change needed by all involved to abandon traditional teaching and make way for innovative student-centred learning styles (Northwood et al. 2003). Traditional learning is considered to usually deliver static knowledge that is not processed further and hence is difficult to be transferred into real world professional environments (Mandl et al. 1996). Therefore, its future capitulation is limited since it is not stored in interlinked concept schemas that can be easily retrieved through corresponding memory stimulation.

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The learning strategy known as Problem-Based Learning (PBL) allows the development of such schemas as well as their easy future retrieval. This strategy shifts the focus from understanding common knowledge to developing new knowledge through "learning by doing" activities. Additionally, the new knowledge tends to be stored in memory patterns that facilitate later recall (Hung 2011).

The implementation of PBL in education usually involves the usage of a model that introduces specified steps to guide the learning process. Today, educational institutions use self-regulated models or adapt established PBL models, depending on their courses' needs. PBL models are more frequently implemented in project-oriented courses since they require active student involvement and collaboration. This occurs because:

> Project-based learning is centered on the learner and affords learners the opportunity for in-depth investigations of worthy topics. The learners are more autonomous as they construct personally-meaningful artifacts that are representations of their learning (Grant 2002).

Even though relevant literature indicates many cases that successfully implement PBL models in project-oriented courses offline, the vast provision of data by the Web as well as the availability of online tools that could act as facilitators has led to an emerging need for technological underpinning of PBL.

However, face-to-face communication is still essential, especially to novice students in problem solving activities. Blended Learning (BL) seems an appropriate solution, since it combines online and face-to-face activities (NSW DET 2005).

Previous research on Blended PBL (Kim et al. 2011; Oscar et al. 2011; Donnelly 2010a; Donnelly 2010b; Yeh 2010; Hoic-Bozic et al. 2009; Konstantinidis et al. 2009; Lo 2009; Beaumont et al. 2008; Dalsgaard and Godsk 2007; Oliver 2005) focuses on the use of collaborative tools (i.e. interactive whiteboards, discussion boards, chat rooms, wikis etc.) and their contribution to successful student collaboration towards solving a problem. Conversely, the incorporation of cognitive tools (i.e. concept maps, argumentation modules, modelling modules etc.) and their contribution to successful project implementation has not yet been investigated sufficiently. Moreover, the aforementioned previous research on blended PBL is implemented in courses where students build new knowledge by solving a given problem, whereas there is no available corresponding research in cognitive tools' effects on project-oriented courses. In such courses students are required to not only build but also apply the new knowledge by implementing a problem-based project within real world contexts and at the same time develop domain-specific and transversal competencies (Grant 2002). They usually involve subjects such as engineering, project management, physics, maths etc., where students work together in order to achieve a goal divided into tasks amongst a group for analysis, implementation and review. According to Perrenet et al. (2000), activities such as time and resources management and tasks delimitation are crucial in project-oriented learning. To this end, fruitful collaboration along with knowledge construction and application, especially during the project's design, require scaffolding (Moesby 2002) since students will need to successfully plan the project to prevent risks that will need to be addressed and corrected during its implementation. Due to this "teacher to student" control shift, it is essential for teachers to effectively pre-structure, thus design, the course curricula and activities in order to create an attractive and adaptable learning environment that will motivate students to effortlessly and actively participate in the designed course.

This paper aims to investigate the incorporation of cognitive technologies within project-oriented courses and determine the prominent factors that should be taken into account while designing such a course. To this end, we adopt the Aalborg Pedagogical PBL model (Kolmos et al. 2004) and develop an online environment supplemented with cognitive tools to underpin the model's steps' execution. We then implement the approach in a Project Management (PM) postgraduate course and gather results from its evaluation. This leads to the construction of a framework that can serve as a starting point towards a holistic and validated structure of design guidelines for cognitively-enriched, project-oriented courses within blended PBL contexts. Our framework includes the evaluation results as concepts and provides additional design suggestions. Even though it is not validated in practice, we endeavor to assess our framework by studying related work on frameworks applied and validated in blended PBL contexts. We conclude that our proposal encompasses all identified concepts that represent PBL steps and is supplemented with guidelines for instructional designers that provide further suggestions for the successful design of project-oriented courses.

Theoretical background

PBL is a learning strategy that has emerged in the late 1960s and can be defined as:

> A constructivist learning paradigm where small groups of students engage in cooperative learning and collaborative problem-solving to solve problems in complex and authentic projects. These projects pursue specified learning outcomes that are in line with academic

> standards and course objectives with assessment focusing, to a varying degree, on the project outcome versus team process (Brodie and Borch 2004).

PBL underpins the development of essential competences (e.g. communication of ideas, information analysis, critical thinking etc.) with the incorporation of cognitive tools that allow students to engage in constructivist activities (Lu et al. 2010). This way, students are also able to familiarize themselves with real world situations through their involvement with context-based problems, and thus become acquainted with professional conditions they will encounter as future workers.

PBL is more commonly adopted in higher education project-oriented courses such as medicine, project management, engineering etc., where students are often required to perform specific tasks for in depth understanding towards the implementation of a project that solves a given problem. According to Liu and Richmond (2005) the stages that should be covered during learning design of project-oriented courses are:

(1) Initial analysis of the project
   - (a) Teacher-student discussion regarding the course's pedagogical goals, students' obligations and benefits
   - (b) Selection of the project topic
   - (c) Initial planning

(2) Design of the project
   - (a) Initial literature review
   - (b) Research goals and research questions identification
   - (c) Research and development methodology specification

(3) Implementation of the project end-product

(4) Evaluation of the project

Therefore, the PBL model that will be incorporated for the facilitation of such courses should address all aforementioned stages and underpin their execution.

The model's implementation is usually realized strictly inside the classroom. However, the most effective approach involves Blended Learning (BL), because:

> Replacing all lectures with discussion groups or tutorials would merely substitute one lop-sided system with another (Armstrong 1997).

BL can be defined as:

> The combination of face-to-face instruction with computer mediated instruction (Bonk and Graham 2006).

The challenges teachers and students face with PBL can be reduced and moderated with BL. According to Scardamalia and Bereiter (2003), the required control shift makes students reluctant to deal with additional responsibilities. Cognitive tools address this problem by providing visual representations of the most challenging tasks and facilitating students towards their execution. Cognitive tools are defined as:

> Technologies that learners interact and think with in knowledge construction, designed to bring their expertise to the performance as part of the joint learning system (Kim and Reeves 2007, 224).

They allow students to represent and express what they already know and what they are learning during the course, by supporting and guiding the visualization of their thinking processes (van Joolingen 1999). Interactive systems and collaborative tools can be considered cognitive when they are used in order to help students assign meaning to new knowledge based on previously gained information and save the new knowledge in concept-based memory patterns (Jonassen and Reeves 1996). Cognitive tools can be categorized depending on their role in the learning process as follows (Robertson et al. 2007):

- *Information presentation*. Tools that present information in a meaningful way e.g. concept maps, graphics software.
- *Knowledge organization*. Tools that classify knowledge into schemas for its visual representation e.g. presentation tools, notebooks.
- *Knowledge integration*. Tools that build new knowledge by interconnecting new information with prior knowledge e.g. mapping tools, simulations, online discussions.
- *Information research*. Tools that assist in discovering new information e.g. search engines, databases.

We develop and add in our environment tools that belong to the first three aforementioned categories, since information research is already feasible in all e-learning platforms through embedded search engines, as well as resources and links provided by the teacher.

Methodology

Initially, we carried out a literature review on PBL models used by higher education institutions that implement a clearly specified model in their project-oriented courses and hold explicit information regarding the model’s steps and its implementation. We distinguished the

Aalborg PBL model because it satisfied these criteria, is more successfully and durably used and provides verified results of improved students' performances. Thereafter, we endeavoured to electronically support the execution of the model's more complex steps and underpin the teacher-to-student control shift with tools that facilitate knowledge construction. To this end, we configured the existing open source Learning Management System (LMS) Atutor and developed cognitive modules that are not already a part of the LMS's tools repository. Even though there are available Cloud technologies that could be used in this case study, we prefer to incorporate rather traditional web solutions. This is so that we can have complete control over the customization process of the platform and tools as well as over the data, both functionalities not always allowed in Cloud systems.

The developed cognitively-enriched Blended PBL strategy was then applied in a postgraduate PM course where twelve students analyzed, designed, implemented and evaluated their projects following the steps proposed by the PBL model and using the cognitive tools developed in the e-learning platform.

When PBL is executed traditionally, i.e. offline with whiteboards and group gatherings, it is usually rather successful; however, the steps of the design (i.e. analysis, task formulation, problem delimitation) are rather complex (Kolmos et al. 2004; Moesby 2002). This is because students are required to initially gather relevant knowledge, build their own and delimiter the issues raised collaboratively, all processes that they usually find frustrating when they have to realize them without any assistance (Dahlgren and Dahlgren 2002; Murray-Harvey and Slee 2000). Moreover, project design should be underpinned more than the subsequent phases because mistakes in the design phase, such as wrong research goals formulation or inadequate literature review, usually lead to weak application of the gained knowledge during project implementation (Stinson and Milter 1996). One of the most challenging tasks in project-oriented courses is the establishment of a connection between the initial research goals with the conceptual knowledge gained throughout the course (Barron et al. 1998). Therefore, there is a need to ensure that the first steps in designing a project are executed correctly and are understood by all members of a project group.

On the other hand, literature indicates that cognitive tools facilitate information organization and enable knowledge building (Brown and Campione 1996). The inclusion of technologies within project-based learning is considered a significant benefit because:

> Using technology in project-based science makes the environment more authentic to students, because the computer provides access to data and information, expands

interaction and collaboration with others via networks, promotes laboratory investigation, and emulates tools experts use to produce artifacts (Krajcik et al. 1994, pp. 488-489).

More specifically, cognitive tools provide a means for students to think and reflect on complex domains while they are absorbing relevant information and thereafter synthesize new knowledge; a process that would be difficult without such tools (Jonassen and Reeves 1996). They also have the ability to help students become aware of the knowledge construction process, since they are able to view the process, depict any misconceptions early on and address them before moving on to the next part of a multi-step process, such as PBL (Brown and Campione 1996).

To this end, it is our aim to investigate whether cognitive tools could transform offline PBL into a BL process that can assist the complex project design execution. This is examined with our first research question as follows:

1. Did the cognitive tools facilitate students during the project's design phase?

Additionally, as already stated, previous literature on blended PBL does not seem to have addressed the use of cognitive tools in blended PBL and their contribution to successful project implementation. This consideration is carried out with the second research question, which is:

2. What were students' reactions using cognitive tools to design their project while following specified PBL steps in a blended learning setting?

For the evaluation of the cognitive tools' facilitating role we created a questionnaire that students filled out at the end of the course. The usage of cognitive tools for the project design was evaluated during the course with qualitative methods, such as personalized interviews, participant observation and online discussion blogs. For these qualitative methods we followed the "Social Constructivism" perspective (Mertens 1998) where we relied on the students' perspectives of the situation at hand (i.e. their experience within a blended PBL course using cognitive tools) to draw our conclusions. This approach claims that when individuals are able to actively engage in real-world tasks they can understand more thoroughly and create subjective meanings of their experience towards newly constructed knowledge. This makes it an appropriate technique for the evaluation of blended PBL in project-oriented courses; students collaborate offline and online without interference towards the construction of their meanings, allowing teachers to observe and draw assumptions regarding the effectiveness of the pedagogical strategy applied.

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All the gathered results were finally grouped into concepts and led to the construction of a generalized framework that embodies guidelines for future designs of project-oriented courses. We then studied relevant work on frameworks used in blended PBL contexts. With this step we concluded that our proposal covers all identified PBL steps and is augmented with guidelines on scaffolding and examples of specified activities.

PBL model

The examined case studies of the literature review on higher education institutions that successfully implement PBL models in project-oriented courses are portrayed in Table 1.

Table 1 Evaluation criteria on implemented PBL models

Higher education institute	**Course(s)**	**Steps**	**Assessment**	**Skills**
Aalborg (Kolmos et al. 2004)	Project Management	**8 steps** (Problem initiation, Problem analysis, Task formulation, Problem Delimitation, Solution, Discussion, Implementation, Evaluation)	Group-based assessment with individual grading	Knowledge processing, Analytical thinking, Argumentation, Communication of ideas, Group-work
McMaster (Saarinen-Rahiika and Binkley 1998)	Medicine	**7 steps** (Objectives identification, Interaction with the scenario, Identification of self-study questions, Self directed study, Discussion, Review and synthesis, Evaluation)	Self assessment, Peer assessment, Tutor assessment	Problem solving, Group-work, Self-directedness, Communication

Maastricht (Schultz and Christensen 2004)	Science, Healthcare, Business etc.	**7 steps** (Setting clarification,, Problem definition, Case investigation, Problem re-structure, Learning goals formulation, Individual learning, Report)	Performance in the problem solving process	Presenting viewpoints, Debating, Writing texts, Working together
Manchester (David et al. 1999)	Medicine, Engineering,	**8 steps** (Terms clarification, Problem definition, Hypotheses brainstorming, Arrangement of ideas, Learning objectives definition, Information gathering, Results sharing, Discussion experience)	Individual, peer and group assessment	Problem-solving, Team-work, Communication
Samford (Mauffette 2001)	Business, Education, and Pharmacy	**7 steps** (Problem analysis, Conceptualization, Prioritization of hypotheses, Plan identification, Data collection, Hypotheses verification, Defence)	Reflection and peer assessment	Critical thinking, Problem solving, Decision making

Delaware (Allen et al. 2003)	Biochemistry, Biology, Science etc.	**5 steps** (Problem analysis, Information identification, Sharing research findings, Formulate solution, Evaluate)	Evaluation forms	Problem-solving, Research, Social skills, Critical thinking, Writing

After critical examination, the Aalborg PBL model was chosen as the most appropriate solution since it fulfils all our selection criteria. The steps the model proposes are as follows (Kolmos et al. 2004):

- *Problem initiation*. Definition of the problem that needs solving. Each problem must be consistent with the course curricula and approved by the teacher in order to ensure the availability of a solution.
- *Problem analysis*. Group investigation of the problem using specific parameters and dimensions. Decisions such as the problem's scope and the needed resources.
- *Task formulation*. Problem objectives specification and subsequent task distribution.
- *Problem Delimitation*. Each group must define limitations of the problem and re-configure the task and responsibilities allocation depending on the group's findings.
- *Solution*. Determination of solution by each group through constant discussions and teacher guidance.
- *Discussion*. Group and class discussion through recursion of the process's steps.
- *Implementation*. Realization of the solution with corresponding resources.
- *Evaluation*. Quantitative and qualitative review and evaluation of the project by the class.

Aalborg University holds more than 30 years of experience in project-oriented, and more specifically PM courses, thus focuses on the knowledge application instead of solely its production (Perrenet et al. 2000). Moreover, there is explicit information regarding the model's steps as well as its implementation, facilitating our comprehension on how to put the model into good practice in our case.

Technology selection

The proper integration of the model in a blended setting requires the incorporation and customization of an e-learning system that would support students during their endeavour to execute the model's most challenging steps, i.e. "Problem Analysis", "Task formulation" and "Problem delimitation", which represent the project's design (Moesby 2002).

Hence, a literature review on studies that have compared the most well known LMSs based on specific criteria led to the examination of open source systems such as Moodle, Atutor, Dokeos, Claroline, Ilias and Nanotrain and the subsequent selection of Atutor (Lengyel et al. 2006). Atutor seems to be highly usable, includes a variety of features and tools and is also easy to install and customize. Moreover, according to a research carried out (Herrera et al. 2008), 65.57% of e-learning platform users prefers Atutor in comparison to other LMSs (e.g. 21.59% for Moodle, 3.19% for Dokeos etc.). Additionally, Atutor is one of the suggested LMSs by a research study on e-learning systems (Drewitz, 2009).

We also investigated the modules libraries of the two most prominent LMSs, i.e. Atutor and Moodle. It seemed that Atutor lacks in the availability of cognitive tools or tools that enable information organization, presentation and integration. Moodle includes some modules that could be used for our case, such as the "checklist" for information organization and the "mindmap" for information presentation whereas there is no module for arguments solving. However, these tools do not provide mechanisms such as task tagging, task priority, and presentation of information in thematic blocks for domain areas distinction etc. Hence, all the examined literature that compares LMSs suggests Atutor as a more effective system and Moodle does not provide cognitive add-ons that could be installed without further customization. In conclusion, Atutor was chosen for the development of the e-learning environment and additional modules were developed to simulate constructivist activities performed face-to-face in traditional PBL. For its proper customization, we examined the design guidelines provided by the relevant documentation.

A blended PBL environment does not need to focus on providing modules for communication, since that is accomplished inside the classroom (Boud 1985; Bridges and Hallinger 1992). Therefore, even though the frequently used Web 2.0 tools should be available, the platform must mainly incorporate functionalities that will not only support group collaboration, but will also enable engagement in constructivist processes. This can be accomplished with cognitive tools. Hence, during the platform's customization, we incorporated add-on Web 2.0 tools, such as chat, blog and forum, that support online collaboration, as well as tools such as file sharing and links repository that support exchange of material and resources.

Cognitive tools development

Students are usually required to use additional tools within project – oriented courses (e.g. domain-specific software), therefore we deemed appropriate to add only three cognitive modules so as to not increase their scatter of focus. More specifically, we developed a module for each cognitive tool role; a task documentation module for knowledge organization, a thematic blocks module for information presentation, and an argumentation module for knowledge integration.

Some PM activities (e.g. project schedule, resource allocation etc.) were realized with specialized tools such as Microsoft Project. However, these domain-specific tools differ amongst subject courses (e.g. Microsoft Project for PM, SAP for Management Information Systems etc.) and focus on tasks realization, i.e. on “doing” and not on the “learning by doing” goal of PBL (Barron et al. 1998). To this end, the developed tools underpin the realization of these activities so as to stimulate students’ constructivist way of thinking through collaboration and knowledge building. Moreover, they aim to help them develop PM-specific (e.g. task management, project management etc.) but also transversal (e.g. problem solving, teamwork, leadership etc.) competencies as well as store knowledge in memory schemes for its easy transfer to their future work environments. This way, students are more equipped to become lifelong learners during their professional careers, since they are not solely able to use domain-specific tools but they have learned how to learn and constantly supplement their knowledge with new information (Hmelo-Silver 2004).

Task documentation module

With the task documentation module (see Figure 1) students are able to record the distributed tasks per group or overall. Furthermore, the module provides functionalities such as tagging, deadline and priority level declaration and drag-and-drop task taxonomy, distinguishing it from the customary to-do list tool.

Additionally, after a task’s deadline has passed, it is automatically categorized as complete, assisting the work organization. Its completion is visually represented by automatic underlining. Students are allowed to add comments regarding each record, and are encouraged to initially complete the tasks with the highest priority level. Also, students are able to tag

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tasks with keywords for an easier searching process. Finally, the module allows constant task editing and their organization into separate lists, allowing flexible multiple task formulation attempts.

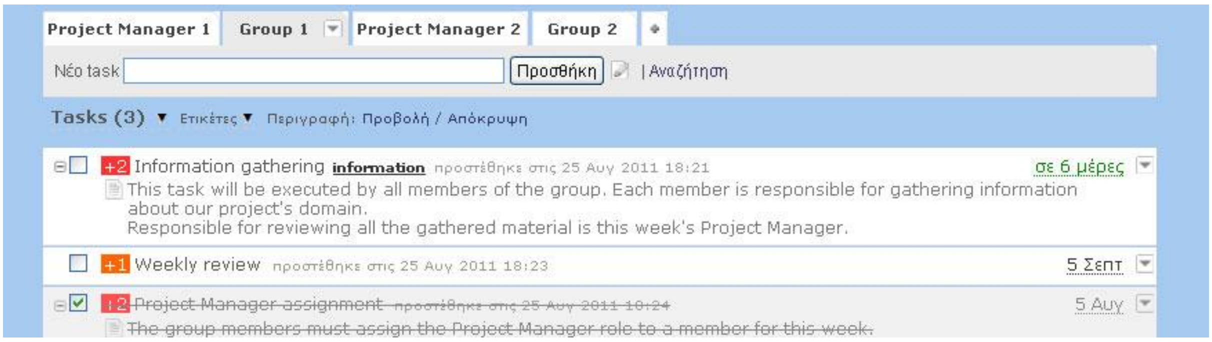

Figure 1 Task documentation module

Thematic blocks module

With the thematic blocks module, each student is able to add a new post-it (i.e. idea, concept, thought), and define the title, a referenced category as well as a colour. For example, let us assume that a group wants to check the project's overall progress. In this case, each post-it title can represent a project's stage while the category can depict the staff responsible for the corresponding stage. Lastly, the colour could indicate the stage's progress (e.g. green for "completed", blue for "in progress" and yellow for "pending"). When all post-its are added the group can further organize them by dragging and placing the post-its with the same colour close together, giving the group a holistic overview of its progress (see Figure 2). Another organization method is by category, for example, to view the workload of each staff and take disciplinary actions if needed.

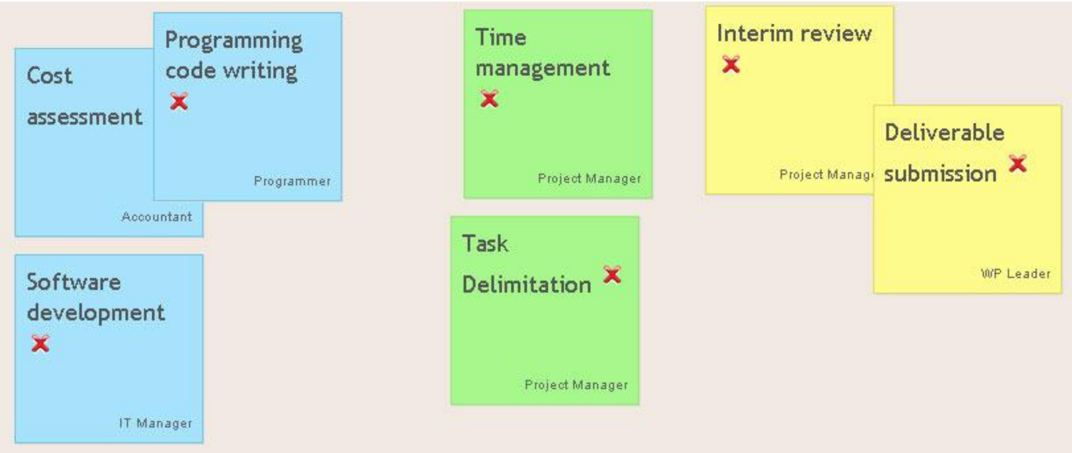

Figure 2 Thematic blocks module

Argumentation module

The third module intents to democratically resolve issues that may arise with as few conflicts as possible. Argumentation tools are known for their ability to provide an online threaded discussion space specifically designed for sorting out issues where different beliefs and multiple acceptable viewpoints exist (Baker 1992). The usage of this tool enables students to express their opinions in an organized and polite manner, and use appropriate information in order to support their argument on the discussed subject. For facilitating the process we enable four reaction choices (see Figure 3) as the most common types of posts that a person adds during an argumentation practice.

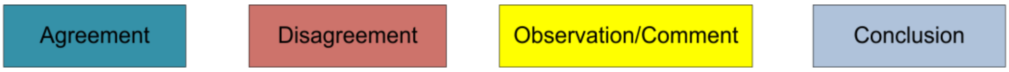

Figure 3 Argumentation categories

Every group member can add a type of argument as a response to any of the already posted arguments in the discussion. By pressing on the preferred type with the corresponding colouring, the student is able to reply and contribute to the discussion. The insertion of the posts is in hierarchical mode threading the arguments and colouring their text according to the argument type (see Figure 4). The different colouring aspires to differentiate every post and visualize the entire argumentation sequence.

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Figure 4 Argumentation module

The development of the e-learning platform follows a set of lectures that help students familiarize themselves with the environment and learn to use the new to their mentality modules.

Context

The designed for project-oriented courses approach is next implemented in a course on ICT PM to test its effectiveness and answer our research questions. The full name of the course is “Administration of Information Systems Development” and is an optional 3 hour weekly course that has been recently added to the postgraduate curriculum of the Interdepartmental Programme of Postgraduate Studies (I.P.P.S.) in Information Systems at the University of Macedonia. Thessaloniki, Greece. The course runs for 12 weeks and carries three ECTS (European Credit Transfer and Accumulation System) credits.

Participants

The students that participated in our study were twelve and ranged in age from 23 to 28. We consider they had mixed knowledge backgrounds since students enrolled in this postgraduate programme usually graduate from Computer Science, Economics or Business Administration university departments. They formed two groups of six and each group was required to propose, decide, design, implement a small-scaled project and evaluate its management process. Each student proposes an idea to the group members as a possible project topic. The most accepted and scientifically justifiable idea is selected by the team. Students can earn up to 50% of their final grade with the successful execution of all activities that lead to the project's completion. The other 50% depends on their performance in a final exam.

Course outline

The course's curriculum is pre-defined and in accordance to the PM theory that needs to be taught. This theory is divided into weekly lectures, which we mapped with steps of the Aalborg PBL model, according to the theory's context and its role in the project's progress (see Figure 5). Every weekly learning outcome becomes an input for the next step of the model, leading to the project's successful execution. Accordingly, depending on each module's functionality and purpose, it is mapped to one or more of the more complex Aalborg PBL model steps that represent the project's design phase (Liu and Richmond 2005) of a project-oriented course.

Every week, the "Project Manager" role is assigned to a student from each group following an alphabetical rotation approach, based on the students' last names. In the beginning of each weekly course, the two Project Managers that were responsible for their respective teams' progress throughout the previous week are requested to present their teams' results. In continuance, two other Project Managers that will be responsible for the teams' progress in the current week research, gather, and refine the week's theory and prepare separate lectures to present during the last hour of the course. The material of the lectures has to be scientific, related to the week's theory and presented clearly. This is underpinned with the tools (web search, notes, thematic blocks, task documentation etc.) and educational material available in the platform. Through this process, the Project Managers are not only more qualified to manage the team's progress throughout the week, but they are also able to exercise competences such as critical thinking, information filtering and abstraction, concept analysis etc. Furthermore, the educational material available to all students is enriched, since the information of the lectures varies according to each Project Manager's perceptive of the theory. These Project Managers will present the teams' progress in the beginning of the following week's course.

In continuance, the teacher answers any possible questions that have arisen during the Project Managers' presentations, and supplements the week's theory with additional material, giving students a holistic knowledge base of the area in focus.

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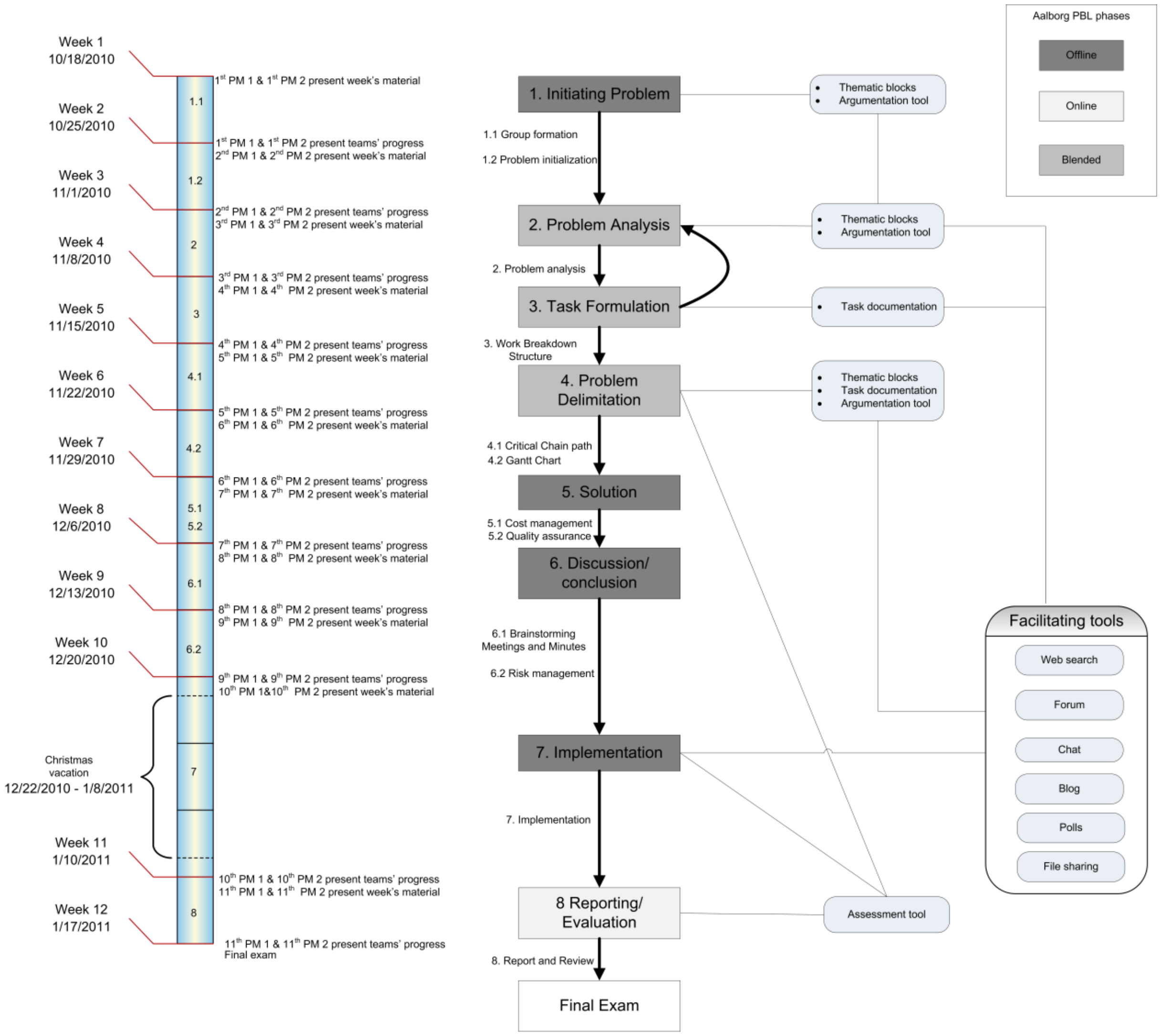

Figure 5 Mapping the weekly course with the Aalborg PBL model and the platform's tools

More specifically, the task documentation module implements one of the most fundamental PBL steps as described in the Aalborg model, i.e. task formulation. This way, students can have a clear and organized overview of the process and apply changes when necessary, e.g. if a process stage gets delayed or if a team member requires assistance. Moreover, the module's functionalities enhance students' competences, such as critical thinking and information organization since they need to be able to sufficiently organize and prioritize the tasks.

The thematic blocks module is developed mainly to provide visual representations of the problem analysis and delimitation steps, but it can be exploited on different occasions, such as for group progress control, complex knowledge clarification etc. Students can work in groups and break up the initial problem into different components, which are represented by the post-its, while at the same time categorize these components into different sections via colouring schemes. Hence, this module acts as a cognitive tool, supporting processes that students traditionally execute in paper through note documenting or in a blackboard with drawn blocks illustrations, a tiring and complex process that does not allow easy editing and re-organization of the identified concepts. Apart from remote usage, this module can also function as a supporting mechanism during face-to-face brainstorming sessions within groups. This way, the discussion can be documented and visually represented, enabling the easier and quicker delimitation of the prominent ideas.

The argumentation module can be used in problem initialization, analysis and delimitation steps, if a conflict in need of a solution arises. Moreover, the teacher can examine which viewpoint prevails in a specific threaded discussion (i.e. if there have been more agreements than disagreements, how many times students disagreed etc.). Thus, this process can help in the identification of behaviour patterns; a student that is prone to disagree more frequently than others might cause un-necessary conflict and tension within the group. Similarly, if a student seems to constantly agree with everything posted, then we may be dealing with either a passive or an introvert case. Hence, an argumentation tool helps the identification of such behaviours and enables the teacher to scaffold and adapt the process or the course accordingly and ensure maximum performance efficiency.

During the presentations of the Project Managers the rest of the students are able to use an assessment tool and engage in a problem-based assessment practice. This Atutor add-on module is included in the platform in order to facilitate the students' assessment according to PBL principles. Each evaluation report consists of three questions, as follows:

- One free text question where students are required to record the positive and negative aspects of the Project Manager's presented content (e.g. information thoroughness, excessive / limited analysis, understanding of theory, inability in simplifying a complicated topic etc.).
- One free text question where students are required to record the positive and negative aspects of the Project Manager's presentation skills (e.g. aesthetic result, communication of ideas, ability to maintain the audience's interest etc.).
- One Likert scale question with values from 0 to 10, where students are required to grade the presentation as a whole, depending on the general evoked impression.

This way, students learn to think critically and objectively, as well as observe more thoroughly, while at the same time contribute to their classmate's evaluation.

Evaluation

The purpose of this research study's evaluation was twofold; first, to determine if cognitive tools are accepted by students as facilitators in effectively executing project design activities within a course that follows a blended PBL approach; and second, to develop guidelines that will underpin future designs of similar courses based on students' reactions. This data was accumulated through a questionnaire at the end of the course and through blended qualitative methods during the course such as offline participant observation, open – ended interviews and online discussion blogs where students assessed the course, their classmates and themselves.

A literature review was carried out on case studies that adapted the Technology Acceptance Model (TAM) (Davis et al. 1989), which is considered the most established model for assessing technologies, and applied it in the e-learning domain. This review resulted in the adoption of a case study that introduces a set of questions for investigating students' impressions on their e-learning experience and categorizes them in thirteen axes, where each axis represents an evaluation factor (Rocaa et al. 2006).

We created an online questionnaire with most of these questions using a 5 point Likert scale and replacing the ones we were not interested in investigating (e.g. email functionality, Web 2.0 tools) with our own that focus on the cognitive tools' usage. At the end of the course we asked the twelve participants to answer the forty-six final questions. Moreover, we carried out a reliability analysis by calculating Cronbach's alpha for the questions of each examined evaluation factor. When Cronbach's alpha varies from 0.7 to 0.8, the reliability of the questions is considered "Acceptable", whereas for values from 0.8 to 0.9 the reliability is considered "Good" (Cortina 1993). The coefficient's value in our case is greater than 0.8 in all factors except for the "Perceived cognitive absorption", where its value is 0.758. Therefore, we consider that even though our sample size is small, the evaluation answers are statistically reliable. The questions along with the Mean, Standard Deviation (SD) and Cronbach's alpha values of the corresponding answers relevant to our first research question are shown in the Appendix.

To supplement the first and answer the second research question we used a set of personal interviews, close examination of students' experience during the course within the classroom and of discussions occurring online. The corresponding results were translated into concepts and composed a framework as guidelines for the design of future blended project-oriented courses.

Findings

Apart from the investigation of the two research questions, observation of the students during the course as well as personal interviews helped us distinguish a number of weaknesses that require addressing during the design of a project-oriented course. These weaknesses reaffirm the literature presented, for example that students are reluctant to the sudden change in the course's process (Scardamalia and Bereiter 2003; Northwood et al. 2003; Mandl et al. 1996). Time and effort was required for them to adjust to their active role towards the design and implementation of their project. Moreover, they faced difficulties on distinguishing relevant scientific material from other resources (e.g. personal websites, blogs etc.) that cannot be considered trustworthy. This indicates, as stated in the literature, that scaffolding is essential in self-directed learning strategies such as PBL (Moesby 2002; Brown and Campione 1996). Additionally, the constant reflection of the knowledge gained as well as the requirement to document their progress seemed a welcome but challenging process, since they had not been familiarized with it beforehand.

The aforementioned observations indicate a general need for scaffolding mechanisms during all PBL steps, so that students can overcome the aforementioned barriers more quickly and with the help of online technologies as well as of the teacher. These needs were added as consequent concepts within the proposed framework so that they will be taken into account during the design of future project-oriented courses.

Cognitive tools as facilitators during project design

The first research question was investigated through the analysis of the questionnaire answers. The results indicated a positive attitude towards the cognitive tools, since the questions related to them gathered a mean greater than or equal to 3.50, which shows that the majority of answers were above the value 3 (neutral position) and closer to the value 4 (positive position) of the Likert scale.

More specifically, the task documentation module was the most used tool (64.28%), since it seemed to benefit the certification of students' progress and provided them with a holistic overview of the group's course towards completing the project. Furthermore, students seemed positively inclined to use the thematic blocks module (71.43%) but only 50% actually used it. According to the interviews, this was because they needed more time to get accustomed to the mentality change such a tool requires. The argumentation tool received divided opinions, since 50% were reluctant towards it because they are not used to immersing in such structured settings where their opinions are recorded. This observed reluctance is in accordance with the relevant literature, which states that students hesitate to challenge their classmates' thoughts during an argument for fear of conflict (Oh and Jonassen 2007). Even when they do respond, they tend to use phrases such as "I agree" or "I disagree" without providing actual argumentation to support their reply. This occurs more with students new to technologically-underpinned argument visualization which requires them to elaborate on their beliefs (Nussbaum et al. 2002) such as in our case.

However, the other 50% showed an interest in using the tool to solve arguments. During the personal interviews, they acknowledged its advantages in organizing a group's arguments and leading to a documented solution, and stated that they would be willing to use it if they familiarize themselves with it beforehand.

Additionally, the elicitation of the interviews' answers as well as participant observation and online discussion blogs indicated that during the PBL's "Problem analysis", "Task formulation" and "Problem delimitation" steps students preferred the cognitive tools that were specifically incorporated to simulate these types of activities. This result answers the first research question positively and is consistent with Kolmos et al. (2004) and Moesby (2002) that the above three phases seem to demonstrate the maximum difficulty level and therefore, need facilitating mechanisms for their execution. On the other hand, students did not use the known Web 2.0 tools (e.g. blogs, forums and chat), preferring their face-to-face meetings and online communication techniques they were already familiar with in their everyday life (e.g. Facebook). This result was expected since the research did not focus on their usage and thus students were not particularly encouraged to use them inside and outside of the classroom

Cognitive tools within PBL steps for project-oriented activities

The second research question was answered via a series of interviews, a process that is performed by similar case studies (Oscar et al. 2011; Donnelly 2010a; Donnelly 2010b; Beaumont et al. 2008), where we asked students questions that focus on the problem-based nature of the learning process.

Since there is no available related work regarding cognitive tools' usage in project-oriented courses following a blended PBL model, we cannot compare our results to other case studies. However, the interviews showed that students were positively inclined to use online tools along with face-to-face activities because they were able to (a) visualize their progress and thinking process, (b) access information regarding their project and knowledge regarding the subject theory and (c) perform brainstorming sessions with their group members. Moreover, they seemed to enjoy following specified steps from the project initiation to its finalization. This was because knowing what the next step is, what tools to use and activities to perform for their completion alleviated some of their reluctance towards this new to them pedagogical strategy.

This positive attitude is in accordance with the relevant literature stating that the usage of cognitive tools in project-oriented courses provides significant benefits, such as facilitating information organization and representation and its integration into new meaningful knowledge. This way, students become aware of their thinking processes (Krajcik et al. 1994; Brown and Campione 1996).

Students also seemed to show a positive attitude towards the new evaluation process. The immediate feedback that was given to the evaluated proved to be an encouraging mechanism that improved their performance. This is an encouraging result since students' reluctance to participate in the traditional evaluation process is a significant challenge of PBL.

Overall, the findings indicate that indeed project-oriented courses that include a multi-steps project design phase require scaffolding. This can be achieved with the incorporation of cognitive tools, which not only facilitate this phase's execution, but also underpin transversal competences' development, iterated knowledge building as well information mapping in interlinked memory schemas.

Proposed Blended PBL Framework

As initial work, a framework is designed that generalizes the research's results (see Figure 6). This framework embodies the most important concepts that need to be taken into account during the design of project-oriented courses and their implementation within a blended environment that follows the Aalborg PBL model. Additionally, the inclusion of useful considerations that instructional designers and/or teachers should take into account provides scaffolding mechanisms to the instructional process. Even though the framework was constructed based on the Blended PBL strategy's application to a PM course, it can be adopted or adapted by other project-oriented courses since it does not include any domain-specific information.

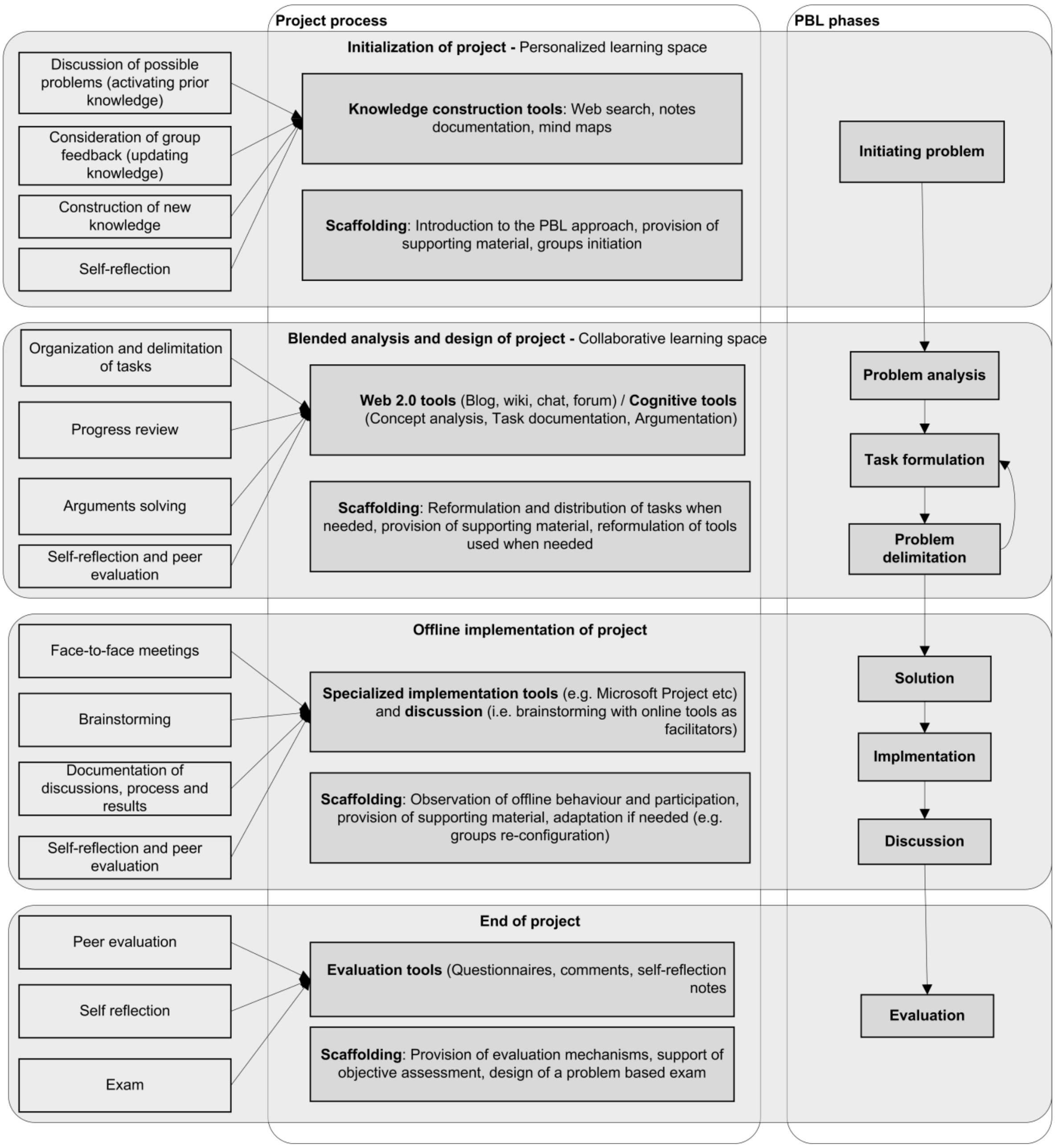

Figure 6 Cognitively-enriched Blended PBL framework

This is a pre-final version. The final paper is available at: Efthimios Tambouris, Maria Zotou and Konstantinos Tarabanis. (2012). Towards designing cognitively-enriched project-oriented courses within a blended problem-based learning context, Education and Information Technologies, p. 1-26, doi: 10.1007/s10639-012-9209-9

The framework is divided into four parts based on the project-oriented courses' phases (Liu and Richmond 2005), providing a more focused view of the Aalborg's model steps as follows:

(1) *Initial analysis*. Students are first introduced with the PBL approach and are requested to propose a possible project to the group. To this end, each student is required to capitulate on already gained knowledge, investigate updated information on the area, form a proposal based on scientific arguments and communicate the idea of the proposal to the group members.

(2) *Blended analysis and design*. During this part students are requested to collaboratively follow the steps of a domain-specific process (e.g. form a project plan) and design the steps that will lead to their problem's solution (e.g. development of a project). This is where the developed cognitive tools are put in use because this project progress phase includes the most complex PBL steps and therefore requires underpinning for reduction of students' cognitive load and their engagement in constructivist activities during knowledge construction.

(3) *Offline implementation*. After the project design each team is required to successfully implement it, thus find a solution to the problem they initially raised (e.g. need for the creation of an e-library for a rural university). During this process, groups usually hold frequent meetings in case of occurring issues that need addressing. Therefore, this part usually requires offline development with specialized tools such as Microsoft Project as well as face-to-face discussions and brainstorming sessions. Online tools can be used as a scaffolding mechanism, such as online communication agendas, meetings documentation, deliverables sharing etc.

(4) *Finalization*. The last part of the framework is associated with the project and students' evaluation. Students review the project's results and assess their own overall performance as well as that of their classmates. However, evaluation (self and peer) is included in every part of the PBL process. This is essential in PBL since consistent reviewing not only improves the educational material produced but also enhances students' performances in this and future courses.

As we were not able to validate the framework's applicability in other project-oriented courses, we carried out a literature review on case studies that use frameworks to examine the effects of blended PBL in students' performances. During our research we did not find a framework that focuses on cognitively-enriched blended PBL for project-oriented courses, therefore we examined the conceptual models used for blended PBL in general. Most cases, as aforementioned in the Introduction, endeavour to underpin students' collaboration and communication and do not focus on the technologies' role as cognitive tools.

Most related work does not include a graphical representation of the learning process, and some cases provide little elaboration on the methodology followed regarding the PBL sequence (Kim et al. 2011; Donnelly 2010a; Dalsgaard and Godsk 2007; Oliver 2005). Some studies simply provide basic models that show the course process or design guidelines for instructional designers (Yeh 2010; Kerres and De Witt 2003; Thomas 2000). Table 2 summarizes the results of the case studies that include specified steps followed during the blended PBL execution within each learning process.

Table 2 Summary of literature review on frameworks for Blended PBL

Concepts	Source
1. Gathering and organizing 2. Setting goals 3. Generating ideas 4. Evaluation of ideas 5. Developing the Project 6. Assessment 7. Presenting the projects 8. Learning from experience	(Oscar et al. 2011)
1. Problem identification 2. Deconstruction 3. Seeking and using knowledge and experience 4. Understanding 5. Thinking 6. Choosing a strategy 7. Acting 8. Critically evaluating and reflecting on the action	(Donnelly 2010b)
1. Face-to-Face lecture (F2F) 2. Studying lessons (online) 3. Discussing in forum (online) 4. Solving self-test (online) 5. Creating seminars (online) 6. Creating courseware (blended) 7. Courseware reflection (F2F) 8. Courseware evaluation (online) final exam (F2F)	(Hoic-Bozic et al. 2009)
1. Course design 2. Setting the problem 3. Discuss / provide information 4. Content development 5. Evaluation	(Konstantinidis et al. 2009)
1. Identifying the problem 2. Brainstorming	(Lo 2009)

3. Collecting and analyzing information 4. Synthesizing information 5. Co-building knowledge 6. Refining the outcomes	
1. Preparation and Induction 2. Communication tools 3. Face-to-Face facilitation 4. Reporting and reflection 5. Facilitation via videoconference	(Beaumont et al. 2008)
1. Analysis design 2. Development 3. Implementation 4. Execution 5. Evaluation 6. Review	(Alonso et al. 2005)
1. Preliminary Phases 2. Team Building 3. Project 4. Team Building selection 5. Information Gathering 6. Project Milestone 7. Feedback 8. Generic Evaluation 9. Instructor: Review Evaluation Reports) 10. Peer-Evaluation	(Derntl and Motschnig-Pitrik 2004)
1. Naming (identifying main issues in the problem) 2. Framing (establishing the limits of the problem) 3. Moving (taking an experimental action) 4. Reflecting (evaluating and criticizing the move and the frame)	(Nelson 2003)

As shown in Table 2, most cases use similar steps to perform blended PBL. All these steps are already encompassed within our proposed framework. None of the aforementioned case studies follow a specified pedagogical PBL model as those showed in Table 1 (e.g. Aalborg, Maastricht etc.) and there is little available information regarding the methodology that led to the particular steps followed. A few cases follow non-PBL models, such as the work presented by Oscar et al. (2011), where the “Think Actively in a Social Context” (TASC) method was adopted and adapted into the PBL needs. Another example was Hoic-Bozic et al. (2009) where the authors followed the sequential model of BL, which, however, does not include any PBL-specific steps.

Moreover, the examined frameworks do not provide concepts that address scaffolding processes such as reformulation and distribution of tasks in the case problems occur, adaptation of the materials based on the students’ comprehension level, arguments solving etc. Scaffolding is essential to be provided (Moesby 2002; Brown and Campione 1996) so that the aforementioned challenges students face in blended PBL can be addressed (i.e. constant collaboration, knowledge construction, peer evaluation, reflection etc.) Therefore, frameworks that assist the design of project-oriented courses should include relevant guidelines.

Additionally, all related work mainly names the steps to be followed within a blended PBL process, without providing additional guidance for the design of such a course. Such guidance could include examples of tools to be used in each PBL phase, facilitating roles for the teacher, specific activities to take place in each phase (e.g. brainstorming, reflection, progress review) etc. These limitations were addressed by our work with the construction of the proposed framework, which includes all aforementioned features as concepts.

Conclusion and future work

This paper examines strengths and weaknesses that occurred during the implementation of a cognitively-enriched Blended PBL strategy in a PM course. The weaknesses identified include the sample's small size and the fact that the proposed framework has not been applied to different project-oriented contexts for validation. However, the results give reason for encouragement as well as for reconsideration of tactics for future work. Moreover, they are considered reliable despite the sample's size since the evaluation questions were verified as acceptable and good through the reliability analysis carried out.

More specifically, students' initial reluctant attitude towards active participation and usage of the new tools suggest that the successful implementation of PBL in a blended setting requires a considerable amount of time for the adjustment of participants to new introduced techniques and eventually for its long-term successful integration in the educational curricula. This does not only include the incorporation of an established PBL model and the corresponding tools, but also modification of educational material. Since students are largely responsible for new knowledge that is produced, it is important that teachers moderate the process to make sure knowledge remains scientifically accurate and in accordance with course's specifications. This can be underpinned through careful design of the course prior to its implementation.

The chosen PBL model seems to appropriately cover the needs of a project-oriented course, facilitating students on their endeavour to engage themselves in real world professional contexts. The cognitive tools seem to significantly assist in the execution of the most difficult PBL phases. They facilitate by graphically representing the problem analysis and delimitation process through concept mapping and visualizing the task assignment process, thus offering an overview of effort distribution. The positive attitude of the students during their familiarization with the tools confirms their added value in a Blended PBL process.

Moreover, students expressed negativity towards the plethora of tools they were required to use throughout the semester. Hence, this calls for an appropriate e-learning environment that will not scatter students' focus. Furthermore, since the alternative communication ways, such as Facebook and face-to-face meetings are more familiar to students, the new environment should provide appealing mechanisms that will entirely engage them in the platform's potentials.

A main contribution of this study is the proposed framework. We acknowledge that additional work is required to verify its applicability given that it has been constructed based on a small research group. Nevertheless, we consider the results encouraging towards its successful adaptation to other project-oriented courses, i.e. in courses where students are requested to solve a problem by designing, implementing and evaluating a project. This is because our review of related work on frameworks applied in blended PBL concluded that the proposed framework includes all identified concepts and is supplemented with features (e.g. scaffolding guidelines, specific activities and tools examples) that facilitate instructional designers to plan project-oriented courses. Moreover, the framework does not include any domain-specific concepts and hence enables their instantiation so that it can be applied in any project-oriented course subject. Lastly, the framework's flow of actions is based on an already established PBL model that has been successfully implemented in various project-oriented courses such as Project Management, Engineering etc. This shows that it can be adapted to such a course's needs.

The iterated instantiation and usage of the framework could produce significant data regarding students' reactions towards a cognitively-enriched, blended PBL process. This way, additional future work would involve the development of a holistic, immersive and adaptive environment that would take into consideration the gathered results and configure the above framework according to specified needs for the creation of blended problem-based courses in any applicable project-oriented domain. This attitude of ongoing enhancement towards a new generation of learning processes with constructivist features is encouraged by the literature, along with the further investigation regarding which technologies should be used in a Blended PBL environment and when.

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Appendix

Question	Cronbach's a	Mean	SD
Perceived cognitive absorption	**0.758**		
Time flies when I am using the e-learning system		3.57	0.938
I have fun interacting with the e-learning system		3.67	0.745
I enjoy using the e-learning system		3.50	0.76
Perceived ease of use	**0.869**		
Learning to operate the e-learning service is easy for me		4.07	0.730
It is easy for me to become skilful at using the e-learning service		4.21	0.893
My interaction with the e-learning service is clear and understandable		4.29	0.726
I found it easy to document my tasks		4.00	0.603
I found it easy to analyze problems with the thematic block tool		3.75	1.138
I found it easy to voice my arguments in the argumentation tool		3.50	1.087
Perceived Internet self-efficacy	**0.84**		
I feel confident in the e-learning system documenting my tasks / to do work		4.09	0.701
I feel confident in the e-learning system exchanging messages with other users in the argumentation tool		3.54	0.967
I feel confident in the e-learning system by analyzing ideas with the thematic block tool		3.50	1.087
I feel confident in the e-learning system posting thoughts in discussion blogs		3.75	0.866
Satisfaction	**0.952**		
I am satisfied with the performance of the e-learning service		3.67	0.842
I am pleased with the experience of using the e-learning service		3.50	0.855

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