Computers & Education 55 (2010) 1312–1320

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Database design learning: A project-based approach organized through a course management system

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A R T I C L E I N F O

Article history:
Received 18 November 2009
Received in revised form
28 May 2010
Accepted 3 June 2010

Keywords:
Teaching/learning strategies
Database design learning
Project-based learning
Course management system

A B S T R A C T

This paper describes an active method for database design learning through practical tasks development by student teams in a face-to-face course. This method integrates project-based learning, and project management techniques and tools. Some scaffolding is provided at the beginning that forms a skeleton that adapts to a great variety of student-proposed domain projects and emulates the real way of working in database design. We include a quasi-experimental study in which the results of five academic years are analyzed. The first three years a traditional strategy was followed and a course management system was used as material repository. The active method was introduced for the last two years and coexisted with the traditional one. The course management system greatly simplifies the management of the numerous documents produced, the description and scheduling of tasks, the identification of teams, as well as all communication needs. In this study we analyze aspects such as exam dropout rates, exam passing rates, exam marks, and class attendance. Students that followed this active learning approach obtained better results than those that followed a traditional strategy. Besides, the experience of the introduction of such a method in a student subgroup positively influenced the whole group.

1. Introduction

Design learning in computer science in general, and in database courses in particular, entails considerable difficulty (Cheung, Li, & Yee, 2003; Connolly & Begg, 2006; Mohtashami & Scher, 2000). Designing implies a creative process without exact formulas. Existent methods for design learning provide some clues about how to approach the problem and discuss the most important issues the designer should focus on. But usually there is no single, simple, well-known, or correct solution. This causes a certain degree of "cognitive dissonance" in the students, because they usually look for a definitive solution. Students normally understand reasoned design solutions and they easily devise and debate possible variants, but generally do not feel secure solving similar problems by themselves. Both knowledge and skills are identified as key points to undertake database design. Knowledge covered in database design is of technical and practical nature. The skills should take account of problem-solving, critical thinking, creativity, verbal and written communication, team working, and time management.

Instructional methods traditionally used for database design include expositional lectures, and closed and hands-on laboratories. In the rest of the article we will refer to this as "traditional method". However, some authors (Martínez & Duffing, 2007; Neely, 2007) suggest that this method seems to be problematic or even ineffective for the abstract and complex domain of database design.

One promising method in this field is based on the development of projects which, in some sense, directly corresponds with the main activity of an engineering graduate in Computer Science and Information Systems (Connolly & Begg, 2006; Kovacs & Baugh, 2009). Project-Based Learning (PBL) (Blumenfeld et al., 1991; Frank, Lavy, & Elata, 2003; Helle, Tynjälä, & Olkinuora, 2006; Thomas, 2000) is a learning method based on developing projects in which students plan, implement, and evaluate projects that have real world application beyond the classroom. There are many benefits of PBL covered in the literature. For instance, the possibility of connecting learning with reality, of increasing motivation, or promoting problem-solving, among others.

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doi:10.1016/j.compedu.2010.06.001

Software projects typically use specific software engineering technologies, techniques, tools, etc. The main characteristics of a project include: a beginning and an end, development in steps, and the uniqueness of the product, service, or result obtained. *Project management* is the application of knowledge, skills, tools, and techniques to meet project requirements (PMBOK, 2004).

The first objective of this work is to integrate both perspectives of a project as an effective database learning method, using PBL with the aim of undertaking a software project that covers all the matters included in a particular subject. The result of this integration should benefit from both PBL techniques and professional practices.

Our second objective is to organize, manage and control the development of project tasks and their deliverables through the adoption of a CMS tool in a face-to-face course, in order to minimize the management time.

The last objective is to examine the results of two academic years using this method.

The rest of the paper is organized as follows: in the next section we introduce preceding related work. In Section 3 we describe the project-based approach. In Section 4, we show the role of the computer tools for the development of the project tasks and for the management of the training process. In Section 5 we present our hypotheses about the experience with the learning method previously introduced and in Section 6 we expose the research method followed. In Section 7, we present the results obtained and we discuss these results trying to identify advantages and problems of the method application. The paper ends with a conclusions and future work section.

2. Related work

Most of the methods proposed for database design learning, as an alternative to traditional methods, follow either a problem (Ma, 1994) or project-based learning orientation (Connolly & Begg, 2006; Marre, Hernandez, Rauncent, Moore, & Bourret, 2006; Mohtashami & Scher, 2000). These works argue that PBL offers opportunities to reach the set of knowledge and skills required in this area. Alternatively, specialized software tools for learning a particular database design step have been developed, generally with limited availability (see, for instance (Cheung et al., 2003)). Martínez and Duffing (2007) compares the experiences using traditional, problem-based and project-based learning methods for database subjects in three European Universities. This work also encourages the use of PBL for this field. These techniques have also been successfully adopted in related areas as in, for instance, mechanical engineering devices design (Frank et al., 2003), design patterns (Chatzigeorgiou, Tsantalis, & Deligiannis, 2008), or even merging complementary disciplines as object-oriented programming, database design and web technologies (Kovacs & Baugh, 2009). Nevertheless, it is not easy to find studies which demonstrate their effectiveness for database design learning. A quasi-experimental work by Connolly and Begg (2006) used an online PBL approach and a face-to-face PBL method to teach two database courses. Preliminary qualitative analysis of the feedback provided by students and faculty members in both courses suggests that PBL can be an effective tool to teach database design (see Connolly, Stansfield, and McLellan (2007) for a quantitative analysis of the data).

Several challenges have been identified in PBL courses (see for instance (Blumenfeld et al., 1991; Helle et al., 2006)). We would like to underline four of them for its application in databases, identified in the literature. The first one is the need of devising project topics each course. They should cover (nearly) all the course concepts. When topics are diverse, their complexity level, their quality, size and the concepts included are usually very different, making the assessment harder (Connolly & Begg, 2006). The use of a single topic reduces the assessment difficulty (Ma, 1994; Marre et al., 2006). However the last practice also simplifies the copying of results among students. The second one is related to the project starting: students that have never developed similar projects need special help at this point (Ma, 1994). Time management is also identified as a difficult task for students (Connolly & Begg, 2006; Marre et al., 2006). The third problem is the increase in the student and teachers workload. Also the concurrence with other projects, from other subjects for instance, can produce an overload in students' work (Connolly & Begg, 2006; Martínez & Duffing, 2007). As a last problem, it is detected that specific skills and knowledge could suffer using PBL, while generic and traversal competence is empowered (Martínez & Duffing, 2007).

Database tasks are usually slightly detailed in the mentioned works. It is not clear if PBL covers or not all course contents, if method application guarantees effort distribution along the course time, and if uncertainty inherent to project launch is minimized in some way. The PBL method described in Section 3 tries to deal with these problems. One of its main features is the supply of certain scaffolding help, part of it related with project management techniques. Rooij (2009) also provides tools and templates from project management to measure some consequences on the scaffolding level offered, in the context of an online course. According to this study, students that obtained more initial help expressed more positive collaborative behavior and intra-team communication.

3. Project-based approach

3.1. Context

The subject, entitled Database Design, is part of the first semester of the second year in a Computer-Engineering Degree. This face-to-face course is made up of three theoretical and three practical credits (one credit corresponds to 10 class hours). Practical sessions are generally computer laboratories but some of them are devoted to exercises.

As a general course aim, students are expected to be able to obtain an efficient database definition satisfying a given set of data requirements. This course encompasses data requirements elicitation and data analysis, conceptual database design, logical database design, normalization, and physical database design. Besides, other tasks related with database design are included, such as the use of XML in databases and distributed database design.

Our approach focuses on the development of a project by a student team following the ideas of PBL, where an entire database is designed and built. At the same time, project management techniques, tools, and skills from the engineering area are used. We try to apply an enterprising way of working during the whole process: deadlines, limited resources, penalization for delays, role-playing, documentation production and checking, etc.

3.2. Scaffolding

The database design stage, that would be understood as a complete project by itself, appears in many real software projects. It is usually divided into some typical sub-phases that correspond with the main subject contents previously presented (Elmasri & Navathe, 2007). Further subject topics have also been included as project tasks; therefore all course concepts have been integrated into the project.

The diagrams in Figs. 1 and 2 constitute the skeleton of a database project that will be given to the students from the beginning. They provide a division into tasks of the project and their temporary distribution. Both diagrams are normally used in project management and system engineering to define and organize the total scope of a project (PMBOK, 2004). More help will be offered for each task such as a brief description of the requirements and the aims of each phase. Occasionally some examples are included and, in specific tasks, instructions for the interaction between the different actors (for instance, the communication channel, if it is anonymous, the kind of acceptable questions or answers…). These two diagrams are complemented with a course calendar with a short description of each lecture and each laboratory offered during the course.

Fig. 1 shows the project set of tasks through a Work Breakdown Structure (WBS). The diagram presents the tasks to be done in a tree-like organization. The higher level represents the full project and its children nodes are the main tasks included in it. Each task can be successively divided in new subtasks in a recursive way.

Fig. 2 reflects the project schedule for the course 2007–2008 through the use of a Gantt chart, which contains an estimated calendar for the phases and a dependence relationship among activities. In this plan, each terminal element of the WBS has a suggested starting date and a deadline. Additionally, the estimated workload (in hours) required for each task is shown. Generally, these tasks are indivisible into subtasks. The time estimation for each task is calculated assuming that only one person will accomplish it. However, students could distribute the work among the team members internally. In any case, our aim is not to monitor the group's internal task management.

These diagrams and descriptions are provided for teams trying to reduce project complexity and to motivate learners. Planning a long-term project poses several problems to inexperienced people. The creation of a temporal sequence of detailed tasks avoids this trouble and minimizes the amount of uncertainty inherent to the launch of a project.

The teams develop the projects outside the programmed lectures. Each phase requires understanding the concepts implied in database design including training exercises. The available resources include a list of books, web materials, and the possibility of attending the scheduled lectures and laboratories. The class and laboratory calendar is built taking into account the task deadlines shown in Fig. 2. Therefore, students have the opportunity to attend them with enough time to submit their deliverables.

This means that students are not responsible for the global planning of the project, but they still control the execution of each particular task. They stay in a project development environment, and are responsible for task realization, time measuring, and deadline meeting. So, students find out how to divide a project into tasks and organize them in time and that serves as an example for future developments. Besides, due to the use of a shared plan, different teams develop the same task simultaneously. This facilitates the interaction among teams trying to solve similar problems. These discussions with other teams could extend the acquired knowledge and skills both for project development and database design.

3.3. Project topics

The proposed task structure constitutes a skeleton that adapts to a great variety of database project topics, also known as the universe of discourse (UoD), that students can propose according to their own interests. Therefore, we have attached an initial project phase, called "domain" in Fig. 2, where the team members must agree which is the UoD for their database project. Examples of chosen UoD were: "nursery", "Rioja wine cellar", "local football championship", etc. In our opinion, all the selected UoDs must be different. It is in the instructor's hands to avoid repeating the same or a similar UoD or to adjust a proposal.

The second phase, called "requirements", is the real beginning of the project. This task, for a database project, consists of describing the data requirements of the domain. It includes a textual report of the needs and uses of data to be stored in the database. We impose a *list of constraints* in order to restrict the size of the project and guarantee the use of different elements that can appear in conceptual designs. For instance, the resulting design must include three strong entity types, one 1:1 relationship type, one derived attribute, etc. This is a way of controlling the project complexity and the quality and size of the results.

3.4. Role playing

The next phase, called "conceptual design", includes two steps and implies playing two different roles. Each data requirements document, submitted in the previous phase, is assigned to a different team that we will call the *developer* team. The authors of a data

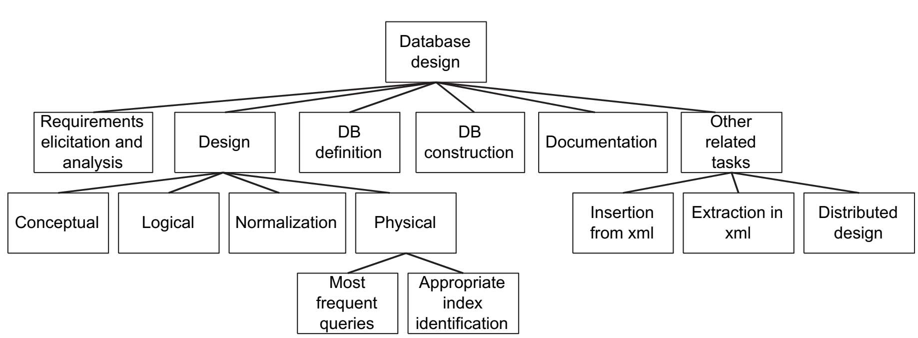

Fig. 1. General project work breakdown structure.

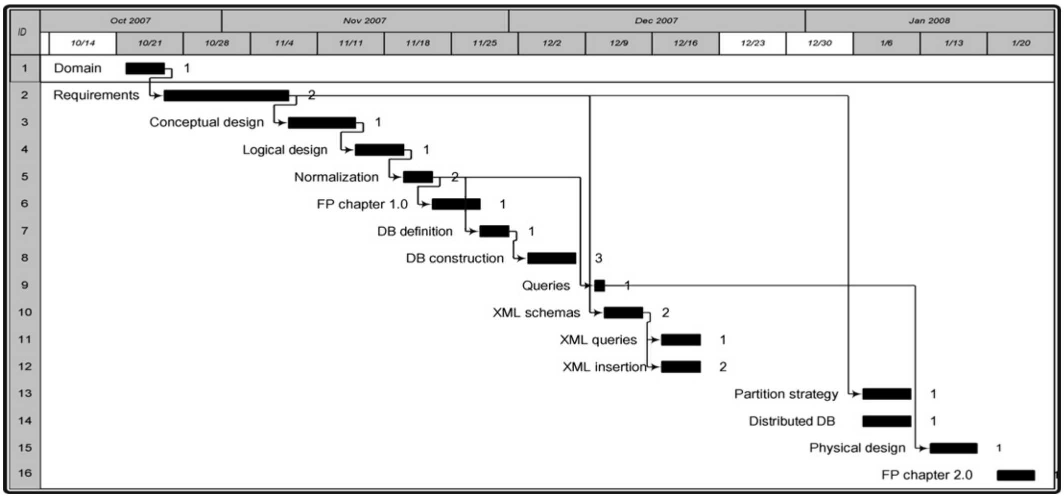

Fig. 2. General project Gantt chart.

requirements document play the role of database end-users, that we will name the *client* team. On the other hand, the developers play the role of database conceptual designers.

In this interchange we aim for each team to comply with both roles. The teams as clients have only to provide and clarify requirements but not give clues about how the design should be done. To this end, developers and clients do not know each other and we impose an anonymous communication channel between them (see the description of the forums in Section 4) for discussions about data requirements. At the end of this first step, each team as client will receive the design proposed by their developer team.

In the second step of this phase, each team plays only the role of developer for their proposed domain, but taking into account the received conceptual design. A better solution may be obtained from all these interactions. Each team develops the rest of the phases for their initially proposed domain.

3.5. Evaluation

It is difficult to create an assessment procedure which fulfils both the students' and the instructors' expectations (Van den Bergh et al., 2006). Researchers have proposed new alternative assessment modes for PBL consisting of a combination of methods (Frank & Barzilai, 2004; Tal, Dori, & Lazarowitz, 2000). In our approach, we use a balanced method based in a project-based assessment and an individual exam. In the latter, students again face some of the phases developed in the project but with a different UoD. Both tests try to be aligned to the main objective of the course (Biggs, 1999), evaluating the knowledge and skills required in the database design process. All the members of a team receive the same project-based assessment. The final grade is the arithmetic mean of this assessment, which tests the design process, and the exam, that individualizes the evaluation.

The assessment of the projects covers several aspects: their correction (non-existence of errors), adaptation (fulfillment of the rules, simplicity of the solution…), and clarity (properly written, clear graphs…). Besides, further criteria are followed as penalties in case of delay.

From the instructor's point of view, there are two significant tasks in the assessment process called Final Project (FP) chapter parts 1 and 2. After reviewing any of the project deliverables, the instructors send their comments and suggestions to the teams. Besides, in the database design process, it is not unusual to find errors in a previous phase while developing a later one. The production of these documents invites the students to check and reflect about the work already done. All the improvements and corrections should be incorporated in those FP documents where the instructors find a final version that compiles the previous tasks.

The introduced interchange of roles during the conceptual design phase is another important aspect in the assessment of a project. In this phase, we request each team to assign one grade for each point of view. They should assess as clients the received conceptual design and as developers the comprehensibility of the requirements document together with the clarity and timeliness of the answers received.

4. Computer's role: database software and CMS

Several of the project tasks need the use of two computer programs for their development, a database management system, and an XML editor. For the creation of the designed database we use SQL Server. We present, in laboratories, their main functions, accessible from the graphical tool Management Studio. The database should be populated with a large amount of data (approximately 100 000 lines per table, randomly generated). This makes it possible to deal with physical design in a subsequent task. Through the realization of these tasks, students face several real-world features such as big databases, security restrictions, concurrent access of multiple users to the same database server, backups, system breakdowns, saturation of disk space, etc.

Besides these software systems, we adopted the institutional and commercial CMS tool Blackboard/WebCT Learning System® (Blackboard/WebCT, 2009), but other similar solutions could be also useful for our purposes. This tool is used as a support of a face-to-face course. Our students knew this system because it has been used in previous subjects.

This tool has been used to resolve four main needs:

1. Learning method description: it is introduced through the *learning modules* tool. Presented here are the general rules, the assessment method, the acquired agreements, the enumeration of the different tasks (WBS), including the estimated tasks workload and deadlines (project Gantt chart) and the course schedule (including lectures and labs).
2. Team management: we create the teams with the *group management* tool. This allows us to update the group composition and automatically create a kind of email distribution list useful for communication with the teams. It also helps to assign the teams to forums. Students identify themselves when starting a session and the CMS uses this identity for all its tools. We also use the *evaluation* tool to collect the individual report of the time spent on each task.
3. Task management: we create a task for each stage of the Gantt chart using the *tasks* tool. This tool collects the deliverables, automatically registers the submission date and time, and allows for delivering several versions for the same task. Once delivered, it is possible to send the feedback to the team and also to assess the task. We use this tool as an organized repository (files submitted from 16 stages of 10 teams which could be approximately 320 documents). Both students and instructors have access to the repository that can be checked in case of conflict.
4. Communication: it is provided through the *email, announcement, calendar* and *forum* tools. E-mail allows personal communication, for example between a particular student and the instructors. With the announcements the students read instructor news at the beginning of a session. The calendar shows all the interesting events related to the project, as task deadlines. These events are easily generated as part of the task definition. The forums allow the participation of authorized students and instructors. We use three types of forums, each one with a different purpose. We create one public *inter-teams* forum for all team members. It should be used for general questions and to explain possible mistakes or problems. We also build a private *intra-teams* forum for each team. It should be used for communication purposes among team members. Expected participations include debates about the different project tasks. Finally, a private *intra-project* forum is defined for each project domain. This kind of forum is aimed at exchanging information in the role-playing experience shown in Section 3.4. The forum is anonymous and constitutes the only communication channel between both teams. We looked for a similar mechanism to moderated distribution lists. In this way, the instructor could supervise the contents of each message before publishing it in order to avoid inappropriate contributions. For instance, the team playing the role of the client should not use technical words or introduce unnecessary clues for the developers in their messages. However, this kind of forum does not exist at the moment in this commercial platform.

The *learning method description* is accessible for the entire course on the main page by the whole student group. With this information they have enough time to reflect and decide if the project development is a good option for them. Interested students should send the list of team components and a project topic proposal before certain deadline.

At the beginning of the first project task, the students have access to the first task description through the *task tool*. The rest of the tasks are gradually incorporated through this tool. Whenever a new task is available, the tool highlights this to the students with a graphical representation on the main page. Each task includes a detailed description of what should be delivered before its deadline. Tasks can also be sent for a while after the time limit. Both, students and instructors, can consult all the past tasks and easily access their deliverables during the entire project.

Each *communication tool* has its own graphic symbol, which appears emphasized on the main page of the interface whenever a new message is available. In those tasks with a compulsory communication via, this extreme is included in the task description. All the forums are available to the students from the first task.

Team management workload was minimized thanks to the CMS. We have shown its usefulness for interchanging instructions, receiving and storing work results, asking and replying to questions, providing feedback, supporting role-playing, etc. The tool requires a brief reconfiguration for each course: defining the teams, assigning task deadlines, adding new teams to the forums and tasks, and so on. However, most of the work is reused from previous courses: method description (general rules, way of assessment, etc.), task presentations and definitions, creation of forums, etc.

We have explained the use of the CMS for management of project tasks and groups. However, we have used the same tool from the academic year 2003/2004 to publish the course materials for the whole student group and also for communication purposes through email, forums, and announcements.

5. Research hypotheses

The authors have taught database design for several years. At the beginning only a traditional learning method was used. With this method, besides expositional lectures and closed laboratories, exercise sheets are provided. Students should solve, during the course, several of these exercises as assignments (the same exercise sheets for all the students). Feedback is given for these tasks in order to correct conceptual confusions among other problems. The evaluation in this method is based on the exam mentioned in Section 3.5.

However, some years ago we decided to introduce the project-based approach shown in Section 3. This new method was followed by one voluntary student subgroup whereas the rest of the students used the former method. Both subgroups can attend to the same lecture and laboratory sessions together and the students could get to know each other. Students of the project-based subgroup could optionally solve traditional group assignments and attend classes and laboratories. We did not track which of these students attempted the assignments and this extra effort could influence in their results. The coexistence of both methods allows us to make several comparisons between them. Besides, from the introduction of the method, we perceive a positive change not only in students that follow the project-based method but also in those that follow the traditional method. We also observe an improvement in the work environment and in the interest towards the subject. The origin of this influence can be similarly explained by the trials “contamination” effect reported by Keogh-Brown et al. (2007) or Torgerson (2001). This situation occurs when people who were not intended to receive an intervention inadvertently do so.

Table 1
Results in traditional approach and PBL in 2007 and 2008.

	Traditional group	PBL group	statistical test
N(%)	188 (80)	48 (20)	
Mean (SD) grade	4.21 (1.88)	5.80 (2.01)	$t = -4.639^a$
% Dropout rates	40.4	10.4	$\chi^2 = 15.275$, $df = 1^a$
% Pass exam	23.9	68.8	$\chi^2 = 34.704$, $df = 2^a$
Mean (SD) attendance	4.67 (4.73)	9.52 (4.71)	$Z = -5.719^a$

[a] $p < 0.001$.

The following hypotheses make conjectures on student results. These results include aspects such as exam dropout rates, exam passing rates, exam marks, and class attendance. Better results mean more valuable learning outcomes for the students. The four hypotheses that we wish to examine are:

- Students that follow the project-based method will obtain better results than their counterparts with a traditional method.
- The students that obtain excellent results preferred to follow the project-based method than the traditional one.
- The project-based method will influence the whole student group: the results of the entire group when some students follow the new method will be better than the results of the group when everybody follows a traditional method.
- The project-based method will influence the students that only follow a traditional method: these students will improve their results compared with groups of students where all their members follow a traditional method.

6. Research design

This is a quasi-experimental study based on a face-to-face course on database design with one group of students per academic year.

We will identify each academic year by its final year. For instance, we will refer to the academic year 2003/2004 as 2004. The sample corresponds to five consecutive courses, from year 2004–2008, with 66, 86, 113, 133, and 103 students attending the course, respectively (501 students altogether).

From year 2007 the project-based method was offered as an alternative and was optional to all the students. All the interested students were admitted. A total of 52 students followed this method (27 in 2007 and 25 in 2008) organized in 20 teams (10 per year). Almost all the teams had three components, with the exception of 3 teams of two students and 2 with only one member. In year 2008, two teams (with one and three members) gave up the work from the beginning, so these four people will not be considered as part of the group that followed the project-based approach. Although one member teams could not be considered a team per se, we are going to initially include this team in the study. Nevertheless we will track its possible effect on the results of the study.

According to Biggs (1999) large groups (40 or more students) can constrain the method being applied and overload instructors and available resources. For that reason we decided to begin the experience with approximately 30 students who would work in teams of three people. The current downward trend in group size could allow us to extend the method to the full group.

For each academic year the two instructors were the same. Each lecturer was responsible for the same parts each year. The subject contents, books and written material were also substantially the same.

To examine the previous hypotheses we use the exam marks, which constitute the common assessment procedure for both learning methods. We also consider the number of students that did not take the exam and the student class attendance. Individual declarations of time spent have been taken into account in order to measure workload and to detect free-riders.

All the exams follow a common structure. They all are composed of the same set of exercises with very similar difficulty level among them. The same instructor has been responsible for elaborating and marking the same questions each year.

As we work with a single group, "contamination" between PBL and traditional subgroups is unavoidable. Besides, we considered their random division into control and experimental subgroups unethical. For these reasons we decided to propose the PBL experience as a voluntary option. Then, the possible bias included by the voluntary factor should be carefully taken into consideration. However, and taking into account the null variance in instructors, contents, and exams, we still can compare the situation of the whole group before and

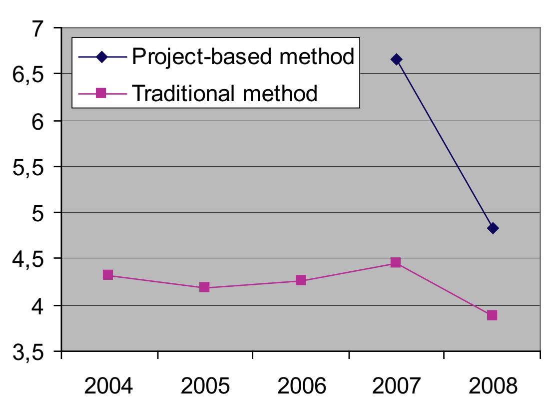

Fig. 3. Exam mean grade comparing both learning methods.

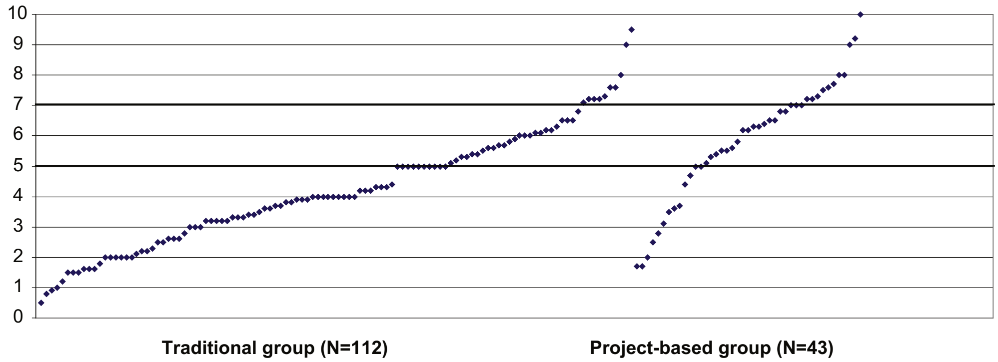

Fig. 4. Exam grade distribution during years 2007 and 2008 comparing both learning methods.

after the introduction of the PBL experience. An alternative study would consider only voluntary students and organize randomized groups with them. However, the sample size becomes smaller and the "contamination" is still present.

As has been mentioned, students either know the required computer tools from previous courses or can learn them in specific laboratories. The whole group uses the CMS for accessing materials. The project subgroup uses some additional tools in order to consult and deliver tasks, but there is no essential difference in both subgroups from a learning point of view.

For this study, we have used SPSS version 15. We have applied t-Student test for comparison of means (or Mann–Whitney test when conditions for t-Student test could not be assured), Pearson's chi-square test for evaluating the independence of two categorical variables, and rho Spearman coefficient for correlations.

7. Results and discussion

This section includes the results obtained with respect to our three main data sources: exam results, dropout rates, and class attendance. Also the workload reported by the students and gender data are analyzed. These results will be used to discuss hypotheses support.

Table 1 compiles the data obtained comparing traditional and PBL methods in courses 2007 and 2008. Also means comparison tests or Pearson's chi-square tests are included. The exam results correspond to the grade (from 0 to 10) obtained in the final exam of the course. We measured dropout rates by the absence of mark in this exam (indicating that a student had enrolled but not taken that exam). This exam was passed obtaining at least 5 points. Attendance of lectures and labs was not compulsory. However, we controlled the attendance of practical classes. Students were informed that this control was only for statistical purposes. The number of practical classes was 13 in 2007 and 14 in 2008. We obtain that attendance has a direct correlation with success in the exam ($r = 0.348$, $p < 0.05$).

The data included in the Table 1 allow us to identify a better attitude towards the course in the PBL group. We can observe that students of the project group obtained better exam grades, more took and passed the exam, and attended more classes than their counterparts of the traditional group in a significant way. These findings seem to support the first hypothesis.

The PBL experience was a bit different when we analyze each of the last two courses (see Fig. 3). The mean grade (SD) obtained in course 2007 by all the students was 5.03 (2.05) whereas in 2008 it was 4.16 (1.94) ($t = 2.672$, $p < 0.05$). In 2007 the mean grade (SD) for the traditional method group was 4.45 (1.87) and in the project-based group it was 6.65 (1.63) ($t = -5.029$, $p < 0.001$). Nevertheless, in 2008 those data were 3.89 (1.88) and 4.82 (1.98), respectively ($t = -1.839$, $p = 0.07$).

Although both courses showed better grades in PBL than in the traditional method, in course 2008 only a trend to a statistical significant difference is observed. This means that the first hypothesis could be only partially supported. A long-term study may possibly illustrate if this current tendency is a permanent factor.

Fig. 4 shows the exam grade distribution during the last two courses comparing both learning methods. We classify the grades into three groups: excellent (from 7 to 10 points), average (from 5 to 6.99), and poor (the rest). Excellent students ($n = 24$, 15.5%) were distributed between the two learning methods ($n = 10$, 42%, with mean grade (SD) 7.77 (0.83) in the traditional and $n = 14$, 58%, with 7.84 (0.93) in the project-based. There was not significant difference in mean grades). If we consider only the project-based group (or the traditional group), excellent students constituted 33% (or 9%), and poor result students constituted 25.6% (or 59.8%).

As students voluntarily joined the project-based group, the sample was not randomized. It could be supposed that hard working or brilliant students would be more interested in enrolling in this group. As shown in Fig. 4, the best results appeared in almost equal proportions in both groups, so a balanced distribution of excellent students seems to be preserved. On the other hand, the students with the lowest results tended to stay in the traditional group. These data do not allow us to clearly verify the second hypothesis.

Table 2 includes exam results and dropout rates obtained from the whole group from 2004 to 2006 (traditional learning) and from 2007 to 2008 (traditional and PBL). The class attendance has not been included because it was not measured the first three years.

Table 2
Results before and after PBL introduction.

	2004–2006 group	2007–2008 group	statistical test
N (%)	265 (53)	236 (47)	
Mean (SD) grade	4.25 (2.31)	4.65 (2.04)	$t = -1.541$
% Dropout rates	51.7	34.3	$\chi^2 = 15.334$, df = 1[a]
% Pass exam	21.5	33.1	$\chi^2 = 8.447$, df = 2[b]

[a] $p < 0.001$.
[b] $p < 0.01$.

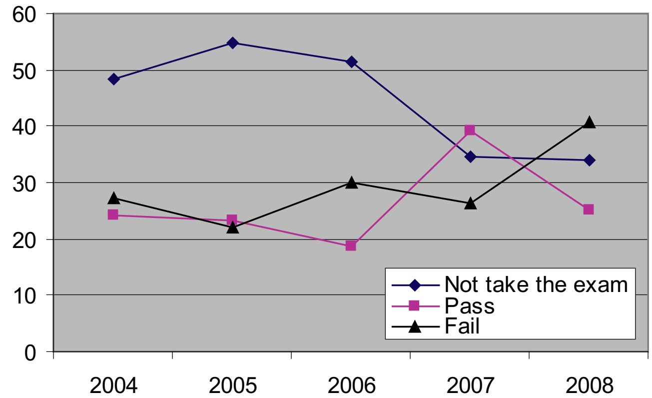

Fig. 5. Percentage of students who did not take, passed, and failed the exam.

From the introduction of the project-based method the results of the whole group have increased. Table 2 reflects better percentages of students that passed and that took the exam than in previous courses. We can also appreciate certain improvement in exam grades, although not in a significant way. All these results seem to support the third hypothesis.

If we analyze each of the last two courses we obtain that in 2007, 34.6% of the students did not take the exam and 39.1% passed it. These data were 34% and 25.2% in 2008, respectively (see Fig. 5).

Fig. 5 shows some influence of the PBL method in the illustrated aspects. However, only the dropout rate maintains during the two last courses. There is not a clear tendency in exam grades. This means that the third hypothesis would be only partially supported.

In order to analyze the influence in traditional students of classmates following PBL, the first column of Table 1 and the first column of Table 2 should be considered. While there were no differences in the grade nor in the percentage of students who passed the exam, the dropout rate decreased ($\chi^2 = 5.610$, df $= 1$, $p < 0.05$).

The project-based method influenced the traditional group, at least in the aspect of taking the exam (see (Keogh-Brown et al., 2007)). Moreover, mean grades obtained by the traditional group before and after the introduction of the project-based method are essentially the same. From the last two ideas (more people participating with similar global results) we can infer a positive overall success improvement in traditional learning students. Hence, these results seem to initially sustain the last hypothesis.

Fig. 6 shows the percentage of students who took the exam in the different courses and learning methods. It illustrates certain exam-taking improvement in the traditional method. However Fig. 3 shows that the mean grade remained flat throughout the five courses and decreases the last year although not in a significant way. This means that the fourth hypothesis could be only partially supported.

Students reported to have spent a mean (SD) of 37 (13.4) hours of individual work developing the project, almost double the estimation (22 h). It is worth mentioning that each team member affirmed to have devoted the same time as the rest of his/her collaborators. This reflects a negative aspect of PBL, a workload increase for both students and instructors (Martínez & Duffing, 2007; Van den Bergh et al., 2006). Students' declarations of time spent were generally twice that of the time scheduled. However, there are two interpretations of the estimated time. The software project viewpoint assumes that an engineer will apply knowledge previously acquired to solve problems. The PBL perspective uses the task as a way to learn (constructing internal structures by discussing and understanding concepts, etc.). The time scheduled corresponds to the first interpretation, whereas the time declared could include aspects related to the second view.

These individual time declarations have not helped to identify the free-riders presence (Connolly & Begg, 2006; Van den Bergh et al., 2006). The coincidence in the spent time in all team members is probably due to the teamwork scheme. Apparently, all team members used to meet to fulfill their tasks collectively. Hence, we have no idea of the level of contribution of each particular member from this data.

Instructor workload has increased compared to the traditional method, although we did not systematically measure this point. The CMS has been revealed to be a very useful tool that significantly alleviates the work related to document, deadline, and communication management. Besides, students need quick feedback, especially in the first steps. The team tutorship and task feedback and assessment also increase the instructor workload.

For the whole sample the percentage of male students was 73.3% and in the last two years (2007 and 2008), it was 74.6%. The percentage of male students in the project-based group was 75%. There are no differences with respect to gender in exam results, dropout rates or class attendance.

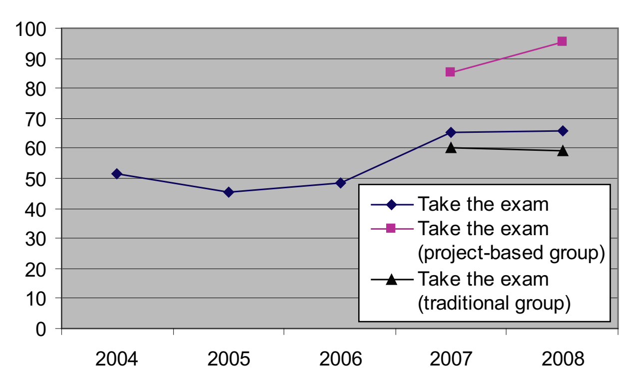

Fig. 6. Percentage of students who took the exam.

We have also identified other benefits of PBL that were not measured, including reflective thinking (improved quality of the questions, more critical contributions, noticeable interest towards the subject topics, etc.), development of work skills (developing a full database design, fulfilling a set of rules and deadlines, etc.), social skills (collaborating with the rest of the team members, unbroken teams, etc.), and communication skills (interaction within the work team, among different teams, and with the instructors).

Finally, the exclusion of the one member team from the study produces essentially the same results. For that reason, we think that it is not interesting to compare both cases.

8. Conclusions and further work

PBL methods have been suggested for database design learning as a more useful (or effective) way for students to acquire the requisite knowledge and skills. On the other hand the development of projects corresponds with the main activity of an engineering graduate on Computer Science and Information Systems. This paper presents an approach that integrates both perspectives of a project as an effective database learning method that tries to overcome several problems of PBL application. Our approach focuses on the development of projects where students, organized in teams, design and build real databases. Certain scaffolding is provided to reduce both the project complexity and the uncertainty inherent in the beginning of the tasks, and also to motivate learners. Students propose the project topics and the imposition of some constraints in the first task achieves the complexity balance control. The communication with end-users is emulated throughout role-playing between pairs of student teams.

The computer is an essential tool to put this method into practice, from the point of view both of the database design and creation (database software) and task management. A CMS is a powerful solution in order to minimize the necessary effort to organize the information shown to the students, team management, deliverable collection and communication with and among students.

There are not many works about PBL effectiveness for database design learning. We have examined the results of two academic years using the proposed project-based learning method. This quasi-experimental study shows that on the one hand, students that follow this method obtain better results than students that follow a traditional learning strategy, and on the other hand, the introduction of such a method in a student subgroup positively influences the whole group.

Further research could include the evaluation of alternatives to the exam, for students that develop projects, which allow determining both the individual contribution and free-riders. One possible improvement could consist in tracking the project-based students who optionally attempt traditional assignments and comparing their results with the rest of the project-based students. We could also examine the effect of the PBL strategy in the long-term, studying the quality and completeness of the databases designed in final grade projects by these students. Another possible study consists in the evaluation of the influence of the attendance to classes and laboratories of all the team members, some of them or none of them. Finally, the study of the team size or the working in group effect could also be interesting.

Acknowledgements

The authors wish to thank the anonymous reviewers for their useful comments. Partially supported by Universidad de La Rioja, project API09/05.

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