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A PROJECT-BASED EXPERIENCE IN DATABASE DESIGN LEARNING

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Este artículo nace de nuestra atención a la docencia, aspecto al que Mirian concedía mucho esfuerzo e ilusión. Queremos dedicarle este trabajo

Resumen. Este artículo describe un método de aprendizaje basado en proyectos que utiliza técnicas, herramientas y destrezas de gestión de proyectos. La propuesta se centra en el desarrollo de un proyecto por un equipo de estudiantes que diseña y construye una base de datos. Se les proporciona apoyo al comienzo, cuando se establece la división en tareas y su distribución temporal. Esta ayuda simplifica el proyecto y disminuye la incertidumbre inherente al comienzo de las tareas. La estructura de tareas es apta para desarrollar infinidad de temas de proyecto y emula la forma en la que se realiza la fase de diseño en proyectos de ingeniería del software. Utilizamos una herramienta de gestión de la docencia que simplifica en gran medida la recopilación y organización de los numerosos documentos generados, la descripción y distribución temporal de tareas, la identificación de equipos y las necesidades de comunicación. Esta orientación coexiste con un método de aprendizaje "tradicional" seguido por otro grupo de alumnos. Apreciamos una actitud más positiva en los estudiantes que desarrollan el proyecto. La mayoría de ellos superaron el examen final y obtuvieron mejores calificaciones que los del grupo "tradicional".

Abstract. This paper describes a project based learning method that uses project management techniques, tools and skills. The approach focuses on the development of a project by a student team that designs and builds a database. Some scaffolding is provided at the beginning, when both the division into tasks and their temporary distribution is established. This support reduces project complexity and the inherent uncertainty in beginning the tasks. The task structure adapts to a great variety of domain projects and emulates the way of working in the database design phase of software engineering projects. We use a course management system that greatly simplifies the collection and organization of the numerous documents produced, the description and scheduling of tasks, the identification of teams, as well as communication needs. This approach coexists with a "traditional" learning method used by a second group. We can observe a more positive attitude in the students that developed the project. Most of them took the final exam and obtained better grades than those of the "traditional" group.

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1. Introduction

Design learning in computer science in general, and in database courses in particular, entails a considerable difficulty [7, 3, 5]. Designing implies a creative process without exact formulas. Existent methods provide some clues about how to approach the problem and discuss the most important issues the designer should focus on. They often include some kind of notation to represent the resulting design. But usually there is no single, simple, well-known, or correct solution. This causes in the students a certain degree of "cognitive dissonance", because they usually, by previous training, look for a definitive solution to the problem [7, 5]. Certain knowledge and intuition is needed about how to deal with the design, together with some experience with the strategies better adapted to each circumstance. In [7] both knowledge and skills are identified as key points to undertake database design. Knowledge includes general database concepts, database analysis, design, implementation, business processes, and project management concepts. On the other side, the skills should take account of problem-solving, critical thinking, creativity, verbal and written communication, team working, and time management.

In this context, active student-centered methods could be more helpful than traditional ones in order to acquire the necessary knowledge and skills. The former methods are based on learning by doing, whereas the latter on memorization and repetition. One promising method in this field is based on the development of projects [17, 15] which, in some sense, directly corresponds with the main activity of an engineering graduate on Computer Science and Information Systems [7, 10].

A "standard" definition of project is given by the Project Management Institute in the PMBOK® Guide [14]. "A *project* is a temporary endeavor undertaken to create a unique product, service, or result". The main characteristics of a project include: it has a beginning and an end, it implies progressive elaboration (*i.e.*, it is developed in steps and continued in increments), and the uniqueness of the product, service, or result obtained. *Project management* is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements [14].

The concept of project appears in different learning contexts. On the one hand, following constructivism guidelines, a learning method based on developing projects has been built: Project-Based Learning (PBL) [17, 15]. This method is defined as an authentic instructional model or strategy in which students plan, implement, and evaluate projects that have real world application beyond the classroom. Projects should be student-centered and student-directed, with a meaningful content, and they produce a tangible real world product. These projects should have connections among academic, life, and work skills. In doing so, opportunities can arise for reflective thinking and student self-assessment. Students build their own knowledge by active learning and by interacting with the environment, while the instructor plays the role of guide and consultant. Students ask questions (to specialists, peers, etc.), make predictions, design investigations, collect and analyze data, make products, and share ideas. Besides, PBL would be better complemented with cooperative learning [15]. There are many benefits of PBL covered in the literature [17, 15, 11]. For instance, the possibility of connecting learning with reality, of increasing motivation, the opportunity to promote problem-solving, develop social and communication skills, and enable students to make and see connections among disciplines.

On the other hand, one of the skills needed by a software engineer is the development and management of software projects. Indeed, in order to obtain a University Degree in Engineering, it is necessary to develop and defend a project, at least in Spain. This work must reflect the knowledge, skills and attitudes obtained through the study of the different subjects of the grade. These software projects typically use specific technologies, techniques, tools, etc. of software engineering [7, 10].

In order to combine both perspectives of a project in an educational environment, it should be possible to use some techniques of PBL with the aim of undertaking a software project. It also should be possible to learn the matters included in a particular software subject through the development of a project, or by elaborating just the project tasks studied in the subject. The result of this integration should benefit from both PBL techniques and professional practices. However, some restrictions should be imposed in order to facilitate this combination. On the one hand, the project should be adapted to the project-based instruction, which assumes, for instance, student-centered problems or self-assessment. This will not be present in all software projects. On the other hand, the projects to be developed following the PBL method should be restricted and constrained, in order to be as close as possible to a real software project (or to some parts of it). For example, since our particular subject deals with database design, we may focus on the database design phase of a software project. This stage appears in many software projects where database design is usually divided into some typical sub-phases or tasks [7, 9]. This set of tasks forms a skeleton followed in real software projects, and for that reason could be part of our project-based instruction. This structure is also present in the list of topics of our subject and therefore it could serve as scaffolding for the PBL.

In this work we propose a method for database design learning by designing. Our approach focuses on the development of a project by a student team following the ideas of PBL, where a real database is designed and built using project management techniques, tools, and skills. This is an active method that gets students involved in their learning process. Some scaffolding is provided from the beginning to the teams trying to reduce project complexity, decrease the inherent uncertainty to the launch of the project, and also motivate learners. This support includes a division into tasks of the project and their temporary distribution. This task structure constitutes a skeleton that adapts to a great variety of student proposed domain projects and emulates the real way of working in the database design phase of a software project.

The use of a Course Management System (CMS) plays a key role in our method. This tool is used to organize the required student effort and it greatly alleviates the instructor's work in the process. For instance, it is used to identify which students belong to each project development team and receive and classify the numerous project documents. Also, it includes essential communication tools that support different needs such as role-playing, asking and responding to questions, feedback provision, etc. Without this kind of tool, we can still use other Internet tools including e-mail and web sites. However, the workload due to document identification, reception, and management (in our case above 300 files per course) can be significant. Besides, there exist other kinds of messages that can contribute to flooding our inbox such as the questions or problems that arise for students during the process.

This project-based approach was followed by one student subgroup in our subject. The rest of the students used a traditional learning method. The coexistence of both methods allows us to make a comparison between them, listing the advantages and disadvantages of each method.

The rest of the paper is organized as follows: in the next section, we describe our project-based approach. In Section 3, we show the key role played by the CMS. In Section 4, we include a comparison between the results obtained by the two student groups, one following our new method and a second using traditional learning. In Section 5, we discuss the advantages and problems identified in our method. The paper ends with a conclusions and future work section.

2. Project-based approach

We have been following, since 2006-2007, the project-based approach detailed in this section for a student subgroup. That entire course had 133 students, in our opinion a large-class [1] to introduce our project-based approach. We suspected that this class size could have overload the instructors and the available resources. So, at first, we limited the experience to 30 voluntary students, who should work in teams of three people.

2.1. Context. Our subject, entitled Database Design, is part of the first semester of the second year in the Computer-Engineering Degree in the University of La Rioja (Spain).

The subject 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 assignments.

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. This course is complemented in the degree curriculum with two other courses on databases. The first one (2nd semester, 1st year) introduces databases, the relational model, and the SQL language. The second (2nd semester, 2nd year) is devoted to database programming. There is an optional subject (3rd year) that deals with database administration. Each one consists of 6 credits.

At this moment, we are adapting to the European Higher Education Area (EHEA) [6]. This will restructure all the student grades in Spain. This context encourages the adoption of active didactic methods and the inclusion of learner-centered educational systems. Students should also acquire some non-technical competences such as teamwork, oral and written communication, time management, and ability to find information and learn independently, among others. The project-based method described in this section follows these guidelines.

2.2. Contents. The concepts covered in the course are of technical and practical nature. Nearly all of these concepts require understanding a problem and developing a good solution. The absence of a unique solution tends to obscure the concepts to the student. For the design tasks, students usually feel very comfortable in sessions where the lecturer explains how to obtain a solution for a particular problem. They can even participate actively in discussions about possible variants of the resulting design. However, students generally do not feel so secure when they have to deal with similar problems by themselves. Our method encourages the students to experiment by themselves and check the advantages and drawbacks of their solutions.

We have organized the concepts included in the subject through the set of tasks shown in Fig. 1 using a Work Breakdown Structure (WBS). This tool is normally used in project management and system engineering to define and organize the total scope of a project [14]. 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. This graph allows summing the subordinate costs of the tasks into their parent tasks.

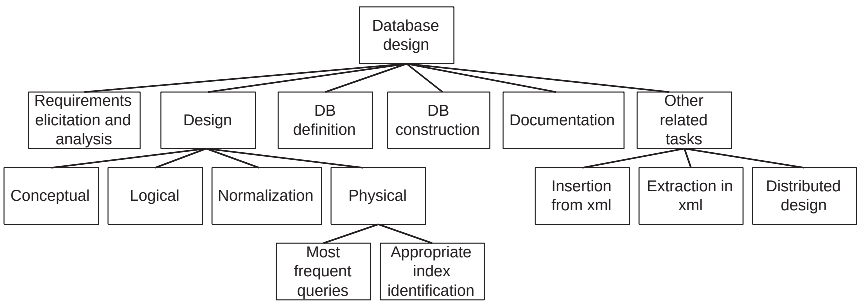

FIGURE 1. General project work breakdown structure.

In the case of software projects a usual phase is devoted to the database design. This stage can be understood as a complete project by itself. It contains the common tasks of a software project: analysis, design, implementation, documentation, and evaluation of the process [14, 16, 9]. This is reflected in the subtasks present in the diagram of Fig. 1, including: data requirements elicitation, conceptual, logical, and physical database designs, normalization, database definition and construction. Further tasks are included such as the use of XML and distributed database design. Following this idea of considering database design as a project by itself, a

Gantt chart could reflect an estimated calendar for the phases and a dependence relationship among activities. For instance, the project schedule for the course 2007-08 is reflected in the Gantt chart of Fig. 2.

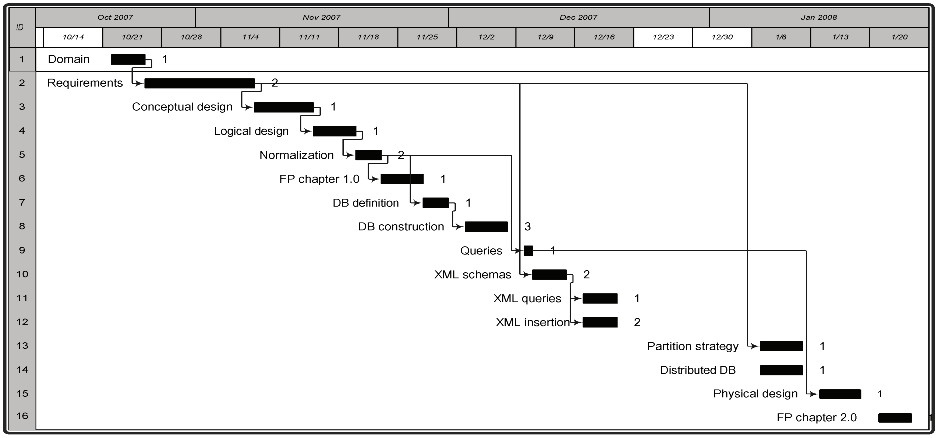

FIGURE 2. General project Gantt chart.

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.

The diagrams in Figures 1 and 2 constitute the skeleton of a project and provide some scaffolding that will be given to the students in our approach. More help will be offered for each task including 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 are provided (including the communication channel, if it is anonym, 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.

2.3. Steps of the project development. The main features of our project-based learning method are presented to the students in the first lecture. This presentation includes the project skeleton, its connection with software project development, the estimated workload required, and the general rules of the work.

As it has been said, this method is open to a group of up to 30 people. The students voluntarily join the project-based experience. They are responsible for building teams limited to three members.

Each team must propose one project topic able to exploit a database. This topic is also known as the universe of discourse (UoD). This phase is called "domain" in Fig. 2, and implies reaching the first agreement among the team members. Usually the chosen issues correspond to real problems known by the students and/or topics of their interest. 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 hands to avoid repetition of a same or similar UoD or to adjust a proposal.

The second phase, called “requirements”, is the real beginning of the project. This task 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 should include three strong entity types, one 1:1 relationship type, one derived attribute, etc.

The phase called “conceptual design” includes two steps and implies playing of 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 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 try that each team complies with their role. The client teams 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. This communication channel is provided via an anonymous forum in the course management system for each domain (see the description of the forums in Section 3). In each forum both teams can discuss the data requirements description and its possible interpretation. At the end of this first step, each client team will receive the design proposed by their developer team.

In the second step of the “conceptual design” phase, each team plays only the role of developer for their proposed domain, but taking into account the received conceptual design. The deliverable of this step is their conceptual design solution for this domain. The team communicates with the former developers of their domain using the same channel. Often each team compares and discusses (with the former developer team) the differences between the two designs on their domain, *i.e.*, the one proposed by them and the design developed by the other team. A better solution may be obtained from this interaction. Each team develops the rest of the phases for their domain. This means that no more interactions among teams are planned for the rest of the project.

We are not going to detail all the phases except two of them called, in Fig. 2, Final Project (FP) chapter 1.0 and 2.0. These are two essential deliverables that collect and summarize the documentation obtained in the previous tasks. The production of these documents invites the students to check and reflect about the work already done. In the database design process, it is not unusual to find errors in a previous phase while developing a later one. These errors should be corrected and also the subsequent tasks should be revised.

The FP chapter 1.0 constitutes a boundary between "pencil and paper" and "hands-on computer" tasks. Computer tasks include the creation (definition), in a database server, and the population (construction) of the designed database with a large amount of data (approximately 100 000 lines per table, randomly generated). The database will be useful for the rest of the tasks. During this process, students face several real-world features such as big databases, security restrictions, concurrent access of multiple users, backups, system breakdowns, saturation of disk space, etc.

In the whole process, we try to apply an enterprising way of working: deadlines, limited resources, penalization for delays, role-playing, documentation production and checking, etc.

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

2.4. Project assessment. The assessment of the projects covers several aspects. We consider their correction (non-existence of errors), adaptation (fulfillment of the rules, simplicity of the solution...), and clarity (properly written, clear graphs...). Besides, further assessment criteria are followed. For instance, as we imposed a deadline to each deliverable, a penalty is applied in case of delay. In the last course, we took off one point (from 10) in the assessment of the task for each week of delay.

From the instructor's point of view, there are two significant tasks in the assessment process called FP chapter 1 and 2. The teams get feedback from the instructors during each phase, through the use of forums, e-mail messages or tutorial support sessions. After reviewing the deliverables, the lecturers send their comments and suggestions to the teams. If a deliverable is of poor quality (errors, misunderstandings, etc.), the team is encouraged to revise it and submit a new version. All the improvements should be included in FP chapters where the instructors find a final version that includes the previous tasks.

The 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 two different grades. For the first one, the team as client has to consider the design received from the developer team. For the second one, the team playing the role of developer takes into account the comprehensibility of the requirements document delivered by the client counterpart. For this second assessment, the team also must consider the clarity and timeliness of the answers received.

All the members of a team receive the same grade for the project. In order to detect problems within a team (as for instance, the presence of free riders [13, 18, 7]) we ask each student to report individually the time spent on each task.

We complete the course assessment with an exam where students face again some of the phases developed in the project but with a different UoD. The final grade of the subject is the arithmetic mean of the grades obtained for the project and the exam.

3. Role of the course management system

In this section, we are going to explain the fundamental contribution of a CMS in our approach and how we could monitor and manage this task without it. We use the institutional tool Blackboard/WebCT Learning System [2], but other similar solutions could be also useful for our purposes.

We distinguish four main aspects of interest:

1. Method description: we present the learning method through the *learning modules* tool. We include the general rules, the way of assessment, the acquired agreements, and the different phases (WBS). Former documents can be reused from one course to another. We also include the phase estimated workload and deadlines (project Gantt chart) and the course schedule (including lectures and labs). The last two documents have to be built every year because they depend on the academic calendar. Without this tool, we should publish and distribute all this information through other methods such as making and delivering copies, using a physical bulletin board, by means of the institutional web pages, e-mail, etc. Some problems identified for these alternatives are: insufficient or excessive copies, absence of interested students, unknown web pages, institutional e-mail addresses are not used, etc.
2. Team management: we create the teams with the *group management* tool. This allows us to update the group composition and create automatically a kind of e-mail distribution list useful for the communication with the teams. They also help 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. Without these tools we would have to create, for instance, distribution lists in our e-mail account. We would also have to track the e-mail addresses of the involved students and identify their messages. The individual reports of time spent could be gathered from a set of e-mail messages or from a form filled during the exam.
3. Task management: we create a task for each stage of the Gantt chart using the *tasks* tool. Task instructions can be reused from one year to another. However, it is mandatory to update the deadlines and groups every year. This tool collects the deliverables, registers automatically the submission date and time, and allows for delivering several versions for the same task (if it is properly configured). Once delivered, it is possible to send the feedback to the team and also to assess the task. The tool is available 24 hours a day, registers the traces of deliverables and their different versions, and can be used as an organized repository. Both students and instructors have

access to these traces that can be checked in case of conflict. In absence of a similar tool, we should manage all the deliverables either with hard-copy documents or through ordinary e-mail. In our case, this work would imply managing (reception, date and time registration, etc.) and storing (identifying, organizing, etc.) several versions of documents submitted from 16 stages of 10 teams (approximately 320 documents). Apart from this, the feedback should be managed by e-mail or in special meetings between the instructors and the teams. In the case of storing physical documents, the e-mail should contextualize the feedback message and look for the receiver addresses.

4. Communication: all the communications among the different components of the process is organized through the CMS *forum, e-mail, announcement* and *calendar* tools. The forums allow the participation of the team members adopting different roles. Their messages are accessible to authorized students and to the lecturer during the project. We define different types of forums as it is explained below. The e-mail allows more 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. Without these tools, we would have to use our e-mail address having to track the different student addresses, and we would also have to create and manage distribution lists or other forum tools with similar problems with the student identities. The calendar could be manually made and published in a web page or in the bulletin board.

We define three types of forums, each one with a different use:

- inter-groups: we create one public forum for all team members. It should be used for general questions and answers about the project and to explain some possible mistakes or problems to all the students.
- intra-groups: we also build a private forum for each team. It should be used for communication purposes among team members. Expected participations include debates about the different project tasks. The lecturers can also participate in the discussions to clarify possible misunderstandings.
- intra-project: we create a private forum for each project domain. This kind of forum is aimed at interchanging information between two teams, every one with a different role for the domain (the client role and the developer role). 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 lecturer 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 in our platform.

The CMS has revealed as a very useful tool that significantly alleviates the hard work related with document, deadlines, and communication management. We have shown its interest for interchanging instructions, receiving and storing work results, asking and replying questions, providing feedback, supporting role-playing, etc. Even though the tool has to be reconfigured at the beginning of each course, we are reusing most of the work from previous courses.

4. Results

For this study, we have used SPSS version 15 in all statistical tests. We have used Pearson coefficient for correlations and t-Student test for mean comparisons. When conditions for these tests could not be assured, non-parametric tests have been used instead: rho Spearman coefficient for correlations and Mann-Whitney test for comparisons of means. In this section, we will identify each course by its final year. For instance, the course 2003/2004 will be called course 2004.

4.1. Sample description. The sample corresponds to five consecutive courses, from year 2004 to 2008, with 66, 86, 113, 133, and 103 students attending the course, respectively (altogether 501 students). These numbers include both first registration students and students repeating the year, with 66 (100%), 61 (70.9%), 69 (56.6%), 64 (51.9%), and 41 (39.8%) first registration students from 2004 to 2008, respectively.

From year 2004 to 2006 we adopted a traditional learning method. However, in 2007 and 2008 we implemented the project-based method explained in Section 2. It was offered as an alternative and optional method 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.

4.2. Assessment. In the following subsections we present the results of the two assessment methods included in our approach: the project-based one and the exam. Besides, a comparison between the exam grades obtained by the students following the two different learning methods is included.

4.2.1. Project-based assessment results. All the teams that followed the project-based method finished the tasks on time. In general, the quality of the projects was high from both the lecturers' and students' points of view. The mean (SD) grade obtained by the teams in the project was 8.44 over 10 (1.52) with a maximum of 10 and minimum of 6.

4.2.2. Exam results. The exam was worth 50% of the final grade for the project-based group and it was the only grade for the rest.

As mentioned before, from course 2004 to 2006 we used only a traditional method. The mean (SD) grade obtained during this period was 4.25 (2.31) points of 10 possible, whereas from 2007 to 2008 it was 4.65 (2.04) for all the students. The traditional method group obtained 4.21 (1.88) in the last two courses, while the project based group got 5.80 (2.01). In this case, we observe significant differences ($t=-4.639$, $p<0.001$). Nevertheless, there are no significant differences between the grades obtained by the traditional group in the last two years and the grades obtained from the course 2004 to 2006.

The experience was a bit different when we compare 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 ($t=-1.839$, $p=0.07$).

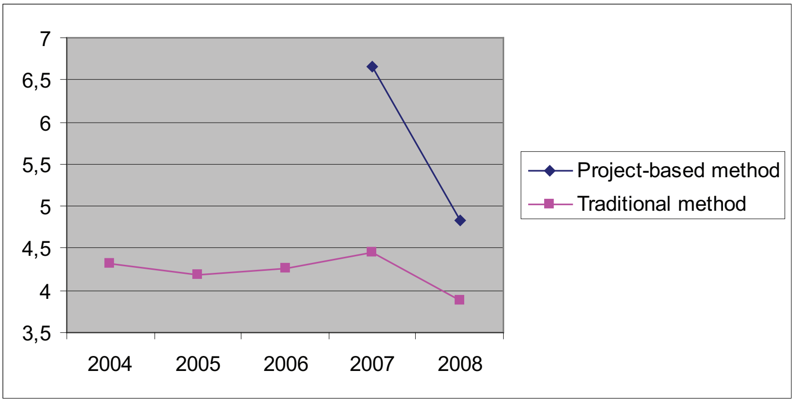

Figure 3. Exam mean grade comparing both learning methods.

Fig. 4 presents 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% in the traditional and $n=14$, 58% in the project-based). If we consider only the project-based group, poor result students constituted 25.6% whereas considering only the traditional group poor result students were 59.8%.

From course 2004 to 2006, the percentage of students that did not take the exam was 51.7%. The percentage of those who passed the exam was 21.5% (i.e., obtaining at least 5 points over 10). However, in 2007 and 2008 these data were 34.3% and 33.1%, respectively (see Fig. 5).

In the last two years, 10.4% of students following the project-based method did not take the exam and 68.8% passed it, whereas in the traditional group, these data were 40.4% and 23.9%, respectively. Then, in the last two years, 89.6% of the project-based group took the exam whereas for the traditional group this data was 59.6%. Besides, traditional group students in these two years took the exam

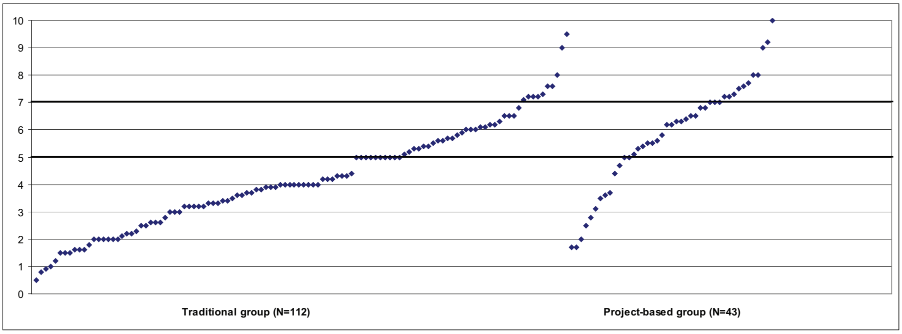

FIGURE 4. Exam grade distribution during years 2007 and 2008 comparing both learning methods.

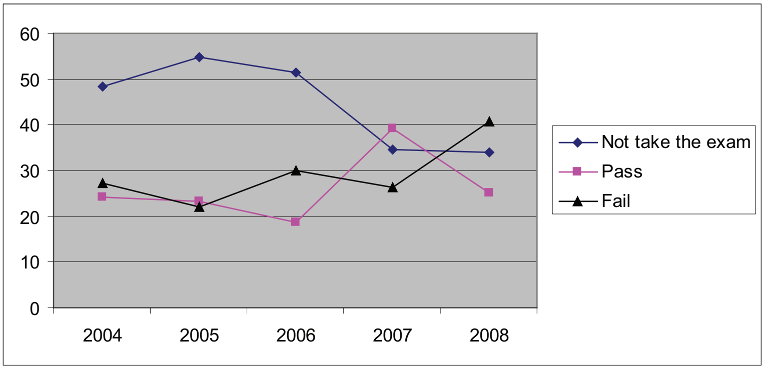

FIGURE 5. Percentage of students who took, passed, and failed the exam.

in a higher percentage than the students of the same group (the only one) in the first three years (48.3%) (see Fig. 6).

4.3. Student workload. The total project scheduled workload was 22 hours. Students reported to have spent a mean (SD) of 37 (13.4) hours of individual work developing the project, almost double the estimation. The maximum amount of time reported was 47 hours and the minimum 11 hours. It is worth mentioning that each team member affirmed to have devoted the same time as the rest of his/her collaborators.

In the last course, the total number of messages in the forums was 149. Intra-project forums had a mean (SD) of 6.75 (2.43) messages with a maximum of 10 and a minimum of 2. Intra-group forums were not used in general.

4.4. Class attendance. Attendance to lectures and labs is not compulsory. However, we controlled the attendance to practical classes including the labs from

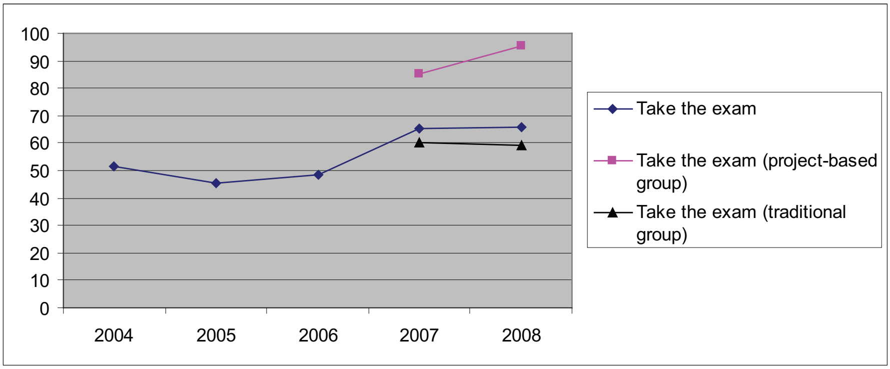

FIGURE 6. Percentage of students who took the exam.

course 2007 to 2008. Students were informed that this control was only for statistical purposes. Nevertheless we observed an increase in attendance since we began this habit.

The number of practical classes was 13 in 2007 and 14 in 2008. Each student (considering both groups) attended a mean (SD) of 5.66 (5.10) practical classes with 71 students (30.1%) that never attended. Attendance has a direct correlation with success in the exam ($r=0.348$, $p<0.05$). Considering only the project-based group, mean (SD) attendance was 9.52 (4.71) for practical classes, with 6 (12.5%) non-attending students. For the traditional group, these data were 4.67 (4.73) with 65 (34.6%) non-attending students. There exist significant differences in class attendance between both groups ($Z=-5.719$, $p<0.001$). This suggests that students in project-based teams were inclined to attend more the practical classes.

4.5. Gender. 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%.

Male students obtained a mean (SD) grade of 4.45 (2.11) considering all the years, whereas female students achieved 4.52 (2.34). Taking into account only courses 2007 and 2008, male students obtained 4.63 (1.98) and female students 4.69 (2.22). If we consider only the project-based group, the results were 5.67 (1.97) for male vs. 6.21 (2.15) for female students. Finally, the mean (SD) number of practical sessions attended by male students was 5.93 (5.08), with 30.1% non-attending; and in the case of female students it was 4.87 (5.13), with 30% non-attending. There are no significant differences in any case.

5. DISCUSSION

We wanted our students to learn design by designing as suggested by [7]. As explained in Section 2, student teams develop the database design phase of a software project with the support of certain scaffolding using a project-based approach. The PBL method has often been used in engineering courses [11, 7, 4, 12, 10]. In this context, students explore the essence of engineering working through project developments. Social and environmental aspects are also taken into account in addition to the scientific-engineering ones through experimental activities.

One issue in PBL has to do with the level of assistance to be provided. On the one hand, it is essential for effective learning that students control the process of development by understanding and using consistently their own way of solving problems. On the other hand, the lecturers should provide the appropriate help to motivate learners and reduce task complexity [16]. The kind of project considered by us is suitable to be arranged following a general task division with a shared schedule. The planning of a long work poses several problems to our inexperienced students. The creation of a temporal sequence of detailed tasks avoids this trouble and minimizes the amount of uncertainty inherent to a project [18, 12]. This organization sets the project skeleton, but students still control the execution of each particular task. This means that they are not responsible for the global planning and management of the project. They are task developers. They stay in a project development environment, and are responsible for task realization, time measuring, and deadline meeting. It is worth pointing out that this overall division is a usual one in database design [9]. 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. Although this kind of communication certainly existed (for instance at the end of lecture sessions, at computer rooms, at the cafeteria, etc.), the only registered interaction occurs in step three, where communications were published in the forums.

Other related works also provide some kind of scaffolding to improve learning quality. In [16], two different learning methods are followed to develop a single project. In the first method, students get only simple tips and must use intuition and research. In the second method, students receive a set of templates and use concrete diagrams and techniques. Team experience satisfaction and intra-team communication are better in students that follow the second method.

The objective data included in the previous section allow us to identify some of the benefits of PBL methods described in the literature [15, 17, 7]. Among them, let us emphasize an improvement of student attitude towards the course. More students took the exam than in previous courses and, comparing the results of both groups, we can observe that students of the project group obtained better exam grades than their counterparts of the traditional group. Besides, it seems that the project-based method clearly influenced the traditional group, at least in the aspect of taking the exam. Moreover, mean grades obtained by the traditional group before and after using our project-based method are not significantly different. From the last two ideas (more people participating with similar global results) we can infer a positive overall improvement in the success of the subject.

Our aim was not to increase class attendance for the project-based group, but indeed their attendance level was significantly higher. Attendance is not compulsory for any student. Lectures and laboratories are offered, among other materials (selected book chapters, notes, slides, e-resources, and so on), as a way to learn the subject. From our point of view, it is easier to tackle a new topic by attending courses or seminars where an expert guides students through the relevant aspects and clarifies their understanding than to use written materials like books, where students must identify which are the main concepts and search for answers to their own doubts. Besides, empirical studies demonstrate a clear relationship between class attendance and academic success [8, 19]. Even for the best students, their presence in the discussion, interaction, and involvement, which should characterize a good class session, enhance their results in the exam. We also obtain a positive correlation between attendance and success in 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). Although we have not elaborated an objective method to evaluate these aspects, we hope that they will be visible in future database designs. One of these database designs will be probably integrated in the student final grade projects, which can be a data source for future studies on these features. Indeed, in the last year, almost all of them included tasks, such as normalization or physical design, which have been repeatedly ignored in previous courses.

As students voluntarily joined the project-based group, the sample was not completely randomized. This could denote a weakness in our statistical results because it could be supposed that only hard working or brilliant students would be interested in enrolling the group. In order to illustrate this issue, we will use again our main comparison source: exam grades. 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 least results tended to stay in the traditional group.

One of the negative aspects of PBL has to do with the workload increase for both students and instructors [15, 13, 18]. As we did not ask for time spent to students following the traditional method we do not have objective data to measure this aspect.

Spent time declarations of the project group were generally twice that of the time scheduled by the instructors. It is worth mentioning that there are two different interpretations of the estimated time: from the point of view of project management and from that of PBL. The software project viewpoint assumes that an engineer will apply knowledge previously acquired to solve problems. The PBL perspective, on the other hand, uses the task as a way to learn; therefore, students will construct internal structures, with their own effort, discussing the solutions among them and understanding the developed tasks. The time scheduled corresponds to the number of hours to be reported for similar tasks in a real software project, whereas the time spent includes aspects related to the PBL point of view. We exclude from the scheduling the time devoted to learning and discussing the solution because we were trying to simulate the way of working in real software projects, where the point is just to reach a solution.

Instructor workload has increased compared to the traditional method, although we did not measure systematically this point. Team management workload was minimized thanks to the CMS. 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. Besides, students need quick feedback, especially in the first steps. The team tutorship and task feedback and assessment also increase the instructor workload.

We had a group of more than 100 students. Our first attempt was to apply our method to a subgroup of approximately 30 students. [1] distinguishes between two situations: groups of about 40 students and larger groups. The number of students should not be a reason to look for a rich teaching-learning context, but it is also clear that a large number can constrain the methods to be applied. We can find other works that point out the same fact in engineering courses [10]. We thought that, if our PBL approach was applied to the whole group, that would overload the instructors and available resources. For this reason, we decided to begin with more or less 30 students. At this moment, there is a general downward trend in group size that could allow us to extend the method to the full group. The change process introduced by the European Higher Education Area [6] should facilitate this extension.

It is difficult to create an assessment procedure which fulfills both the students and the instructors expectations [18]. In our approach, we use a balanced method based in a project-based assessment and an exam. Both tests try to be aligned to the main objective of the course [1], evaluating the knowledge and skills required in the database design process. On the one hand, the project-based assessment tries to test the complete design process. This process is solved by working in groups. On the other hand, the exam individualizes the assessment. Students face again some of the phases developed in the project but with a different UoD.

Students' spent time reports could also be useful to determinate the individual contribution to the teamwork and the presence of free riders [13, 18, 7]. However, in all the cases, every participant reported the same amount of time as the rest of his/her team colleagues. This coincidence is probably due to the lack of anonymity in the data collection process. Another possible interpretation is based on the teamwork scheme. Apparently, all team members used to meet to fulfill their tasks collectively. So, the report is based on the time spent on team meetings, but we have no idea of the level of contribution of each particular member. To overcome this problem, we should use a more detailed survey and introduce anonymity in time declarations. Another unsolved difficulty has to do with the student enthusiasm, which is sometimes poorer than the instructors' expectations [13, 18]. This usually results in projects of lower quality.

Other works related with PBL assign projects to student teams following different approaches. One of these approaches uses the same project for all the teams [10, 11]. The advantage of this approach it that it is easier to compare the results and assign a grade. The disadvantage is that it is easy for a team to copy a task from another team and it is difficult to interpret collaboration among teams. A second approach implies assigning a different project to each team [7, 12, 4], where the proposal can be done either by the instructors or by the students. As a disadvantage, the assessment difficulty increases due to the diverse project complexity level and the different quality and size of the results. Among the advantages, collaboration among teams is possible and domain variety makes the assessment task less boring for the instructors, in spite of the additional work necessary to understand the different problems. Besides, the proposals can be closer to the student interests. Our approach tries to follow an intermediate way. On the one hand, we use a different domain for each project. On the other hand, all the projects must follow a common set of requirements that equalizes the difficulty, necessary quality and size of the projects. In addition, the common skeleton also facilitates the task comparison, monitoring, and assessment.

Finally, we can observe that 2008 results were considerably worse than 2007 results as shown in Fig. 3. If we only consider the traditional method, course 2008 also obtained the worst results for all the courses. Subjective opinions of colleagues from others courses agree on a general lower level for that group. Some hypotheses that try to explain this situation are: the whole group composition, where the ratio of first registration students was the lowest; the noticeable decrease in the use of tutorial sessions, forum, and e-mail to solve problems, and finally, the lack of interest shown for several students including some who initially joined the project-based group.

6. Conclusions

We have described a method for database design learning by designing. We think that designing a database is a better way to understand this kind of task than only by attending lectures on how to design a database and studying examples of it.

Based on PBL and using project management techniques, tools, and skills, our approach focuses on the development of projects where a real database is designed and built. These projects are accomplished by the students organized in teams. Some scaffolding is provided from the beginning to the teams trying to reduce project complexity, decrease the uncertainty inherent in the beginning the tasks, and also motivate learners. This support includes a separation of the tasks used in the project and their temporary distribution. This task structure constitutes a skeleton that adapts to a great variety of domain projects proposed by the students. We also introduce some constraints to the initial problem description as a mean to balance the quality and size of the work to be done.

This approach coexists with a traditional learning method. This fact allows us to compare both methods through an exam. The results obtained show that in the project-based group more students took the exam and got better grades. A positive influence in the whole group was also identified: increase in exam attendance and maintaining the level of success. Other non-measured beneficial aspects derived from the project-based approach are: reflective thinking and development of social, communication, and work skills. Some habitual disadvantages of PBL were perceived, such as a workload increase of the students and instructors.

Teams and projects management is minimized thanks to the use of a CMS. The project-based experience is presented through this platform, including the structure of the different phases, the estimated workload, and the phase deadlines. Besides, students use this tool to submit all the deliverables and declare the time spent in the different tasks. The tool serves as a document repository and time log, as well as a communication support for the various needs of the participants.

We have proposed the method in the context of a particular database design course. Obviously, we do not intend to generalize the idea to any kind of subject. Our course includes some methodological and well-defined steps to design and build a database for a given domain. So, the result is a product. Other courses aimed at including one or several products or services could also benefit from our ideas developing several smaller projects. In order to build each one of these products or services some steps and deliverables should be identified. If these steps form a known method, it is possible to create similar scaffolding structures. In our case, a WBS and a Gantt chart are provided to the teams. This kind of schedule guides the development and facilitates the early stages for inexperienced students. The use of well-established steps and the possibility of applying them to diverse domains allow us to leave in student hands the domain selection. In other more restrictive contexts, instructors could perform this choice. Another important aspect of our experience is the different roles played by the students. If this aspect is not present in other courses, our method can still be adopted, because it is not an essential part of our method.

We believe that our method could be applied to the entire student group in the near future. This would be possible considering the expected decrease in the number of students attending due to, among other things, the birthrate background. We should also take into account the introduction of a new methodological context connected with the European Higher Education Area, which will reconfigure all the studies in Spain. Our method follows directives of this regulation.

Some further research can be pointed out. First, we could evaluate suitable alternatives to the exam which allow both to determine the individual contribution and identify free riders. Second, it could be interesting to make a comparison of the quality and completeness of the databases designed in final grade projects in the next years. Finally, it could be possible to adopt some methods that allow us to measure further aspects such as skills derived from PBL.

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