Assessing the Participatory Design of a Project-based Course on Computer Network Applications

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Abstract: New teaching methodologies which foster student involvement, such as project-based learning, are nowadays part of the study curriculum of many engineering schools. Project-based learning courses, however, often build upon other previously taught technical courses, where the technical content for the project to be developed is studied. That type of course design focuses on building the transversal capabilities of students, and the technical challenges of the project are the mean to acquire these non-technical skills. In this paper, we present and assess a project-based course on computer network applications of a computer science school, which has been designed to improve within the same course both the transversal and technical skills of the students. The proposition of interest is that the course not only aims to train the students' transversal skills by a group work project, but also to practise new technical topics and technologies. We argue that the key element of the proposed course design is that each student project group defines with the instructor the project they would like to develop in the course. We present first the design of the course and then an assessment with questionnaires, which were conducted over two semesters with the students enrolled in the course. The obtained results indicate that the students achieved both technical and transversal skills, while the instructors need to be flexible to adapt to diverse technical topics of the proposed projects.

1 INTRODUCTION

In the recent years, new teaching methodologies which foster student participation have become part of engineering study curricula. Project-based learning is one of these methodologies (Kokotsaki et al., 2016). Its aims that students acquire more transversal or non-technical competences like working on a complex practical problem together in a group, the capacity to manage projects, the oral and written presentation of the work, the capacity to learn independently and being able to solve new problems.

One possible design of a project-based course consists in the instructor proposing one single project to all the student groups. Such a project is then defined in a way that leverages the technical knowledge acquired by the students in previous courses, e.g. it integrates or applies this knowledge in a group project. In this type of course design, principally no new technical knowledge is required to develop the project. The focus is on reaching a deeper usage of the previously acquired technical skills, e.g. by working at the level of application, to become more experienced in the technologies through the project development.

This design of a project-based course which uses a single project proposed by the instructor to all student groups has some valuable features, but also limitations: Among the desired features is that all the students, after finishing the project, have faced the same challenges, and by this, have undergone the same learning process, leading to a homogeneous progress among the students in their acquired skills. Among the limitations of this design is that the participation required from the students is limited to the completion of the steps defined in the project exercise. Additionally, such a course design rather deepens on the previously acquired technical knowledge in terms of the learning domains of Bloom's taxonomy (W. Anderson et al., 2000) than exploiting the possibility to extend the technical knowledge of the students with regards to integrating new technologies in the project.

In this paper, we consider a different design of a project-based learning courses, which in addition to practise the transversal skills of the students through a group project, aims to integrate new technical knowledge. We consider the course "Project on Computer Network Applications", given at the Computer Science School of a Technical University of Catalonia in

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Project-based courses are nowadays integrated in the curricula of many computer science studies (Pucher and Lehner, 2011) (Fincher and Petre, 1998) (De los Ríos et al., 2010). The course we present in this paper has been held for several years and experiences on different designs of the course were gained, which allows us now to assess the questionnaires replied by students and draw consolidated conclusions.

The focus of this paper is to present the assessment of this specific course design we have applied. For this we analyze the replies which students gave us via questionnaires on the course during two semesters and discuss the overall effects of the course design. We look at aspects with regards to participation of the students in choosing the project work and active participation in the selection of the project they wish to elaborate in group.

2 PROBLEM STATEMENT

2.1 Course Objectives

The course Project on Computer Network Applications[1] in the Computer Science Curriculum of the Technical University of Catalonia, which is the subject of this study, has both transversal and technical competences which are summarized as follows:

Transversal competences:

- Teamwork: to work as a team member and contribute to develop projects in a pragmatic way while taking into account the available resources.
- Entrepreneurship and innovation: to develop creativity, entrepreneur spirit and detect innovation tendency, have initiative which generate opportunities.
- Effective oral and written communication: to communicate knowledge, procedures, results and ideas orally and in a documented way.

Specific technical competences:

- ICT infrastructure installation: define, plan and manage the installation of the ICT infrastructure of the organization which includes to select, design, deploy, integrate, evaluate, build, manage, exploit and maintain the hardware, software and network technologies.
- ICT infrastructure operation: guarantee that the ICT systems of an organization operate correctly, are secure and adequately installed, documented, personalized, maintained, updated and substituted, and the people of the organization receive a correct ICT support.
- ICT system design: design solutions which integrate hardware, software and communication technologies and the capacity to develop specific solutions of systems software for distributed systems and ubiquitous computation devices, which includes to conceive systems, applications and services based on network technologies, to implement and manage systems, to design, establish and configure networks and services.

[1] https://www.fib.upc.edu/en/studies/bachelors-degrees/bachelor-degree-informatics-engineering/curriculum/syllabus/PTI

2.2 Design Challenge

Project-based courses in engineering studies often focus on the students to acquire non-technical skills and to prepare students to gradually develop into professional practitioners (Sindre et al., 2018). From the perspective of the study career curriculum, the project-based courses complement the technical courses of the career. In the project-based course, the previously acquired technical skills are put into practise by the development of a project in a group work.

As indicated in the previous section, the project-based courses we consider aims to develop transversal *and* technical competences. In the context of our course, the technical competences which are targeted address specifically the areas of computer networks and distributed applications.

Therefore, the challenge consists in designing a project-based courses which fosters students to acquire the *transversal competences*, while at the same time contributes to improve the *technical skills* of the students in information technologies.

3 DESIGN OF THE PROJECT-BASED COURSE

The course "Project on Computer Network Applications" has 6 ECTS credits, which corresponds to a total dedication of around 150 hours to the course. In the study curriculum, this course addresses third year students. These students have selected in the third year the focus on information technologies within a four year study plan for the undergraduate computer science studies. The courses in the first and second year of the are obligatory and not selective. Therefore the preparation of the students enrolled in the

course “Project on Computer Network Applications” can be considered homogeneous with regards to previous knowledge.

Following the technical competences described in the previous section, the technical context, which the project of this course should address, includes information technologies, computer networks and distributed applications.

As to the transversal competences of the course, the students should develop non-technical skills through the experience of conducting and organizing a project in a group work, and presenting and documenting it.

In the case we present here, the previous knowledge of the students about the targeted technical context can be classified as being familiar with the fundamentals, since these topics were presented at an introductory level in a previous course on networking in the second year of the study curriculum.

Similarly, while problem-based learning is also part of the teaching methodology in the subjects of the first and second year, a formal course on project development is not given in any previous course of the study plan. Therefore, students have a certain previous experience with problem-based learning, but not at the scale of an engineering project.

There is a key design decision in a project-based course between defining a single project to be developed by all student groups or defining individual projects for each student group.

One of the advantages of a single project defined by the instructor is that the parameters of the project to be developed are more controlled. These parameters include the technical scope of the project, and the difficulty and challenges that will arise during the project development. Therefore, a clear list of objectives can be established and their fulfillment can be verified both by the students and the instructor.

Among the disadvantages of a single project design we can identify that the project proposal must make a previous choice of technologies to be included, done by the instructor. The choice will need to focus on certain relevant technologies, but must also exclude others in order to fit to the scope and dimension of the effort the project is designed for. Another limitation is that the students cannot participate in the project definition, and this fact may not fully exploit the motivation potential, which a project development can create in students.

The advantages of each student group developing an individual project include a better response to incorporate individual preferences. For instance, a specific project proposal may integrate technologies which each student is interested to explore. Another effect is that having participated in the project proposal usually produces a higher motivation in the student in developing the project.

Conducting individual projects in the project-based course, however, has also some difficulties. One important issues is that the risk of the project is not always clear at the project definition phase. This fact happens when the project builds on less known or recent technologies, for which less documentation and experience is available to take an appropriate decision. Another difficulty for the instructor is the evaluation and comparison of different projects after completion. Since each project has had its specific difficulties, often mostly technical but sometimes also in the group organization, establishing too specific evaluation criteria may not fit to all types of projects.

Taking into account the advantages and disadvantages of these two options, we have chosen for the presented project-based course the design of individual projects for each student group. An important reason was the potentially higher motivation of the students to develop a project in which they participated from the beginning by defining the project.

Figure 1 shows the overall course structure over the time of 15 weeks. The course starts in a first part with some laboratory exercises, where hands-on works are performed. These laboratories include exercises with Web applications, Web API design, JSON data representation and blockchain. The laboratories help to introduce a few potentially interesting technologies for project proposals. During the first two weeks, the students form project groups with 3-5 participants. Within the first four weeks, in which the laboratory exercises are carried out, each student group develops a project proposal. The proposed project is developed in the second part of the course during around 10 weeks. The time of the 6 credit course of around 150 hours is distributed to roughly one third to the initial classes and laboratories of the course, including the proposal preparation, and two thirds of the time to project development and preparation of the project deliverables.

The definition of the project proposal is carried out in interaction with the instructor. Interesting topics are initially identified in a brain-storming session with the students and discussed subsequently. The students present preliminary ideas and then in an iterative process with the instructor, the student groups consolidate a pre-proposal into a final documented project proposal. The proposal is presented in a public session to all participants of the course.

The project development in the second part of the course then carries out the work plan established for the project. A mid-term presentation validates the

achieved progress and by the end of the course, a project report is delivered and a final presentation is done by the students, which includes a demonstration of the results.

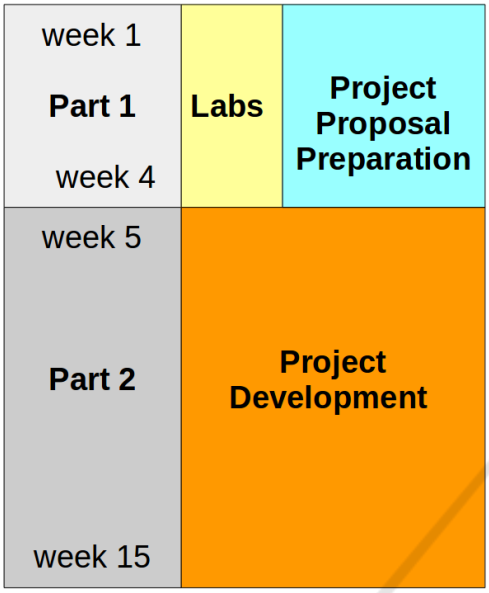

Figure 1: Overall structure of the proposed project-based course.

4 EVALUATION

We conduct an evaluation of the proposed course design by means of a questionnaire conducted with the enrolled students after finalizing the course. The questionnaire was run during two semesters when the course was given, namely the first and second semester of the academic year 2017-18.

In the first semester (indicated in the following by 2017_18_Q1), the course had 28 students enrolled. Out of the 28 students, 19 answered the questionnaire. There were 7 group projects in this semester.

In the second semester (indicated in the following by 2017_18_Q2), the course had 26 students enrolled. Out of the 26 students, 18 answered the questionnaire. Like in the first semester, the course had 7 group projects.

The questionnaire was addressing different aspects of the course to understand if the chosen design, e.g if developing individual and different group projects instead of a single common one, was perceived positively. The answers to the questions were typically numerical values (scores) with a range from 1 to 5, were 1 was the minimum (not affirmative) and 5 the maximum (affirmative) value.

4.1 On the Project Definition Possibility

In the chosen design of the presented project-based course, the students of the project groups were encouraged to define in collaboration with the instructor the project to be developed. The question in the questionnaire asked the students on the value which they give to the possibility for participation in the project definition.

The Figures 2 and 3 present the answers given by the students for semester 1 and semester 2, respectively. It can be seen that in both semesters, there is a clear affirmative score between 4 and 5. That is the students considered important having been able to participate in the project definition.

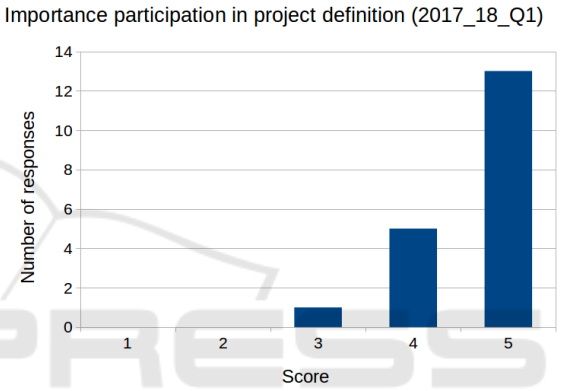

Figure 2: Student valorisation of participation in the project definition (course 2017_18_Q1).

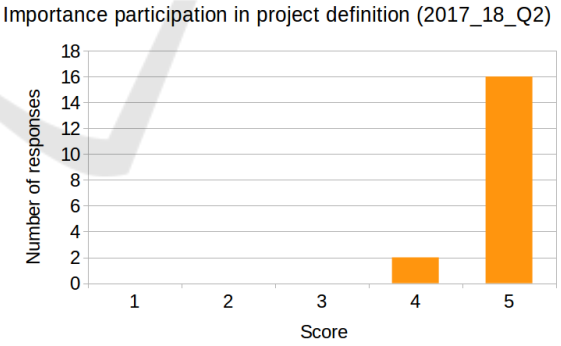

Figure 3: Student valorisation of participation in the project definition (course 2017_18_Q2).

4.2 On the Integration of Technologies Achieved in the Project

The question asked if after finalizing the project development, the students considered to have achieved integrating interesting technologies in the project.

The Figures 4 and 5 show the students' answers for each semester. There is a clear affirmative score in the answers for having been able to integrate interesting technologies in the project.

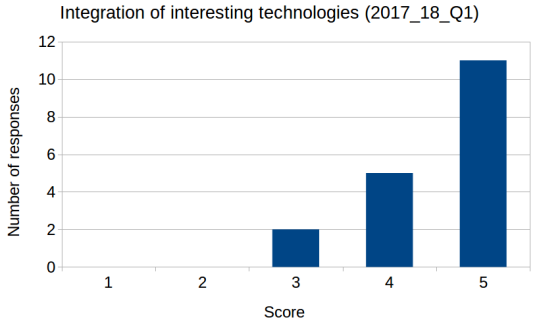

Figure 4: Student valorisation of having achieved to integrate interesting technologies in the project (course 2017_18_Q1).

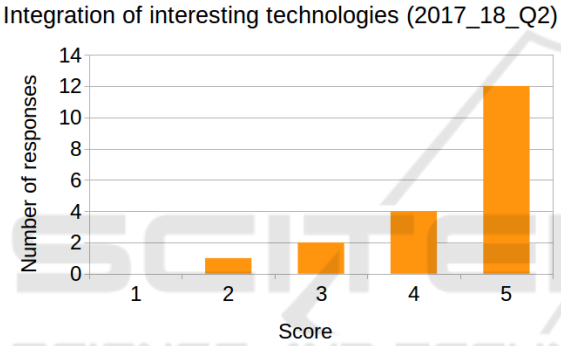

Figure 5: Student valorisation of having achieved to integrate interesting technologies in the project (course 2017_18_Q2).

4.3 On Exceeding the Initial Expectations about Technologies

This question aimed to identify if the initial expectations of the students with regards to the number of technologies were exceeded by the development of their project.

The Figures 6 and 7 present the students' answers for both semesters. While in the first semester there were two students which answered negatively to the question, all other answers were given with a score of 3 to 5. The answers indicate that for the majority of students, the initial expectations on the applied technologies were exceeded.

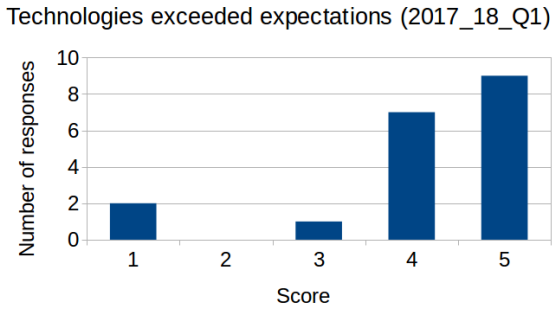

Figure 6: Student valorisation on the technologies applied exceed the intitial expectations (course 2017_18_Q1).

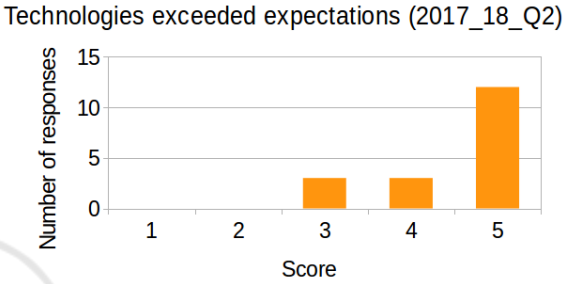

Figure 7: Student valorisation on the technologies applied exceed the intitial expectations (course 2017_18_Q2).

4.4 On Having Preferred a Pre-defined Project or Not

This question asked the students if they had preferred a single pre-defined project, i.e. not defined in a participatory way among the group of students and the instructor.

In Figures 8 and 9 the answers on this question are depicted. From the answers we can identify two groups of students, on larger group (a clear majority) which give a low score, i.e. does not prefer a pre-defined project, and another smaller group which had preferred to have a pre-defined project.

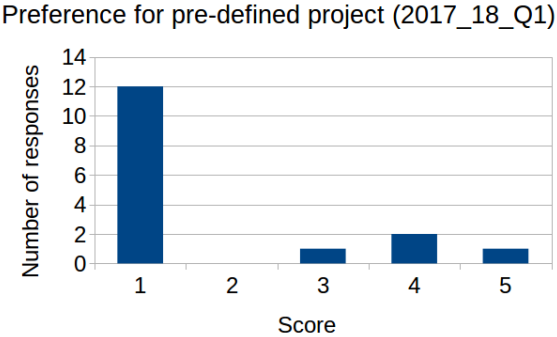

Figure 8: Student valorisation on preference for pre-defined project (course 2017_18_Q1).

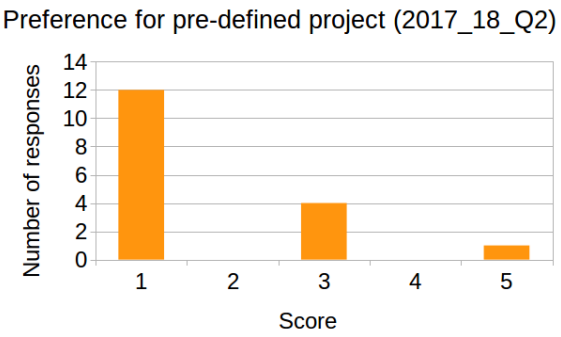

Figure 9: Student valorisation on preference for pre-defined project (course 2017_18_Q2).

4.5 On the improvement of the students' technical skills

The challenge for the design of the course was on one hand to achieve the transversal competences through a project-based learning methodology, but on the other hand also to improve the students' technical skills. The question aimed to know if the students perceived that their technical skills had improved.

The Figures 10 and 11 show the answers of the students. It can be seen that the most chosen value was 4, i.e. the students considered that their technical skills had improved, but not always at the maximum (score 5). This result is affirmative for the design of the course, but the results also indicate that there may be room for further improvement in this aspect.

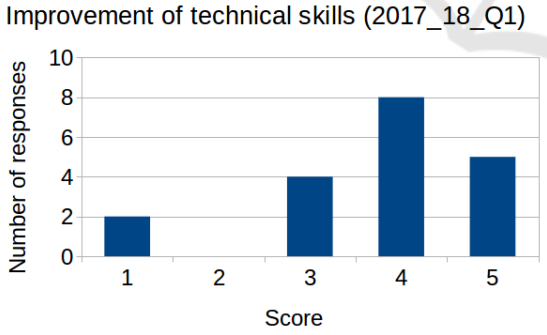

Figure 10: Student valorisation on preference for pre-defined project (course 2017_18_Q1).

4.6 Technical Scope of Projects

After finalizing the projects at the end of the course, the students often write a brief overview of their technical project on the course Wiki[2]. From this Wiki we can obtain an initial orientation on the technical content of the projects.

[2]http://wiki.fib.upc.es/pti/index.php/Portada

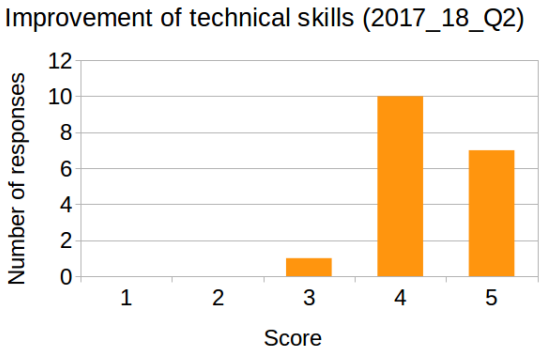

Figure 11: Student valorisation on preference for pre-defined project (course 2017_18_Q2).

It can be seen that the projects done by the students are diverse in their technical content as well as in their ambition. There are projects which are based on proven tools, e.g. consolidated Web frameworks, and others which experiment and integrate very recent technologies, e.g. blockchain. Most projects target the applications layer of computer networks and focus on some type of Web-based distributed applications. Less frequent are projects focusing on lower levels of the networking protocol stack. In terms of application domains, the spectrum of the areas addressed in the projects is very broad, and often the application context chosen seems to be inspired by current popular applications.

4.7 Summarizing Remarks

The overall results from the questionnaire (answered by in total 37 students over two semesters of the course) indicate that the students perceived positively the chosen design of the course, i.e. developing individual projects by each student group instead of a single pre-defined project.

The results indicate that this design also enabled the students to work with a large number of technologies. At the end of the project, the initial expectations of the students with regards to the number of technologies experienced were exceeded.

According to the replies to the questionnaire, the design of the course also achieved some improvement in the technical skills of the students.

Another positive effect we observed which is interesting to mention is that by working with individual projects, that students not only learned about the specific technologies used in their own project, but by participating in project presentations of the other groups, they also got introduced to additional technologies used in the other projects. Contrarily, with the design of a single project for all student groups, this effect would not have happened.

Regarding the instructor experience, for this kind of course design, the instructors need to be flexible and adapt to the different interests and topics which the students propose. A clear assessment of the risk of a technology is not always possible a priori, for which a project work plan sometimes needs to be redefined along the project duration if a chosen technology produces unforeseen difficulties.

An important aspect to state is that the chosen design enables an active participation of the students in the course. The questionnaire showed that a very large part of the students appreciated the opportunity to participate in the project definition, but we could also observe that there was a smaller group of students, which had preferred working on a pre-defined project.

5 CONCLUSIONS

This paper presented and assessed a specific design of a project-based course for computer science students. Instead of all students conducting the group work on a single project definition, in the presented design of the course each student group, in collaboration with the instructor, defines an individual project from scratch, which subsequently is developed by the student group during the course.

The results from the questionnaire answered by the enrolled students during two semesters confirm the positive perception of the presented course design over the alternative of each student group developing the same project defined by the instructor. The questionnaire furthermore indicated that this design contributed not only to develop transversal skills through a group work, but also the technical skills of the students improved in terms of the technologies which they could experiment with during the project development.

There are several issues that may be addressed in future work. One topic refers to how the student form the project groups of the targeted four participants. Currently, the students are encouraged to organize the groups by themselves, and the lecturers only interact actively if after the time limit any students are not integrated in a group or if there is a mismatch between the technical scope of the proposed project and the number of participants. This scheme, however, leads often to project groups in which the participants know each other in beforehand. It could be interesting to explore what are the effects of other group formation schemes, e.g. random formation of groups. Another topic that could be interesting to be analyzed in more detail is how the participatory design at the beginning of the course is conducted, and if variations of the participatory design for the definition the project could produce other effects and learning outcomes.

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