Teaching Project Management to Graduate Students of Electrical Engineering and Computing

Zeljka Car, Kresimir Pripuzic, Hrvoje Belani
University of Zagreb, Faculty of Electrical Engineering and Computing, Department of Telecommunications, Croatia

Abstract

This paper describes the methodological and organizational aspects of teaching on a project management course. A specific feature of the course is its simultaneous offer to graduate students of both electrical engineering and computing. We apply an approach in teaching where students work in a client-oriented project environment that is closely related to their domain of study. The students are grouped in project teams and encouraged to mutually explore and combine project management and technical skills in the simulated project environment. From the organizational point of view, this requires that lecturers constantly monitor multiple domain projects, consult student teams with different backgrounds and cooperate with experts from different domains, including both the academia and industry. Additionally, we explain procedures used to evaluate students’ knowledge and work effort. To illustrate different types of student projects, we discuss some of the project results. Using surveys as a research method, we have conducted an extensive research of student work on the projects and on different course aspects. The total number of 348 students that had participated in one of 46 projects has been involved in the series of surveys presented in this paper.

Key words: Project management, Practical skills, Education, Training.

1. Introduction

Today, there are two international project management (PM) organizations that offer official programs for project management certification: Project Management Institute (PMI) and International Project Management associations (IPMA). Without going into further details, these organizations offer PM certificates of different levels that are intended for project managers with few years of real project experience. Therefore, today’s graduate students will have to work for a few years, after finishing their studies, before they could apply for these certification programmes. On the other side, they will have to start working on real projects from the moment of their employment. To bridge this gap, we have decided to offer a course in PM to our students. The purpose of this course is not only to teach our students to efficiently manage projects, but to work on real projects and therefore it is quite different from the mentioned PM certifications programs. Most importantly, we see this course not as an alternative for the official PM certifications, but as the first step in PM education.

In the past few years, the need for teaching PM at faculties has been recognized by the academia. For example, the American National Academy of Engineering Committee on Engineering Education has launched a two-phase project as a vision-

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1 This work was carried out within the research project "Content Delivery and Mobility of Users and Services in New Generation Networks", supported by the Ministry of Science, Education and Sports of the Republic of Croatia.
casting initiative on engineering in the future and educating engineers to meet the needs of the new era [1]. The most important trends that are likely to redefine the boundaries of engineering are identified in the project vision. One of these trends is “the increasing number of engineers working in non-traditional areas that require technological competence and fluency in management, finance, marketing, public policy, etc.”. Additionally, “If our students are going to successfully function as professional engineers in the international corporate world of the 21st century, they must be equipped to be global engineers who are technically versatile, able to solve problems from system-level perspective, effective communicators, function in diverse ethnic teams and demonstrate social responsibility” [2].

Over the past few years, a lot of effort has been made by the academia to define an adequate curriculum for teaching PM skills such as project initiation and planning, project integration, controlling and closing. Among the possible ways of PM concepts integration to the university curriculum, the following two offer the best chance of success: integration as an individual course and integrated into other courses [3]. To avoid the complicated changes in curriculums of all different study programmes offered at our Faculty, we have chosen the former approach. The most important part of teaching PM is to teach students to mutually develop technical and soft skills. The soft skills include people management, work ethic promotion, ability to finish work on time and relate adequately with customers and colleagues. It is crucial that students experience the difficulties and benefits of working in a team environment. The student teams transform students’ collective thinking: they learn to mobilize their energies and actions to achieve common goals, which then result in skills and abilities greater than the sum of their individual talents [2].

PM courses should emphasize teamwork, interpersonal communication, responsibility and preparation of professional documents. Additionally, a teaching method that involves students in client-centred projects with real clients is strongly recommended [4]. Evaluations of some project-based courses employing this method indicate that students strongly feel that this method is excellent for learning, and they also believe that such projects provide a realistic environment, where the principles of engineering, management, science and mathematics can be applied to solve practical problems [2].

Concepts and processes of PM are already well known and thus can be taught in a straightforward way. However, the difficulty lies in teaching students tools and techniques effective in practice. On the other side, it is simple for students to realize the importance of establishing project objectives which are specific, measurable, and agreed upon by all major stakeholders. Furthermore, it is very important to teach students the nature of difficulties in applying these concepts and processes in practice [5].

Studies have shown that the academia must design curriculum that addresses both the theoretical and practical aspects of managing projects [6]. The PMI’s guide to the Project Management Body of Knowledge [7], known as the PMBOK, is the leading publication that benchmarks PM practices. Although the PMBOK (and related PMI certification) is respected in industry, it is over-extensive to be completely covered by a university curriculum centred on technical skills. Nonetheless, it is an excellent basis for PM educators.

While designing our course we had the following goals: 1) to educate students in the formal definition, teamwork and common life cycle of projects, 2) to teach them the prerequisites for successful PM, with an emphasis on project domains [8], business environments [9] and communications aspects [10], and 3) to teach them to use a theoretical basis and practical skills in teamwork. This will prepare them to successfully carry out different roles in industry projects [11]. Following these goals, we have organized student projects in the way which allows them to plan, monitor and work on the activities, while producing high quality project outcomes.

The paper is organized as follows. Section II describes the PM course and its specifics regarding similar courses. Section III analyzes finished student projects and briefly describes several of them. Section IV presents some of the most frequent problems experienced by the students, the common ways to solve these problems, as well as the students’ perception of knowledge and experience gained in the project. In the final section we conclude the paper by summarizing our work.
2. Project Management Course Description

Due to a broad applicability of project-based work and development in all fields of electrical engineering and computing, the course is offered to fourth year students enrolled in all graduate study programmes at our Faculty. During the period of three years, the total number of 348 students that participated in 46 projects has been involved in a series of surveys presented here. Figure 1 gives an overview of students’ reflections on the course.

During introductory year, significant efforts were made to establish a laboratory environment for practical student exercises with PM tools. In the next years, the emphasis was on taking advantage of high-quality student projects to improve the course itself, e.g. implementing of e-Exam application for online testing and grading the students [11].

Since the course is offered to students with different study programmes (Figure 1e) it is taught in a manner that allows the students to improve their organizational and communication skills. The course emphasizes teamwork, project role responsibilities, interpersonal communication, and writing technical documents. The specifics of our course, in comparison to other PM courses, are as follows:

1. Project types. At the beginning of a semester, each student has either to propose his/her own project or to choose among offered projects. Students are strongly encouraged to search for technical projects outside of the classroom, possibly related to their research area of interest. In this way, key project stakeholders and/or customers become people from the industry or faculty staff from different departments of the Faculty. This allows each project team to fully experience the complexity of working with customers and end-users in real-world situations.

2. Project exchange and staffing. As suggested in [12], students first submit their project proposals and team size to the lecturers by e-mail. Approved projects are announced to other students with a Web application particularly developed for this purpose. Other students interested in an approved project can join using the application. An alternative approach is that a student proposes a project topic and all or some team members.

3. Team structure diversity. As stated before, project teams are composed of students from different graduate study programmes at the Faculty. Figure 1f shows different student motivations for taking this course. Team

![Figure 1. Results of the student survey about the PM course](image)
structure diversity contributes to better knowledge and skill transfer, and potentially increases team synergy. On the other side, more time is required for students to get acquainted and to identify team roles.

4. **Team building.** Students themselves establish team dynamics and self-assign the roles within a team of maximum 10 members. Team building exercises were performed during lectures to improve communication within teams. As Figure 1c shows, these exercises are well accepted and supported by the students.

5. **Lecturers’ role.** During the course, lecturers act as project supervisors without interfering in the selection of team leaders (as opposed to [13]) and task assignment. In this way lecturers are involved in each teams work, informed about problems appeared and engaged in finding their solutions. In projects where lecturers lack technical knowledge additional consultants among other teachers or external stakeholders (domain experts) provide technical assistance.

6. **Teaching the use of software tools for PM.** Teams are required to plan and track task progress by using a professional PM tool. A short course about the tool is given only to team representatives, and not to all students. These representatives are further responsible to teach other team members. Student surveys show that this way of learning is quite successful since 75% of the students used the tool (Figure 1d).

7. **IT supported communication.** The largest part of team communication involves sharing and updating documents. Each team store technical documents at a central repository to make them easily accessible for updates, modifications or reviews. The students have an alternative to use public applications (e.g. Google Groups, Groove tool, etc.) instead of the professional PM tool.

8. **Various types of team meetings.** Regular meetings are conducted with lecturers and team leaders, discussing common or specific project problems. These problems are mostly related to scope and effort creep or non-compliant team members. Each team is required to meet at least once per week to discuss additional issues. Teams have to submit minutes of meeting to the lecturers at the end of the project.

9. **Scheduling project documentation.** At defined time points during the semester, teams received project documentation templates to fill out. There are two reasons for this: one is to recognize the phase when writing a particular project document is relevant, and the other is to allow each project team to fully experience the complexity of working with real time constraints and deadlines.

10. **Involving students in soft skill researches.** During the course, students interested in soft skill research topics (e.g. leadership, conflict management and negotiation) give short exercises under the lecturers’ supervision to other students. This helps each student to become more effective in his/her role.

11. **Project outcome assessment.** All projects have the same predefined duration of 7 weeks. Project results are summarized in both written and oral reports. Teams present their results and project work to the entire class allowing others to learn from their experience. Domain experts from the industry or academia take parts in the evaluation of project outcomes, while course lecturers assess the quality of project documentation and other PM aspects.

12. **Student self assessment.** Each student is required to self-assess his/her work effort by a percentage which is then used to calculate personal project grade from his/her team grade assigned by project assessors. According to [2], this gives students a sense of empowerment in the assessment process and encourages accountability of each individual student to his/her team.

13. **Continuous course assessment.** As stated above the lecturers have regularly conducted student surveys. The results of these surveys (see Figures 1, 4 and 5) are used for gradual course improvement.
a) Lectures

The first part of the lectures covers the fundamental theory regarding project definition, PM discipline, the characteristics and examples of successful projects and project failures. The students learn about the project life-cycle and planning techniques, the role of a project manager and the profession itself. The second part of the lectures covers negotiation, communication and conflict management, PM tools, and project documentation. Results of the student survey show a satisfying ratio between theory and practice as shown in the Figure 1a.

The remaining lectures are composed of invited talks of recognized PM professionals from different segments of industry, as advised in [14]. The Invited speakers are mostly from recognized IT/ICT companies (IBM, Ericsson, Siemens, Microsoft), and civil construction companies [11]. In the surveys students expressed their satisfaction with this type of lectures (Figure 1b).

b) Projects

The most important practical part of this course is work in projects. Project work also involves the following documentation: project proposal, project plan, revised project plan and project closure documents. The documentation has to follow predefined templates set by lecturers. Students should plan their activities, make work breakdown structures (WBS), design Gantt diagrams, determine project milestones and identify and manage project risks. All team members should take part in planning future tasks, while the leader is responsible for controlling and coordinating all these activities. Students are encouraged to work iteratively and to monitor project progress through appreciable validation of determined project milestones [11].

c) Software Tools for Project Management

Using software tools for PM has many benefits, such as:
- Easier understanding and more effective management of project schedules,
- Increased team productivity,
- More effective communication between members and
- Easier tracking of various project related information.

This knowledge will give our students a starting advantage in their professional careers compared to their competitors [15]. Among the tools available on the market we have decided to use Microsoft Project mainly because of its smooth integration with other Microsoft Office programs. Additionally, a server version of Microsoft Project allowed students to access their work from different computers, laboratories, and even their homes, see Figure 2 below.

![Figure 2. The configuration of the project management tool](image)

Instead of the time spent in the laboratory, we controlled the output of student’s work. The tool was mainly used for the following set of activities:
- Creating a new project and defining the associated tasks,
- Allocating resources and assigning them to the tasks,
- Storing necessary documentation to a repository, and
- Communicating about the project’s progress.

d) Grading and Assessment

We considered it necessary to allocate a portion of the grading weight to examinations. We felt that this encouraged the students to keep pace with the course lectures [16]. We found the following system to be quite successful in grade assignment:
- Team Project Grade 50%,
- Examinations 40%,
- Regular class attendance, active participation in different exercises 10%.
- Student surveys shows that students are satisfied with the scoring system (Figure 1g)
3. Analysis of Student Projects

The three main types of student projects are: software development projects, software/hardware implementation projects, and research study projects. Figure 3 shows the distribution of project types for the three year period.

![Figure 3 – The distribution of student project types](image)

There was a noticeable growth in the areas of development and implementation, and the number of research studies stagnated. This was expected since students from all study programs are increasingly aware of the applicability of ICT technologies to their program.

In Figures 4 and 5 we see that initial knowledge of team members and leaders were similarly estimated by leaders and members. As expected, the leaders had better initial knowledge about project thematic. Most of the team groups were formed on the basis of members’ previous acquaintance. Surprisingly, openness of leaders for suggestions was better graded by the members than the leaders themselves.

The scope of problems was almost equally observed by the leaders and members. As expected, most of the leaders worked harder than the members. Surprisingly, around 30% of the members think that they would have been better team leaders. As we see, around 90% of the students expressed learning a new skill while working on projects. From the last two diagrams, we see that the members had more than enough time to work on projects.

For the purpose of this paper, we have selected and briefly described one project of each type, in order to illustrate the kind of challenges and problems students run into, and how they resolved them.

![Figure 4. The first part of the post-project survey](image)
a) Lawful Interception Study

The goal of this research project was to learn the concepts of lawful interception (LI) in telecommunications, the standardization aspects and their implementation status into different network environments, such as IP networks and GSM networks. The student team had 9 members divided into 4 sub-teams. Their research covered detailed logical and physical architectures with security and privacy requirements analysis for each architecture, as well as commercial devices and technical solutions available on the market. The study's final results were made public for the education and research community.

b) Actuating Voltage Transition

The goal of this implementation project was to make a feasibility analysis for transition of actuating voltage from 10 kV to 20 kV in a medium voltage distribution network. Because of the rising demand for electrical energy, the power lines and cables working on actuating voltage of 10 kV are often current-overloaded. This results in raised voltage sag and energy losses, which can be reduced by actuating voltage to 20 kV. The project was conducted by 10 electrical power engineering students. The case study was a primary distribution network in north-western Croatia, which is a part of the national power system that provides electrical energy for transformer-end substations and direct consumers.

c) Library Web Application

The goal of this software development project was to create a Web application for management of books, magazines, and other scientific literature. The application allowed users to search for books, proceedings, and magazines, and an administrator to add and edit entries and user information. The team of 7 students has worked on this project. The activities consisted of software analysis, design, implementation, testing, and documentation.

4. Analysis of encountered Problems and Gained Knowledge

All final reports should clearly state problems faced by the teams, applied problem solutions, and skills and knowledge gained. Some of the encountered problems are similar to real-life problems, which is particularly valuable for students’ future career. The most common problems and their solutions are grouped as either external or internal problems, and are given in the Table 1. It is important to mention that we successfully solved all reported problems.
Table 1 - Most common reported problems and their solutions

<table>
<thead>
<tr>
<th>External problems</th>
<th>Internal problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-cooperativeness of the external stakeholders – solved by establishing active contacts between external stakeholders and lecturers.</td>
<td>Lack of teamwork experience – solved by using clear guidelines for effective communication within teams.</td>
</tr>
<tr>
<td>Inadequate technical materials and literature for research topics – solved by contacting eminent technical experts from the industry.</td>
<td>Poor work synchronization – solved by constant communication between team members. Problem is partly related to students’ obligations on other courses that which more refined project planning.</td>
</tr>
<tr>
<td>Overly ambitious external stakeholder expectations – solved by involving lecturers in project planning and scoping.</td>
<td>Too ambitious team leaders – also solved by involving lecturers in the project planning and scoping.</td>
</tr>
<tr>
<td>Unequal level of knowledge in team – solved inside the team by sharing of knowledge.</td>
<td>Team structure diversity – solved by assigning roles according to recognized capabilities and personalities of team members.</td>
</tr>
</tbody>
</table>

In the final reports the majority of students highlighted the following knowledge and skills as gained during the course: a) knowledge on particular technical topics and PM theory basics, b) knowledge about project documentation, c) experience on working in teams on real client-based project with limited time and resources, and d) knowledge about professional PM software tools. This feedback strongly confirms that the goals of our PM course (mentioned in Section I) were fully achieved. Also, students successfully adjusted to the work in teams and to the specific project conditions. They had the opportunity to realize their own capabilities and techniques for self-motivation and motivation of other team members. A very important finding is that a high level of freedom in performing project tasks given to highly motivated team members increases their creativity, but at the same time consumes more time and causes additional inter-team conflicts.

5. Conclusion

In this paper, we present the syllabus of a PM graduate course according to the four building blocks of project management [17] – people, process, tools and measurements. The main motivation for adding this course to the Faculty curriculum was to teach our graduate students the basics of PM methods in theory and practice so they will be better prepared to work efficiently on projects in their future careers. The main challenge for the lecturers was to organize a PM course that is intended for students of different study programmes. We demanded that students follow the syllabus and accomplish projects according to defined processes, using appropriate PM tools, which allowed us to evaluate and grade their work and results. An additional challenge was to assign near-equal difficulty projects to teams from different study programs.

During several years we performed an extensive research about different course aspects: its adequacy regarding PM practice in industry, the most common problems students run into while working on projects, and knowledge and experience students gained on the course. This research was based on student surveys, reports and the participation of lecturers in different project aspects. The research showed that over 90% of the students learned at least one new skill while working on their project (Figure 4e and 4f). At the same time they were very satisfied with the ratio of theory and practice on the course (Figure 1a). Interestingly, the results of some student projects were applied to improve the course itself. Organizing and conducting a PM course in the way we suggested and described in this paper is time and effort consuming for lecturers, but students greatly appreciated the increased involvement (Figure 1h).
References


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Corresponding author:
Zeljka Car,
University of Zagreb,
Faculty of Electrical Engineering and Computing,
Department of Telecommunications,
Croatia,
e-mail: zeljka.car@fer.hr